



“School of Social Sciences”

Postgraduate Course

Postgraduate Dissertation

The Energy Landscape and Its Impact on the Technology Business
Sector

Sofia Exizidou

Supervisor: Prof. Dr. Panagiotis Fousekis

Patras, Greece, May, 2026

© Hellenic Open University, 2017

The content of this thesis/dissertation along with its results is owned by the Hellenic Open University and his/her author, where each of them has the sole and exclusive right to use, reproduce, and publish it (totally or partially) for educational or research purposes, with the obligation to make reference to the thesis's title, the author's name and to the Hellenic Open University where the thesis / dissertation was written.



The Energy Landscape and Its Impact on the Technology Business Sector

Sofia Exizidou

Supervising Committee

Supervisor:

Prof. Dr. Panagiotis Fousekis

Aristotle University, Thessaloniki

Economic Analysis at the Department of
Economics

Co-Supervisor:

Prof. Dr. Georgios Filis

Panteion University of Social and Political
Sciences,

International Economics

Patras, Greece, May 2026

Dedicated to my parents

Abstract

This dissertation analyses how the ongoing transformation of the European energy landscape and its implications for the technology business sector. Over the past decade, Europe has been moving toward cleaner and more sustainable energy systems, driven by climate goals, concerns about energy security and continued technological developments. These developments have a huge impact on how energy markets operate and they are regulated.

The study focuses at the main parts of the European energy system, such as the development of renewable energy sources, the liberalization of energy markets and the increasing volatility of energy price. It also analyses the role of digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT) and smart grids, in improving energy efficiency and supporting more flexible and reliable energy systems.

This research also examines how these developments affect technology companies. The findings show that energy is no longer just a basic operational need but has become an important strategic factor for the companies. Technology companies are adapting by using data-driven solutions, improving energy efficiency and investing more in sustainable practices to respond to higher energy costs and more strict environmental requirements.

Overall, the dissertation shows the growing connection between the energy sector and the technology business sector. As the energy systems become more digital, technology has very important role in supporting this transition, while at the same time has an influence by it.

Keywords

Energy transition, European Energy Market, Technology Sector, Artificial Intelligence (AI), Sustainability

Περίληψη

Η παρούσα διπλωματική εργασία εξετάζει τις αλλαγές που γίνονται στον ενεργειακό κλάδο της Ευρώπης και τον τρόπο με τον οποίο αυτές επηρεάζουν τον τομέα των τεχνολογικών επιχειρήσεων. Τα τελευταία χρόνια, η Ευρωπαϊκή Ένωση προχωράει σε μια ενεργειακή μετάβαση προς πιο καθαρές και βιώσιμες μορφές ενέργειας, λόγω της ανάγκης να αντιμετωπιστεί η κλιματική αλλαγή, η ενίσχυση της ενεργειακής ασφάλειας και η τεχνολογική εξέλιξη.

Η εργασία αναλύει τα βασικά στοιχεία του ευρωπαϊκού συστήματος, όπως η ανάπτυξη των ανανεώσιμων πηγών ενέργειας και οι αλλαγές στη δομή της αγοράς ενέργειας. Παράλληλα, εξετάζεται ο ρόλος των ψηφιακών τεχνολογιών, όπως η τεχνητή νοημοσύνη (AI), το Διαδίκτυο των Πραγμάτων (IoT) και τα έξυπνα δίκτυα, στη βελτίωση της ενεργειακής αποδοτικότητας και στη διαχείριση των σύγχρονων ενεργειακών συστημάτων.

Δίνεται ιδιαίτερη σημασία στο πώς αυτές οι εξελίξεις επηρεάζουν τις τεχνολογικές επιχειρήσεις. Τα αποτελέσματα δείχνουν ότι η ενέργεια δεν αποτελεί πλέον μόνο λειτουργικό κόστος, αλλά έναν σημαντικό στρατηγικό παράγοντα. Οι επιχειρήσεις του κλάδου προσαρμόζονται, υιοθετώντας νέες τεχνολογίες, βελτιώνοντας την ενεργειακή τους απόδοση και επενδύοντας σε πιο βιώσιμες πρακτικές, ιδιαίτερα λόγω αύξησης του κόστους ενέργειας και των πιο αυστηρών περιβαλλοντικών κανόνων.

Συνολικά, η εργασία θέλει να δείξει τη στενή σχέση που υπάρχει μεταξύ του ενεργειακού τομέα και του τομέα της τεχνολογίας. Η τεχνολογία συμβάλλει ενεργά στην ενεργειακή μετάβαση, ενώ ταυτόχρονα επηρεάζεται από τις εξελίξεις στον ενεργειακό τομέα.

Λέξεις – Κλειδιά

Ενεργειακή μετάβαση, Ευρωπαϊκή αγορά ενέργειας, Τεχνολογικές επιχειρήσεις, Τεχνητή Νοημοσύνη, Βιωσιμότητα

Table of Contents

1.	Introduction	11
1.1.	Background and Context of Energy Sector in Europe	11
1.2.	Significance of the Energy Transition in Europe.....	13
1.3.	Energy in the Technology Business Sector	15
1.4.	Purpose and Research Objectives of the Study	16
2.	The European Energy Landscape	17
2.1.	Structure of Energy Market in Europe	17
2.2.	Renewable Energy Deployment and Investment Trends	18
2.3.	Regulatory Framework and EU Energy Policies	19
2.3.1.	Legal Foundations and Institutional Context	19
2.3.2.	Renewable Energy and Energy Efficiency Directives	20
2.4.	Price Volatility and Energy Security in Europe.....	20
2.5.	Digitalization of the Energy Sector.....	22
2.5.1.	Digitalization as a Driver of the Energy Transition	22
2.5.2.	Smart Grids as the Foundation of Digital Energy Systems	23
2.5.3.	Internet of Things (IoT) in the Energy Sector.....	23
2.5.4.	Artificial Intelligence and Data-Driven Energy Management	24
2.5.5.	Impact on the Technology Business Sector	25
2.6.	Implications for Technology-Driven Industries	25
2.6.1.	Energy Costs and Industrial Competitiveness	26
2.6.2.	Sustainability Pressures and ESG Integration.....	26
2.6.3.	Digitalization of Energy Systems as Market Opportunity.....	27
2.6.4.	Energy Security and Industrial Resilience	27
2.6.5.	Innovation Ecosystems and Industrial Policy	28

3.	Technology Business Sector in Europe	28
3.1.	Overview of the Technology Business Sector in Europe.....	28
3.2.	Structure of the European Technology Market.....	30
3.3.	Economic Contribution and Productivity Effects	30
3.4.	Energy Intensity and Infrastructure Dependence.....	31
3.5.	Regulatory Environment and Sustainability Pressures	33
3.6.	Strategic Autonomy and Digital Sovereignty.....	34
3.7.	Critical Evaluation	34
4.	Interconnections Between Energy and the Technology Business Sector	36
4.1.	Energy as a Critical Input for the Technology Sector.....	38
4.2.	Impact of Energy Prices and Volatility on Technology Firms	39
4.3.	Technology as a Driver of Energy Transformation	39
4.4.	Sustainability Pressures and Green Technology Adoption	40
4.5.	Feedback Effects: The Energy-Technology Loop	42
4.6.	Conclusion	43
5.	New Technologies Transform the Energy-Technology Relationship	44
5.1.	Artificial Intelligence and Data-Driven Energy Optimization	44
5.2.	Smart Grids and the Internet of Things (IoT).....	45
5.3.	Energy Storage Technologies and Flexibility.....	46
5.4.	Blockchain and Decentralized Energy Systems	47
5.5.	Cloud Computing and Data Centers as Energy Actors	47
5.6.	Electrification and Green Hydrogen Technologies.....	48
5.7.	Conclusion	49
6.	Economic, Strategic Implications and Associated Challenges	49
6.1.	Introduction.....	50
6.2.	Economic Implications for the Technology Business Sector	50
6.3.	Strategic Responses by Technology Firms.....	52

6.4.	Sustainability Pressures and Regulatory Challenges	54
6.5.	Energy Security and Geopolitical Risks.....	55
6.6.	Structural and Technological Challenges	57
6.7.	Future Outlook and Strategic Directions	59
6.8.	Conclusion	60
7.	Conclusion.....	60
7.1.	Recommendations and Future Research	61
8.	REFERENCES	62

List of Figures

Figure 1. European Integration and Energy Politics	12
Figure 2. Renewable Energy share in the European Union (2022)	14
Figure 3. Growth of Data Centre Electricity Consumption in Ireland 2015-2024....	38
Figure 4. The European Green Deal (2019)	46

List of Abbreviations & Acronyms

AI	Artificial Intelligence
CSRD	Corporate Sustainability Reporting Community
EU	European Union
ICT	Information and Communication Technologies
IoT	Internet of Things
IRENA	International Renewable Energy Agency
ESG	Environmental, Social and Governance
PPAs	Power Purchase Agreements
LCOE	Levelized Cost of Electricity
ECSC	European Coal and Steel Community

1. Introduction

1.1. Background and Context of Energy Sector in Europe

Energy has played an important role in the development of the European Union, influencing not only the process of European integration but also the formulation of common policies. Energy policy in Europe includes the formal and informal rules, strategies and regulations that shape decision-making regarding energy production, distribution and the consumption of energy. These policies are implemented through legislation, international and regional agreements and economic incentives, with the aim of attracting investment, improving energy efficiency and supporting public policy.

The European Union's energy policy is based on three main pillars: environmental sustainability, energy market competitiveness and the security of energy supply. These objectives are often a challenging because the progress in one area may create pressures in another. These pillars have theoretical background in the evolution of the modern concept of security and further in the formation of the concept of energy security and the principles that shape it (European Commission, 2020).

Historically, energy has been closely connected to the European integration process (Mavromatis, 2017). Coal was the first energy source to be exploited on a continental scale, with the 1951 Treaty of Paris establishing the European Coal and Steel Community (ECSC). After that the focus expanded to nuclear energy with the 1957 Euratom Treaty, which means how is the energy as a foundation for European cooperation. In the same year, the Treaty of Rome created the European Economic Community, further strengthening the economic framework for energy collaboration

The oil crisis of the year 1973 have showed the weaknesses of Europe's fragmented energy structure and demonstrated the need for a more coordinated approach to energy security (Mavromatis, 2017). An important step to the market integration occurred with the Single European Act of 1987, which reduce barriers and facilitate cross-border energy trade.

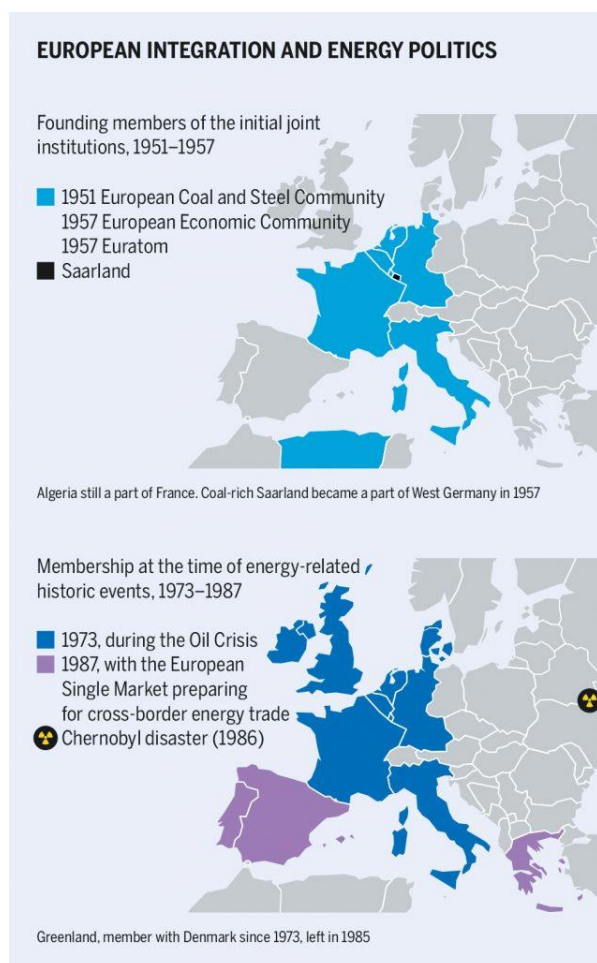


Figure 1 European Integration and Energy Politics (adapted from Energy Transition Wiki)

Figure 1 presents the historical development of energy governance in Europe, showing the gradual shift from national control toward greater European coordination.

Despite these developments, energy was not initially recognized as a fully integrated policy area within many European treaties, such as Maastricht Treaty of 1992. Member States remained reluctant to transfer authority over national energy resources to supranational institutions. However, important progress was made during the 1990s, through the adoption of Directives 96/92 and 98/30, which introduced common rules for the electricity and natural gas markets across the European Union.

Although, the Treaties of Amsterdam and Nice did not expand the Community's involvement in additional policy areas, such as energy. However, the participation of the European Community in

the Rio Earth Summit in 1992 and the Kyoto Protocol in 1997 helped to build stronger relationship with other countries by setting important long-term objectives which aimed to tackling climate change and protecting the environment.

In recent years, the energy sector in Europe has experienced deep changes that have affected not only the energy markets but also the wider economy. Factors such as climate change, the need to reduce greenhouse gas emissions, concerns related to the energy security and the dependence on imported energy resources drive the European Union to redesign the energy strategy. This strategy now focuses on renewable energy sources, improvements in energy efficiency and the adoption of innovative technologies, including smart grids and hydrogen solutions, with the aim to create a more sustainable and competitive energy system (International Energy Agency [IEA], 2023).

Finally, the energy sector is becoming more interconnected with technological development and the emergence of new business models that combine energy services, digital technologies and industrial innovation (International Energy Agency [IEA], 2020).

1.2. Significance of the Energy Transition in Europe

The energy transition in Europe has become one of the most important developments in the Europe's economic, technological and environmental future. This process involves a gradual move away from fossil fuels to the renewable energy sources, such as wind, solar and hydro energy, in response to many environmental challenges, including climate change and greenhouse gas emissions. The transition is not only an ecological necessity but also a strategic priority that aimed to improve energy security, reduce dependence on imported fuels and foster economic competitiveness.

European countries are adopting energy efficiency measures, smart grids technologies and digital solutions in their energy systems. These developments are creating new opportunities for technology-driven business activities, innovation and sustainable industrial growth (European Commission, 2022; International Energy Agency [IEA], 2021).

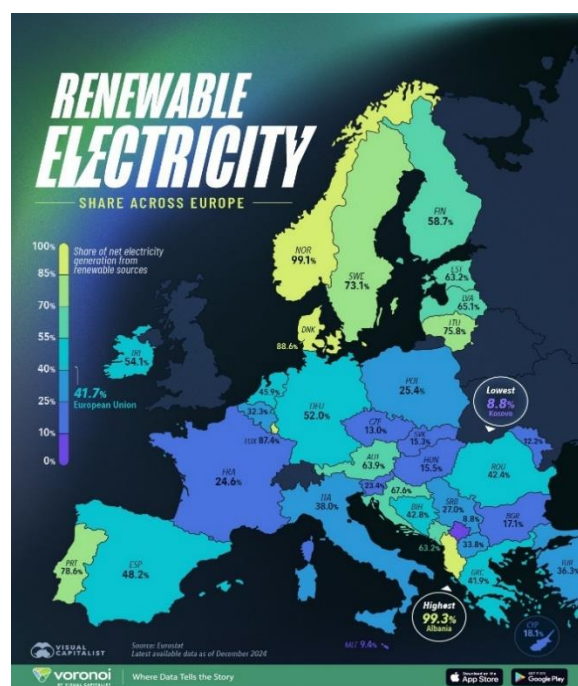


Figure 2 Renewable Energy share in the European Union (2022)

Figure 2 presents the share of renewable energy in the European Union in 2022, showing both the overall progress and the differences between the countries. As shown in Figure 2, while the European Union average shows a clear upward trend in renewable energy adoption, the data also reveal uneven implementation across member states, reflecting differences in national energy systems, policy frameworks and investment capabilities. Except the substantial progress has been made, the energy transition process remains a difficult process that requires continued coordination at the European level.

Economically, the energy transition is influencing labor markets, industrial investment and business practices. The expansion of renewable energy industries and clean technologies has created new employment opportunities, while traditional energy industries, including coal, oil and natural gas, are having an important structural change. In addition, the increase of the investment in infrastructure, research and development improves the technological innovation and the position of Europe as a global leader in the energy sector.

Many policy initiatives have played an important role in supporting this transformation. The European Green Deal, the Fit for 55 package and the REPowerEU strategy, provide important policy frameworks and financial support that aimed to speed-up this transformation. This way, reflect the European Union's commitment to achieving climate neutrality by 2050 while maintaining economic resilience and market competitiveness (Catarinella & Kram, 2025; European Commission, 2022; International Energy Agency [IEA], 2020).

Beyond the economic and technological considerations, the energy transition also has important social and political implications. By using different energy supply sources and investing in renewable energy infrastructure, European countries aim to reduce their exposure to geopolitical crises and energy price changes which helps to improve the energy security across the region. Moreover, public participation, social acceptance and regional development policies play an important role to ensure that the transition remains inclusive and socially balanced.

Overall, the energy transition is not only a tool for environmental sustainability but also, a factor in broader social and economic change, helping Europe become a leader of the global energy sector (International Energy Agency [IEA], 2020).

1.3. Energy in the Technology Business Sector

In today's economy, energy supports digital infrastructure, manufacturing and data operations. It also helps companies create new services, technologies and business models.

The energy sector is changing because of technological progress, digitalization and growing environmental goals. These changes are not only about moving from fossil fuels to renewable energy sources. They also involve the use of digital technologies, data and smart systems to improve how energy is produced, delivered and used. For example, companies use digital technologies in energy networks to help them improve the energy use, reduce operational costs and improve system reliability. They also support the use of renewable energy sources in electricity markets and energy grids (Madani et al., 2025).

Energy is not only needed for daily operations but is also an important strategic resource for technology companies. Companies that operate data services, such as cloud services and data centers, face large amounts of energy because they depend on servers and network equipment. At the same time, companies are investing in energy-efficient technologies and renewable energy sources to reduce carbon emissions and meet sustainability goals.

Technology companies change the way that they use energy and also the way they do business. Developments such as smart grids, energy trading platforms and prosumer models, show the close connection between technology and energy markets. These developments create new opportunities for companies. For example, companies can offer digital energy services, use renewable energy certificates and use blockchain technologies to support secure energy transactions.

Finally, effective energy use and sustainable energy strategies can improve competitive advantage, attract investment and influence corporate Environmental, Social and Governance (ESG) reporting (Fatemi et al., 2018). As technology companies continue to support the energy transition, they are finding ways to balance profitability with sustainability.

1.4.Purpose and Research Objectives of the Study

The purpose of this research is to study the relationship between the European energy sector and the technology business sector. Focusing on how energy trends, policies and technological developments influence businesses, strategic decision-making and their competitiveness. As Europe continues the energy transition, technology companies face important challenges and opportunities that affect their growth and sustainability.

More specifically, this study looks at the current energy landscape in Europe and how important is for the technology sector. The research analyzes energy supply, energy security and renewable energy sources and how they affect technology companies.

2. The European Energy Landscape

2.1. Structure of Energy Market in Europe

The European energy market changed during 1990s through a process known as liberalization. Before this period, energy system in Europe were controlled by governments and a small number of national companies. These monopolies system, made it difficult for new companies to enter the market and reduced energy flow between the countries.

The liberalization process changed totally the European energy sector. Open markets for electricity and natural gas were created, allowing more companies to enter the market. This increased competition and improved the efficiency of the energy sector.

As a result, energy markets became more open and dynamic and the prices more competitive. These changes also helped energy markets to become more connected. Basically, national markets became part of a larger European system known as the Internal Energy Market (IEM). This system was designed to improve efficiency and energy security. It also helped electricity and natural gas move freer between the countries and supported more similar prices across Europe.

Today, Europe's market helps support the energy transition. It supports the renewable energy, energy storage technologies and new ways of trading energy systems. Also, it helps provide reliable and sustainable energy to consumers. In addition, energy markets support broader goals, like the development of flexible energy resources, the attraction of investment and transition a low-carbon.

The European energy sector is changing because of climate policies, geopolitical developments, electrification and digitalization. These changes affect energy markets and business strategies. As a result, energy markets in Europe are becoming more connected and more competitive, helping the economy and the environment too.

2.2. Renewable Energy Deployment and Investment Trends

Over the past two decades, renewable energy has become very important in Europe. The use of wind and solar power has increased because of climate goals, energy security concerns and technological progress. This has changed the production of electricity, the investment and the business strategies in the energy sector.

The use of renewable energy in Europe has increased since the early 2000s with the support of the European Union targets and national policies. According to the European Commission and Eurostat, renewable energy now represents an important share of electricity in many Member States. For example, countries such as Germany, Spain, Denmark and Netherlands are leaders in renewable energy production. Wind and solar energy have grown rapidly, because technology has improved and costs have decreased (International Energy Agency [IEA], 2022).

Technological progress has helped in supporting the renewable energy grow. Studies show that improvements in technology and production processes have reduced costs of renewable energy. As a result, renewable energy has become more competitive related to fossil fuels (International Renewable Energy Agency [IRENA], 2023; Gross et al., 2018).

In the past, renewable energy projects mostly depended on government support programs. Today, private investors, institutional funds and technology companies are investing more in renewable energy projects. Financial tools such as power purchase agreements (PPAs), green bonds and sustainability-based financing helps support these investments (Polzin et al., 2019; Mendicino et al., 2019). These changes show that renewable energy is becoming more connected to financial markets, helping reduce investment risks and support projects.

Finally, renewable energy is becoming increasingly connected with digital technologies. Companies use smart forecasting tools, data analytics and digital asset management systems to improve renewable energy production and help connect variable energy sources to the electricity networks. This connection between renewable energy and digital innovation has attracted

technology companies and startups to the energy sector, supporting investment and innovation (International Energy Agency [IEA], n.d.).

2.3.Regulatory Framework and EU Energy Policies

2.3.1. Legal Foundations and Institutional Context

According to European Commission, energy policy is important for Europe's economy, energy security and climate goals. Responsibility for energy policy is shared between the European Union and its member countries under Article 194 of the Treaty on the Functioning of the European Union (European Commission, n.d.).

Energy policy of European Union focuses on three main areas (Georgiadou, 2022). First, it aims to ensure a secure energy supply for all member countries. Second, is keeping energy affordable for citizens and businesses. Third, is promoting the production of clean and sustainable energy to support the EU's climate goals and reduce the carbon emissions (European Commission, n.d.).

To address these challenges, the European Union has developed policies that support the transition to a low-carbon energy system. These policies focus on improving energy efficiency, promoting research and encouraging the use of clean energy. In addition, they encourage businesses, governments and consumers to take part in the energy transition process.

Finally, energy security is one of the main priorities of European Union. The European Union is trying to ensure a stable energy supply, reduce energy risks and make stronger the resilience of the energy system (Georgiadou, 2022). Also, it plays an important role in international discussions and cooperation related to climate policy and the global energy transition (European Parliament, n.d.).

2.3.2. Renewable Energy and Energy Efficiency Directives

European Union energy policy influenced by the Renewable Energy Directive (RED) and the Energy Efficiency Directive (EU 2023/1791). These policies set goals and rules which must be followed from all the European Union member states. The Renewable Energy Directive focuses to increase the use of renewable energy in Europe. In November of 2023, was the latest update set a target for at least 42.5% of the EU's total energy consumption to come from renewable energy sources by 2030, with an aim to reach 45%. These targets influence national energy policies, investment decisions and infrastructure development across Europe (European Commission, 2023).

The Energy Efficiency Directive aims to reduce overall energy consumption across the European Union. It sets a target to reduce energy consumption by 11.7% by 2030. The directive is based on the principle that energy efficiency should be considered in all important decisions. This shows that climate goals, requires the increase of renewable energy use and the reduce of energy demand.

Member states must follow these directives through national laws. This includes supporting renewable energy projects and the use of renewable technologies. The European Commission helps countries to understand and follow the rules correctly in the European Union.

2.4.Price Volatility and Energy Security in Europe

Price volatility in European energy markets has become more unstable, especially after the energy crisis of 2021-2022. This has created challenges for economic stability and energy security. Research shows that geopolitical events, especially Russia's war against Ukraine, have caused large increases in fossil fuel costs and electricity prices.

Academic studies show that unexpected geopolitical events and economic crises can increase uncertainty in energy markets and create higher market risk. These findings show the need for effective risk management strategies in the European energy sector (Halkos, 2018). Unpredictable

energy prices can create problems for households, businesses and industries. The dependence on a limited number of energy suppliers creates additional energy security risks.

In response to these challenges, European Union is developing long-term solutions. These include energy supply sources, improve of electricity networks and changes in energy markets. The aim is to reduce the price instability and reduce the risk (European Parliament, 2024).

One of the main characteristics of Europe's energy market in recent years has been extreme price volatility, especially for natural gas and electricity prices. During the 2022 energy crisis, the prices of natural gas at the Dutch Title Transfer Facility (TTF) exceeded 300 € per megawatt-hour (MWh). After the European Union introduced measures to increase gas storage and reduce demand, prices fell around 34€/MWh by December 2023 (Council of the European Union, 2023).

However, electricity prices have remained higher before the crisis. In early 2025, the average household in the European Union paid about 28.7€ for every 100kWh of electricity. This was a little lower than the end of 2024 but it was still higher than the pre-crisis levels (Business Daily, 2025).

Energy prices in Europe are still unstable. Studies show that electricity prices changed a lot during 2022 because of political events and changes in fossil fuel prices. The situation improved in 2023 and 2024, the prices remained more unstable than before 2021 and increased again in 2025. This shows that energy markets are still affected by changes in energy supply, demand and renewable energy production.

Household natural gas prices also decreased in 2025. According to Eurostat, gas prices fell by 8.1% compared with the second half of 2024, reaching about 11.43€ per 100kWh. This suggests that gas markets were becoming more stable after the large price changes of previous years (Eurostat, 2025).

European Union countries, to improve energy security increased gas storage levels before winter. In 2023 and 2024, storage facilities were more than 90% full, helping to reduce the risk of supply problems and high energy prices. During the winter months, storage levels fell and reached around 63% in late 2025. This reflects the seasonal pattern of energy demand and supply in Europe (World Energy News, 2025; Council of the European Union, 2023).

These developments show two important realities. First, energy markets of Europe are still affected by political events, climatic conditions and global energy supplies. Second, European Union policies, have helped improve energy security and market stability. The European energy market is now more stable than it was in 2022 but still faces challenges that affect consumers, businesses and future planning.

Research and policy studies show that reducing price volatility is very important for the economy in Europe, but also is the key for a stronger energy security in Europe, especially in this rapidly changing environment.

2.5.Digitalization of the Energy Sector

Digitalization has become a central pillar of the European energy transition (International Renewable Energy Agency [IRENA], n.d.). The use of renewable energy and also the role of consumers have increased, made the energy systems more complex. Studies by the International Energy Agency (2017) and the European Commission (2020) show that digital technologies help to improve the efficiency, flexibility and reliability of future energy systems.

In Europe, digitalization is a strong part of the European Green Deal and the European Union Digital Strategy (European Commission, 2020). These two initiatives show that digital technologies are important for the future of the energy sector (International Renewable Energy Agency [IRENA], n.d.). Nowadays, in energy systems the use of information and communication technologies (ICT) is a necessary condition. Digital tools help Europe to achieve its goals which are related to climate, energy supply and economic strength (European Commission, 2019; 2020).

2.5.1. Digitalization as a Driver of the Energy Transition

Traditional energy systems were designed for centralized the electricity production but the use of renewable energy has increased and changed the structure of the energy systems. According to the

International Energy Agency (2017), energy systems now require better monitoring, improved control systems and more flexible energy management.

Academic research shows that digitalization helps the energy systems operate in a more efficient and flexible way (International Renewable Energy Agency [IRENA], n.d.). Lund et al. (2015) argue that smart energy systems, supported by digital technologies, are essential for integrating renewables while keeping the energy systems stable. Digital tools help reduce system costs and improve operational efficiency by supporting a better balance between energy supply and demand (European Commission, 2020).

2.5.2. Smart Grids as the Foundation of Digital Energy Systems

One of the most important examples of digitalization in the energy sector are the smart grids (International Energy Agency [IEA], n.d.). According to Fang et al. (2012), smart grids use digital communication systems and manage electricity flows in real time. These systems allow better communication between electricity producers, grid operators and consumers (International Energy Agency [IEA], n.d.).

Research shows that smart grids help integrate renewable energy into electricity networks. Especially, smart grids help to improve the reliability and flexibility of electricity networks and help manage changes in energy supply and demand (Gungor et al., 2011). Also, smart grids support the energy efficiency and help reduce high electricity demand (International Energy Agency [IEA], n.d.).

In Europe, smart grids help connect energy markets and support electricity trade between countries and create a more connected European energy system.

2.5.3. Internet of Things (IoT) in the Energy Sector

The Internet of Things (IoT) is another important part of modern smart energy systems. It includes digital devices such as smart meters, monitoring systems and sensors, that collect and share data

automatically. The IoT, allow monitor energy systems and support better decisions through the use of real-time data information (Gubbi et al., 2013).

IoT technologies help monitor energy use, electricity networks and equipment performance. Smart meters allow consumers to understand better their energy use and support programs that encourage more efficient energy use. Furthermore, IoT systems support to find early technical problems, improving the reliability of energy networks.

At the same time, cybersecurity and data privacy have become important challenges in digital energy systems. The European Union to address these challenges, introduced the European Union Agency for Cybersecurity (ENISA). ENISA was founded in 2004 and later reinforced by the European Union Cybersecurity Act with a serious role of supporting European cybersecurity policy. It works with Member States and other institutions in Europe to improve cybersecurity, protect critical infrastructure and support cooperation between European countries that deal with cyber threats. It also helps to increase trust and security in the digital environment (European Union Agency for Cybersecurity [ENISA], 2019).

2.5.4. Artificial Intelligence and Data-Driven Energy Management

Artificial Intelligence (AI) plays one of the most important roles in modern energy systems. It helps analyze large amounts of data from smart grids and IoT devices. AI technologies such as machine learning and neural networks, improve energy forecasting and system management (International Energy Agency [IEA], 2017).

Accurate forecasts of electricity demand and renewable energy production help keep energy systems stable. Studies show that AI-based models are often more accurate than traditional methods, especially when renewable energy use is in high level (Hong et al., 2016). AI technologies are also used to detect technical problems early like the IoT, support maintenance and improve the management of energy systems (International Energy Agency [IEA], 2017).

Recent research shows that AI technologies improve energy forecasting, maintenance planning and energy management in smart energy systems (Safari et al., 2024). These technologies help energy companies make better decisions, improve system performance and increase reliability.

Studies also show that data-driven energy management systems can improve the use of energy resources and help energy systems adapt to changing conditions (Safari et al., 2024). In the future, much better AI technologies which are expected to be necessary in energy management will support more efficient and sustainable energy systems.

2.5.5. Impact on the Technology Business Sector

Energy markets depend on digital platforms, software solutions and data analytics technologies (International Renewable Energy Agency [IRENA], n.d.). As a result, technology companies now play a serious role in providing smart grid technologies, energy management systems and cybersecurity services (International Energy Agency [IEA], 2017).

This connection between the energy and technology sectors has also created new business opportunities. Some examples include digital energy platforms and energy-as-a- service models. Researches show that digitalization supports innovation and encourages cooperation between energy companies and technology firms (International Energy Agency [IEA], 2017). Consequently, digitalization is changing the energy systems but also is changing the way that companies compete and create value in the energy market.

2.6.Implications for Technology-Driven Industries

The transformation of the European energy sector has many effects on technology-driven industries. Changes in electricity markets, the growth of renewable energy, energy price volatility and digitalization are influencing the way that technology companies operate and make strategic decisions. These changes affect costs, investments and innovation activities.

Technological innovation has changed manufacturing systems. As discussed in previous paragraphs, the Internet of Things (IoT), artificial intelligence (AI), automation and data analytics help companies improve productivity, reduce costs and increase efficiency. These digital

technologies also support more flexible, energy-efficient production models processes (International Energy Agency (2017); Safari et al., 2024).

Moreover, the energy transition creates new challenges and opportunities for technology industries. Companies need to adapt to these changes in the energy sector while also meeting sustainability goals. For this reason, energy efficiency, innovation and flexibility have become important part of maintenance, competitiveness and support of long-term growth (International Energy Agency [IEA], 2023).

2.6.1. Energy Costs and Industrial Competitiveness

Energy is an important operational cost for many technology-driven industries, particularly data centers, semiconductor manufacturing, telecommunications networks and advanced digital infrastructure. The recent volatility in European electricity and gas markets has affected cost for many technology-driven industries (Eurostat, 2025).

The 2022 energy crisis following Russia's invasion of Ukraine created many challenges for many industries in Europe. The electricity and natural gas prices have been raised and the operating costs increased, creating the importance of energy security. As a result, many companies invested more in energy efficiency and renewable energy sources to reduce their dependence on volatile energy markets (European Commission, 2022).

For example, Microsoft has used long-term renewable energy contracts to reduce exposure to energy price volatility and support its sustainability goals (Microsoft, 2023).

2.6.2. Sustainability Pressures and ESG Integration

Technology-driven industries face increasing sustainability requirements in the European Union. Policies introduced through the European Green Deal have set more strict targets in trying to reduce emissions, improving sustainability reporting and addressing climate risks. Finally, Environmental, Social and Governance (ESG) criteria has become an important part of business strategy (European Commission, 2019).

Research shows that companies with strong Environmental, Social and Governance (ESG) performance often benefit because they attract more investors and have easier access to financing. Companies that invest in renewable energy, energy efficiency and lower carbon emissions can increase the confidence of investors and improve their competitive position (Bolton & Kacperczyk, 2021). Finally, sustainability is not only an environmental issue but also is an important factor for a business success.

2.6.3. Digitalization of Energy Systems as Market Opportunity

The digitalization of Europe's energy systems creates new business opportunities for technology companies. Smart grids, IoT, AI and real time analytics help improve the integration of renewable energy sources into electricity markets. Technology companies act as enablers of grid flexibility and system optimization (International Energy Agency [IEA], 2017).

At the same time, the use of digital technologies increases cybersecurity risks. All the digital energy systems require strong cybersecurity protection mechanisms, to ensure the security and reliability of energy networks. This creates demand for cloud computing services, cybersecurity and digital risk-management solutions (European Union Agency for Cybersecurity [ENISA], 2019).

2.6.4. Energy Security and Industrial Resilience

Energy security has become a big issue for industries in Europe, especially after recent energy supply disruptions and geopolitical risks. The energy crisis of the early 2020s showed that external events can have a huge impact on industrial production. In response, the European Union has focused on diversifying energy sources and reducing dependence on a small number of suppliers with aim to create stronger energy security and resilience (European Commission, 2022).

A stable energy supply is essential for technology industries. Many industries such as semiconductor fabrication, automated production systems and advanced manufacturing facilities need a supply of electricity to operate effectively. Even a short power interruption can stop

production, damage the equipment and increase costs. For this reason, companies are paying now more attention to reliable energy supplies and better risk practices (European Commission, 2022).

2.6.5. Innovation Ecosystems and Industrial Policy

The European energy transition supports innovation and technological development. Through programs like Horizon Europe, the European Union supports research and innovation in energy and digital technologies (European Commission, 2024). Research also shows that environmental policies can encourage innovation and improve productivity (Porter & van der Linde, 1995).

European Union also supports cooperation between companies, public organizations and research organizations through partnerships. These partnerships help develop new technologies, improve industrial performance and support sustainability. Also, they help Europe to remain competitive while supporting the green and digital transition (European Commission, 2024).

Overall, European policies encourage research and development, support new technologies and create opportunities for companies. This helps companies improve their performance, adapt to the energy transition and remain competitive in global markets (European Commission, 2024).

3. Technology Business Sector in Europe

3.1. Overview of the Technology Business Sector in Europe

The technology business sector is an important part of the European economy. It helps new technologies, support economic growth and business development across the European Union. The sector includes activities such as information and communication technologies (ICT), software

development, artificial intelligence (AI), digital services and advanced manufacturing. These industries work closely with traditional sectors and help improve productivity and economic development (Organisation for Economic Co-operation and Development [OECD], 2024).

European companies also play an important role in research and innovation. Although Europe still face a strong competition from the United States and China in terms of technologies and large digital platforms (Centre for Economic Policy Research [CEPR], 2023).

One of the main characteristics of the European technology sector is that the level of innovation differs across member states. Countries such as Germany, the Netherlands, Sweden and Finland have better digital adoption, research and development (R&D) investment and technological innovation than many Southern and Eastern European countries (European Investment Bank [EIB], 2023). These differences are influenced by digital infrastructure, education and skills, which affect the digital transformation in Europe.

Digital technologies such as cloud computing, big data, automation and AI, help companies improve the production process and economic performance. Studies show that investing in digital technologies can help companies improve efficiency, competitiveness and innovation (Centre for Economic Policy Research [CEPR], 2023).

Despite the progress, the technology sector in Europe still faces some challenges. Compared with the United States, Europe has limited access to funding which is difficult for startups and new businesses to grow. These challenges can slow the development and adoption of new technologies (European Investment Bank [EIB], 2023).

Finally, the European technology sector has strong research capabilities, important technology hubs and increasing use of digital technologies. Europe still faces challenges in investment and business development which can affect its position in the global technology market (European Investment Bank [EIB], 2023).

3.2. Structure of the European Technology Market

The European technology market is made up of many different companies and industries. Small and medium sized enterprises (SMEs) play an important part, while the level of digital adoption differs in European Union countries. The sector is influenced by European policies that support competition, sustainability and digital development. Europe's information and communications technology (ICT) sector is a key for the economic growth but it remains less connected than the technology markets of the United States and China (European Parliament, 2025).

The Digital Economy and Society Index (DESI), is one of the main tools used to measure digital development in the European Union. It looks at the digital infrastructure, digital skills, business digitalization and public digital services. DESI reports show that Europe has improved in these areas but there are still differences between countries, especially in the use of digital technologies by businesses.

Many of these businesses have difficulties to adopt digital technologies and improve their competitiveness. Research shows that digital technologies are used more by Northern and Western European countries than Southern and Eastern Europe (Eurofound, 2023).

The European technology sector, still faces some challenges that based on different rules in European Union countries which can make it difficult for companies to grow. This can reduce the ability of Europe to compete with the United States and China. At the same time, European policies focus on protecting consumers and data, which can create both benefits and challenges for businesses (European Parliament, 2025).

3.3. Economic Contribution and Productivity Effects

The technology business sector is a central part of the European economy. It supports economic growth, creates jobs and helps businesses improve their production process. Research shows that investment in information and communication technologies (ICT) help businesses work more

efficiently and improve their performance across different sectors. Digital technologies are used in many sectors of the economy, including manufacturing and services and also support long-term economic growth (Bresnahan & Trajtenberg, 1995; Organisation for Economic Co-operation and Development [OECD], 2020).

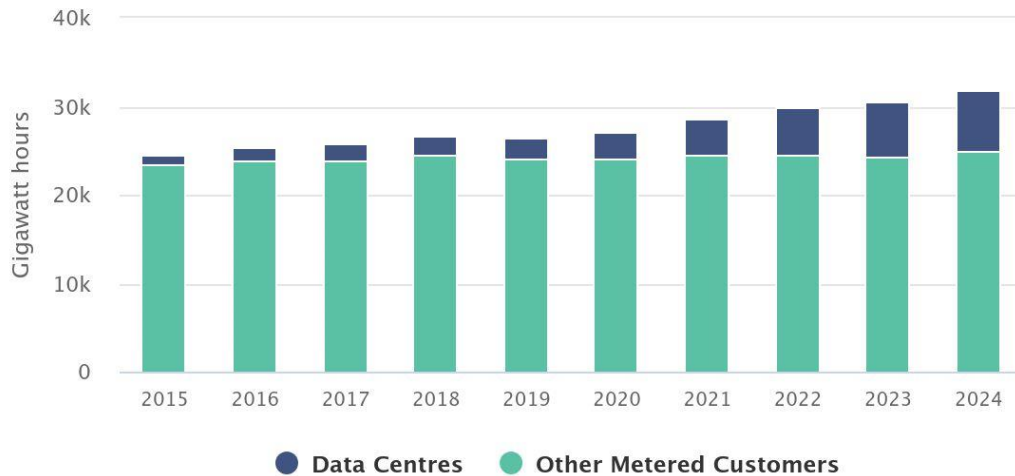
However, the benefits of digital technologies are not the same in every country of the European Union because countries with better digital skills often achieve better productivity than countries which the adoption of digital technologies is more limited (van Ark, 2016).

3.4. Energy Intensity and Infrastructure Dependence

The technology sector is often considered as a low energy industry but the continuous use of cloud computing, artificial intelligence (AI) and digital services has increased its energy consumption (International Energy Agency, 2023).

One of the main reasons for this increase of energy consumption is the rapid growth of data centers, which are essential for storing and processing digital information. Despite the fact that the data centers have become more energy efficient, their total electricity continues to rise because has increased the demand for digital services. In countries such as Ireland, data centers already are very important for sharing the electricity use (European Commission Joint Research Centre [JRC], 2024; Central Statistics Office Ireland, 2024). Figure 3 shows the increasing electricity consumption of data centers in Ireland between 2015 and 2024, emphasizing the growing energy dependence of digital infrastructure.

**Figure 1 Metered Electricity Consumption 2015-2024
(GWh)**



Source: CSO Ireland
Highcharts.com

Figure 3 Growth of Data Centre Electricity Consumption in Ireland 2015-2024 (adapted from Central Statistics Office Ireland 2024)

The expansion of 5G networks and connected devices has also increased energy demand. Even though these technologies are more efficient than the older systems, the growing amount of data traffic continues to increase the electricity consumption (International Energy Agency [IEA], 2023; Andrae, 2020).

The technology sector needs a reliable supply of energy to operate effectively. Power cuts and increases in energy prices can create problems and increase operating costs (International Energy Agency [IEA], 2023). For this reason, many technology companies invest in renewable energy projects and long-term energy agreements to secure their energy needs (Google, 2023; Amazon, 2023).

The technology and energy sectors are becoming more connected. Digital technologies support modern energy systems, while technology companies depend on reliable energy supplies to operate effectively. Cooperation between these two sectors is very important for economic growth and sustainability (International Renewable Energy Agency [IRENA], 2022).

3.5.Regulatory Environment and Sustainability Pressures

In the European Union, rules and regulations affect the way that the technology companies operate. In recent years, the European Union has introduced policies which can support environmental sustainability by reducing emissions and improving energy efficiency. These policies encourage companies to pay more attention to environmental issues and energy use (Porter & van der Linde, 1995; European Commission, 2019).

The Corporate Sustainability Reporting Directive (CSRD) was one of the most important changes, which requires many companies to give information about their environmental and social activities. Technology firms must monitor and report their energy use, emissions and sustainability actions (European Union, 2022).

Energy policies also can affect technology companies. The European Union Emissions Trading System (EU ETS), for example, increases electricity costs which may lead to higher operating costs. For this reason, many firms invest in renewable energy and long-term energy contracts to reduce costs and secure their energy supply (International Energy Agency [IEA], 2022).

Furthermore, investment decisions have been more influenced by environmental, social and governance (ESG) issues. Companies with a strong sustainability performance are often more attractive to investors (Bolton & Kacperczyk, 2021).

Finally, the use of digital technologies has increased interest in reducing energy consumption. Many technologies companies are investing in “green IT” solutions, including more efficient data centers and other solutions that help save energy (International Energy Agency [IEA], 2023).

3.6.Strategic Autonomy and Digital Sovereignty

In recent years, strategic autonomy and digital sovereignty have become important priorities for European Union. Strategic autonomy refers the ability of European Union to reduce its dependence on external countries and companies in the technology sectors. This issue has become more important because of supply chain problems, political tensions and the strong role of non-European technology companies (European Commission, 2021).

Digital sovereignty is related to the control of data and digital systems. The European Union wants to reduce its dependence on foreign technology companies while protecting data, privacy and competition. Regulations such as the General Data Protection Regulation (GDPR) and the Data Act support these objectives by setting rules for the collection, storage and use of data (European Parliament & Council of the European Union, 2016; European Commission, 2022).

Despite these efforts, Europe still depends on non-European technology companies especially in areas such as cloud computing, digital platforms and artificial intelligence (AI). This has made the concerns bigger about data security and Europe's ability to compete in the global technology market.

These changes also affect technology companies operating in Europe. Businesses must follow rules related to data protection, cybersecurity and the use of digital technologies. Although these changes may increase costs, they can also help companies gain customer trust and become more competitive in the market.

Overall, strategic autonomy and digital sovereignty are becoming very important for the European technology sector and will continue to influence future business and technology developments.

3.7.Critical Evaluation

The European technology business sector operates within a highly ambitious but complex regulatory and strategic framework, shaped by sustainability goals, digital sovereignty ambitions

and industrial policy. While these initiatives reflect a clear long-term vision, their practical implementation often reveals tensions between policy objectives and market realities. On the other hand, the European Union seeks to promote innovation, competitiveness and openness. On the other, it introduces extensive regulatory requirements that may increase operational burdens for firms. This duality raises an important question: whether the current policy mix effectively supports technological growth or unintentionally constrains it.

A key area of debate concerns the impact of sustainability regulations on the competitiveness of technology firms. Policies such as emissions reduction targets, ESG reporting requirements and energy transition measures are essential for addressing climate change, but they also impose additional costs, particularly on smaller firms with limited resources. While large multinational companies are often able to absorb these costs or even benefit from them through economies of scale, smaller technology enterprises may face barriers to growth. This creates a potential imbalance within the sector, where regulation could unintentionally favor established players over emerging innovators (Organisation for Economic Co-operation and Development [OECD], 2021).

Similarly, the EU's push for digital sovereignty, while strategically justified, presents both opportunities and limitations. Efforts to reduce dependence on non-European technology providers aim to enhance security and control over data, but they may also lead to fragmentation of the digital market. In a globalized technology ecosystem, innovation often relies on cross-border collaboration, access to international markets and integration within global value chains. Excessive focus on autonomy could therefore risk isolating European firms or limiting their ability to compete globally, particularly in fast-moving sectors such as artificial intelligence and cloud computing.

At the same time, it is important to recognize that regulation can also act as a catalyst for innovation. The so-called "Porter Hypothesis" suggests that well-designed environmental regulations can stimulate technological development and improve efficiency. In the European context, strict data protection rules and sustainability standards may encourage firms to develop new solutions, such as energy-efficient data centers or privacy-enhancing technologies. Therefore, the impact of regulation is not purely restrictive. It depends on how effectively policies are designed and implemented (Porter & Van der Linde, 1995).

Overall, the European approach to regulating and shaping the technology sector reflects a delicate balancing act between control and openness, sustainability and competitiveness and autonomy and globalization. While the current framework provides a strong foundation for long-term resilience and ethical governance, it also introduces risks related to complexity, cost and global positioning. A critical evaluation suggests that the success of this approach will depend not only on the ambition of policies but also, on their flexibility, coherence and ability to adapt to rapid technological and economic change.

4. Interconnections Between Energy and the Technology Business Sector

The energy sector and the technology business sector are very connected with each other. As digital technologies continue to grow, technology companies need a reliable and affordable energy supply. At the same time, new technologies help improve energy systems and support the use of renewable energy. In Europe, this relationship has become more important because the European Union is promoting both the digital transition and the green transition (European Commission, 2020; International Energy Agency [IEA], 2017).

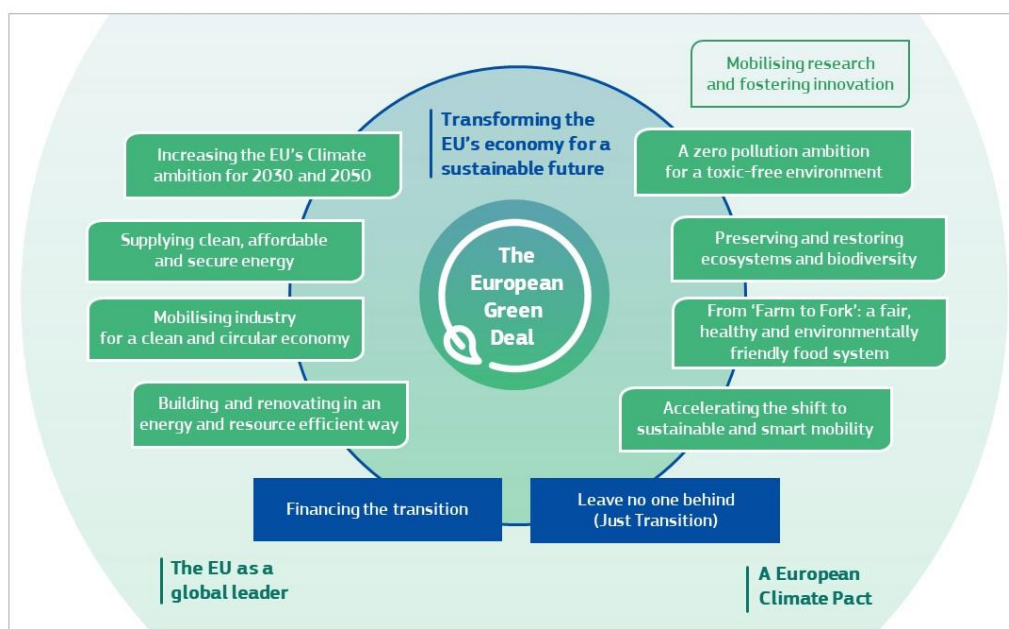


Figure 4 The European Green Deal (European Commission, 2019)

Figure 4 shows how the European Green Deal connects clean energy, industrial development and digital innovation. It shows that the energy transition and digital transformation support each other and are both important for Europe's future development (European Commission, 2019).

In addition, the rapid growth of cloud computing, artificial intelligence (AI) and the Internet of Things (IoT) has increased energy demand in the technology sector. Data centers and communication networks, requires a continuous electricity supply, making energy availability and cost critical factors for the sector's development (Organisation for Economic Co-operation and Development [OECD], 2020).

Digital technologies are helping to improve the energy sector. Smart grids, smart meters and artificial intelligence (AI) systems help manage electricity more efficiently and support sustainability. Finally, the technology sector is not only dependent on energy systems but it also actively reshaping them, reinforcing the bidirectional nature of this relationship (International Energy Agency [IEA], 2017).

4.1. Energy as a Critical Input for the Technology Sector

The strong connection between the energy and technology sectors is mainly because technology companies need a stable supply of electricity to operate. Digital services, cloud computing platforms and communication networks depend on continuous electricity to provide reliable services. For this reason, energy has become an essential part of technology sector (European Commission, 2020; International Energy Agency [IEA], 2020).

This dependence in the case of data centers, which are an important part of the digital economy. They use large amounts of electricity to power servers and cooling systems. As demand for digital services continues to grow, the energy use of data centers and communication networks is also increasing (International Energy Agency [IEA], 2023).

In addition, a reliable energy supply is equally important as the quantity consumed. Technology companies require high levels of power stability, as even short interruptions can lead to system downtime, financial losses and reputational damage. This makes access to well-developed and reliable energy infrastructure to support their daily operations (International Energy Agency [IEA], 2022; Organisation for Economic Co-operation and Development [OECD], 2020).

Furthermore, technology companies are trying to reduce their environmental impact by improving energy efficiency and using cleaner energy sources. This is encouraged by European Union policies but also the need to align with environmental, social and governance (ESG) issues (European Commission, 2019; International Energy Agency [IEA], 2021).

Finally, companies often choose to invest in regions with reliable and affordable energy. Energy availability and infrastructure make these areas more attractive for data centers and other digital investments (International Energy Agency [IEA], 2022).

4.2. Impact of Energy Prices and Volatility on Technology Firms

Technology companies depend on large amounts of electricity to operate. For this reason, changes in energy prices can affect their operating costs and business performance. In Europe, energy prices have become more unstable because of geopolitical events, energy supply problems and the energy transition (International Energy Agency [IEA], 2022).

Energy price changes also affect business decisions. When the electricity prices are uncertain, companies may delay new investments or choose to build data centers in regions where energy is more reliable and affordable. As a result, energy price can influence where technology companies decide to invest (International Energy Agency [IEA], 2023).

To reduce these risks, many technology companies use long-term power purchase agreements (PPAs), invest in renewable energy and improve the energy efficiency of their facilities. These actions help reduce energy costs and support sustainability and decarbonization objectives (International Renewable Energy Agency [IRENA], 2021).

In addition, higher electricity prices can also reduce the competitiveness of European technology companies compared with firms in other parts of the world. As a result, some companies may move energy intensive activities to regions with lower energy costs or adjust their businesses strategies (International Energy Agency [IEA], 2022).

European policies such as carbon pricing mechanisms and emissions trading systems also influence energy prices. May increase costs in the short term, they also encourage companies to use cleaner energy and improve energy efficiency (European Commission, 2023).

4.3. Technology as a Driver of Energy Transformation

Energy is important part of the technology sector, but technology also plays an important role in changing the energy sector. Smart grids, artificial intelligence (AI), the Internet of Things (IoT) and blockchain, help improve the production, distribution and the use of energy. These

technologies make it easier to use renewable energy and improve the efficiency of energy systems (International Energy Agency [IEA], 2021).

One of the best examples is the development of smart grids. These systems help manage electricity more efficiently, balance energy supply and demand and support the use of renewable energy sources such as solar and wind power. Technology companies help develop and maintain these systems, making them important parts in the energy transition (International Energy Agency [IEA], 2022).

In addition, to grid-level innovations, digital technologies are facilitating energy efficiency at the consumption level. Artificial intelligence (AI) allows commercial buildings, industrial facilities and data centers to optimize electricity usage, anticipate peak demand and reduce waste. Internet of Things (IoT) enabled devices provide granular monitoring of energy flows, enabling organisations to make data-driven decisions that minimize environmental impact and operational costs. These developments illustrate how technology is not only enabling the energy sector to transition toward sustainability but also, generating new business models, such as demand-response services and virtual power plants (International Energy Agency [IEA], 2021).

Finally, digital technologies also support battery storage and local energy networks. Technology companies provide the software, analytics and cybersecurity infrastructure required for these systems to function effectively. While technology companies depend on reliable energy to operate, they also provide the digital solutions that help create, more efficient and more flexible energy system (European Commission, 2019).

4.4.Sustainability Pressures and Green Technology Adoption

The increasing focus on sustainability is a major driver of technological innovation and energy transformation within the European technology sector. As energy-intensive digital operations grow, firms face huge pressure from regulators, investors and consumers to reduce their environmental footprint. European policies such as the Green Deal and Fit for 55 package,

alongside international climate commitments, have established ambitious targets for carbon reduction, renewable energy integration and energy efficiency. Consequently, technology firms are increasingly adopting green technologies not only to comply with regulations but also to achieve strategic advantages in a market that increasingly values environmental responsibility (European Commission, 2019; Organisation for Economic Co-operation and Development [OECD], 2020).

One of the primary areas of adoption is renewable energy integration. Technology firms, particularly those operating data centers, cloud computing facilities and large-scale digital infrastructure, are investing in on-site renewable energy generation and long-term power purchase agreements (PPAs) with green energy providers (International Renewable Energy Agency [IRENA], 2018). These measures allow firms to stabilize energy costs, reduce carbon emissions and align with corporate sustainability goals. Moreover, the adoption of renewable energy technologies strengthens energy security by reducing dependence on volatile fossil fuel markets (International Renewable Energy Agency [IRENA], 2018).

The adoption of green technologies also fosters innovation in business models and services. For instance, demand-response solutions, virtual power plants and energy as a service platform enable technology firms to actively participate in the energy market while promoting sustainability. By leveraging these solutions, firms can contribute to grid stability, integrate decentralized renewable resources and offer energy-efficient products to clients, further embedding sustainability into their operational and strategic frameworks (European Commission, 2021).

Finally, sustainability pressures and green technology adoption are not purely regulatory responses but also key determinants of corporate reputation, stakeholder engagement and investment attractiveness. Firms that proactively implement green technologies signal environmental responsibility, align with ESG criteria and position themselves competitively in a market increasingly sensitive to climate-related risks. This trend reinforces the bidirectional dynamic of the energy-technology relationship, wherein technological capabilities enable energy transformation while sustainability imperatives shape technology deployment strategies (International Energy Agency [IEA], 2021; European Commission, 2020).

4.5. Feedback Effects: **The Energy-Technology Loop**

The relationship between energy and the technology sector is inherently bidirectional, creating a feedback loop in which developments in one sector reinforce transformations in the other. On one hand, energy availability, cost and sustainability pressures shape the operational efficiency, investment strategies and technological choices of firms. On the other hand, technological innovations actively influence the structure, efficiency and sustainability of energy systems. This mutual dependence creates a dynamic interaction that drives both sectors toward greater integration, resilience and innovation (International Energy Agency [IEA], 2021; European Commission, 2020).

Technological advancements allow the energy sector to operate more efficiently, integrate renewable energy sources and provide real-time data on consumption and generation. These improvements reduce operational risks for technology firms by ensuring reliable, flexible and predictable energy supply. At the same time, as technology firms expand energy-intensive digital services like cloud computing, AI processing and high-performance computing, they increase demand for more efficient and resilient energy infrastructure. This cyclical interaction strengthens both sectors and accelerates systemic transformation (International Energy Agency [IEA], 2022).

The feedback loop is particularly evident in the context of sustainability and green technology adoption. As technology firms invest in energy efficiency and renewable energy solutions, they reduce the carbon intensity of digital operations while simultaneously stimulating demand for innovative energy solutions. This encourages further technological development within the energy sector, creating a reinforcing cycle of efficiency, decarbonization and digital innovation. European policies, including the Green Deal and digital strategy initiatives, explicitly recognize and aim to leverage this mutually reinforcing relationship (European Commission, 2019; International Renewable Energy Agency [IRENA], 2022).

Feedback effects also manifest in strategic and economic outcomes. Regions with advanced, digitalized energy infrastructure attract technology investments, while technology-driven innovations reduce energy costs and increase system reliability, further incentivizing investment

in these areas. Similarly, energy market volatility, sustainability pressures and technological capabilities interact to influence corporate decision-making, risk management and competitiveness. The energy-technology loop thus represents a dynamic system in which both sectors continuously adapt to and shape one another, creating both opportunities and challenges for European economic development (International Energy Agency [IEA], 2023).

Ultimately, understanding this feedback loop is crucial for policymakers and industry stakeholders. It highlights that interventions in one sector, such as regulatory changes, investments in smart grids or incentives for green technology adoption, can have amplified effects on the other sector. Recognizing and leveraging these interactions enables more effective alignment of digital and energy strategies, contributing to sustainable growth, technological competitiveness and a resilient energy-technology ecosystem in Europe (European Commission, 2020).

4.6. Conclusion

This chapter examined the close relationship between the energy sector and the technology business sector in Europe. It showed that the two sectors are strongly connected and the developments in one's sector straight affect the other.

The chapter also showed that energy prices, European policies and sustainability goals influence the decisions of technology companies. At the same time, digital technologies help improve energy systems and support the use of renewable energy.

Finally, cooperation between the energy and technology sectors is becoming very important for Europe's future. A stronger connection between these sectors can support economic growth, improve competitiveness and help achieve the European Union's energy and climate goals.

5. New Technologies Transform the Energy-Technology Relationship

In recent years, new technologies have changed the relationship between the energy sector and the technology business sector. Digital technologies are helping improve energy systems, while technology companies continue to depend on reliable energy. In Europe, this relationship has become more important because the European Union supports both digital transformation and the transition to clean energy (European Commission, 2019; International Energy Agency [IEA], 2021).

New technologies are now an important part of the energy transition. They help improve energy production, distribution and consumption while supporting more sustainable and efficient energy systems.

5.1. Artificial Intelligence and Data-Driven Energy Optimization

Artificial intelligence (AI) has emerged as one of the most influential technologies shaping the modern-technology nexus. By enabling advanced data analytics, machine learning algorithms and predictive modeling, AI allows energy systems to operate with unprecedented efficiency and responsiveness (Safari et al., 2024).

Within the technology sector, AI plays a crucial role in reducing energy consumption in high-demand infrastructures such as data centers. These facilities require continuous power supply and efficient cooling systems, which traditionally account for a large portion of their energy use. AI-driven optimization tools can dynamically adjust cooling mechanisms, server loads and power distribution, significantly lowering energy consumption and operational costs (Safari et al., 2024).

Nevertheless, the growing adoption of AI also creates new challenges. Advanced AI systems require substantial computational power, particularly in areas such as machine learning and large-scale data processing. Consequently, technologies designed to improve efficiency may

simultaneously intensify electricity demand and deepen the technology sector's dependence on energy infrastructure.

5.2.Smart Grids and the Internet of Things (IoT)

The development of smart grids represents a fundamental shift from traditional, centralized energy systems to more decentralized and interactive networks. Smart grids utilize digital communication technologies, sensors and IoT devices to enable real-time monitoring and control of electricity flows. This allows energy providers and consumers to exchange information continuously, facilitating more efficient and flexible energy management (European Commission, 2021).

In Europe, the development of smart grids is closely aligned with policy objectives aimed at improving energy efficiency, integrating renewable sources and enhancing system resilience (European Commission, 2021). Smart grids enable more accurate balancing of electricity supply and demand while supporting the integration of decentralized renewable generation such as solar and wind power.

For the technology business sector, smart grids create new opportunities and responsibilities. Technology firms can actively manage their energy consumption through demand-response mechanisms, adjusting usage based on real-time price signals or grid conditions. This not only reduces costs but also contributes to overall grid stability. In addition, IoT-enabled devices allow companies to collect vast amounts of data on energy usage patterns, which can be analyzed to optimize operations and reduce waste.

Moreover, this integration of IoT in energy systems also supports the growth of decentralized energy models, such as microgrids and distributed generation. These systems enable businesses to produce their own electricity, often through renewable sources and either consume it internally or feed it back into the grid (International Energy Agency [IEA], 2021).

5.3. Energy Storage Technologies and Flexibility

Energy storage technologies play an important role in enabling the integration of renewable energy sources and enhancing the flexibility of energy systems. Renewable energy, particularly wind and solar, is inherently intermittent, which creates challenges for maintaining a stable and reliable electricity supply. Advanced storage solutions, such as lithium-ion batteries, pumped hydro storage and emerging solid-state technologies, address this issue by storing excess energy during periods of high generation and releasing it when demand exceeds supply (International Energy Agency [IEA], 2023).

For technology companies, energy storage provides both operational and strategic benefits. On an operational level, it ensures a stable power supply for energy-intensive activities, such as cloud computing and data processing. This is particularly important for firms that rely on uninterrupted service delivery. On a strategic level, storage technologies enable companies to increase their use of renewable energy, thereby reducing their carbon footprint and exposure to energy price volatility (International Energy Agency [IEA], 2023).

Furthermore, large-scale energy storage systems are increasingly being integrated into corporate energy strategies. Technology firms are investing in on-site battery installations and participating in energy markets by providing grid services such as frequency regulation and peak shaving. These developments show the growing role of technology companies as active participants in energy systems, rather than passive consumers. However, despite these advantages, the expansion of battery technologies also raises concerns regarding critical raw material dependence, supply chain security and the environmental impacts associated with battery production and disposal. Consequently, the long-term sustainability of energy storage technologies remains an important issue within European energy and industrial policy discussions (International Energy Agency [IEA], 2023).

5.4. Blockchain and Decentralized Energy Systems

Blockchain technology introduces a new way for energy transactions by enabling decentralized, transparent and secure systems. Unlike traditional centralized energy markets, blockchain-based platforms allow peer-to-peer energy trading, where individuals and companies can buy and sell electricity directly. This is particularly relevant in the context of distributed energy resources, such as rooftop solar panels, where excess energy can be shared within local communities or business networks.

For the technology sector, blockchain offers opportunities to enhance efficiency, reduce transactions costs and improve trust in energy markets. Smart contracts – self executing agreements coded on blockchain platforms – can automate energy transactions based on predefined conditions, reducing the need for intermediaries. This not only streamlines operations but also increases transparency and accountability.

In addition, blockchain can be used to track renewable energy certificates and carbon emissions, providing verifiable data that supports sustainability reporting and regulatory compliance. As environmental concerns become more prominent, the ability to demonstrate the origin and impact of energy consumption is increasingly valuable for technology companies. However, it is important to say that blockchain itself can be energy-intensive, particularly in proof-of-work systems, which raises questions about its overall sustainability.

5.5. Cloud Computing and Data Centers as Energy Actors

Cloud computing has become a cornerstone of modern digital economy, supporting a wide range of services from data storage to artificial intelligence applications. However, the rapid expansion of cloud infrastructure has also led to a significant increase in energy demand. Data centers, which form the backbone of cloud computing, are among the largest consumers of electricity globally. This has prompted technology companies to rethink their energy strategies and invest heavily in sustainable energy solutions (International Energy Agency [IEA], 2023).

In response, technology companies are increasingly transforming their energy strategies. Many firms are entering long-term power purchase agreements (PPAs) to secure renewable energy providers, often directly financing the development of wind and solar projects to secure stable and low-carbon electricity supplies. This ensures a stable and predictable energy supply and also contributes to the broader expansion of renewable energy capacity. In some cases, data centers are designed to operate entirely on renewable energy, demonstrating the feasibility of low-carbon digital infrastructure (International Energy Agency [IEA], 2023).

At the same time, data centers are increasingly acting as active participants in energy systems. Through demand-response programs, facilities can adjust their energy usage in response to grid conditions, helping to balance supply and demand during peak periods. In addition, advances in cooling technologies, such as liquid cooling and waste heat recovery, are improving energy efficiency and reducing environmental impact. These developments illustrate how cloud computing infrastructure is evolving from a passive energy consumer into a dynamic and strategic energy actor (International Energy Agency [IEA], 2023).

5.6. Electrification and Green Hydrogen Technologies

Electrification and green hydrogen are key components of the transition toward a low-carbon economy, with significant implications for the relationship between energy and technology sectors. Electrification involves replacing fossil fuel-based processes with electricity, ideally generated from renewable sources. This trend is particularly relevant for technology firms, which are increasingly reliant on electricity to power digital infrastructure, manufacturing processes and emerging technologies such as electric mobility.

Green hydrogen, produced electrolysis using renewable energy, offers an alternative energy carrier that can be used in sectors where direct electrification is difficult. For the technology sector, hydrogen has potential applications in backup power systems, energy storage and even data center operations. It also plays a role in supporting the decarbonization of supply chains, particularly in

industries such as semiconductor manufacturing and hardware production (International Energy Agency [IEA], 2023).

The adoption of these technologies is supported by European policy initiatives, which aim to scale up hydrogen production and promote electrification across sectors. As these technologies mature, they are expected to be stronger the interdependence between energy systems and technological innovation, creating new opportunities for collaboration and investment (International Energy Agency [IEA], 2019).

5.7. Conclusion

This chapter examined how new technologies are changing the relationship between energy sector and the technology business sector. Technologies such as artificial intelligence (AI), smart grids, energy storage, blockchain, cloud computing and green hydrogen are helping improve energy systems while creating new opportunities for technology companies.

These technologies support energy efficiency, renewable energy and digital innovation. At the same time, they help companies improve their operations and support Europe's transition to a more sustainable and competitive economy (International Energy Agency [IEA], 2023).

6. Economic, Strategic Implications and Associated Challenges

6.1.Introduction

The evolving relationship between the energy sector and the technology business sector in Europe reflects a broader structural transformation driven by decarbonization and digitalization. Energy is no longer a passive production input but a strategic factor influencing firm competitiveness, innovation capacity and long-term sustainability. At the same time, the rapid expansion of digital technologies is reshaping energy demand patterns, creating new interdependencies between the two sectors. Consequently, the interaction between energy and technology has become increasingly important for understanding contemporary economic development and industrial transformation within the European Union.

In recent years, European policymakers have prioritized both the digital transition and the green transition as central pillars of long-term economic strategy. This dual transition has intensified the integration of energy systems and digital infrastructures, particularly through the expansion of cloud computing, artificial intelligence (AI) and data-intensive services. However, while digitalization contributes to energy efficiency and system optimization, it also generates substantial increases in electricity demand, particularly from data centers and communication networks (International Energy Agency [IEA], 2023).

This chapter examines the economic and strategic implications of the evolving energy–technology relationship while also addressing the associated regulatory, geopolitical, and structural challenges faced by technology firms operating in Europe. Particular attention is given to energy price volatility, sustainability pressures, strategic corporate responses and long-term infrastructure constraints. The chapter further analyzes how companies are adapting to increasing uncertainty through renewable energy investments, energy efficiency strategies and digital innovation.

6.2.Economic Implications for the Technology Business Sector

Energy price volatility has fundamentally altered the financial landscape for technology firms (Eurostat, 2025). The European energy crisis highlighted the extent to which fluctuations in

electricity and gas prices can directly impact operational costs, particularly for energy-intensive infrastructures such as data centers. For technology firms operating on thin margins in highly competitive markets, such volatility represents a significant economic risk (International Energy Agency [IEA], 2023).

The sharp increase in electricity and natural gas prices during the Russia-Ukraine war exposed the vulnerability of energy-intensive digital infrastructures, particularly data centers. According to the International Energy Agency (2023), wholesale electricity prices in Europe increased during 2022 compared to previous years, placing substantial pressure on operational expenditures. Given that large-scale data centers can consume as much electricity as small cities, fluctuations in energy prices directly translate into increased operating costs and reduced profit margins for firms operating in highly competitive environments.

At the same time, the declining cost of renewable energy has significantly improved the economic attractiveness of corporate renewable procurement. Recent evidence from International Renewable Energy Agency (IRENA, 2021) indicates that the rapid reduction in solar and wind generation costs has enabled firms to increasingly contract renewable electricity at competitive or even lower prices than fossil-based alternatives. More specific, the levelized cost of electricity (LCOE) for solar photovoltaics and onshore wind has fallen by approximately 80% and 60% respectively over the past decade, making renewables increasingly cost-competitive with fossil fuels. As a result, many large companies, particularly in the technology sector, have adopted long-term Power Purchase Agreements (PPAs) to stabilize electricity costs and reduce exposure to wholesale price volatility.

These agreements function as financial hedging instruments, allowing firms to lock in fixed electricity prices over extended periods. Beyond cost considerations, corporate renewable procurement is increasingly driven by strategic and sustainability objectives, as firms seek to improve environmental performance and respond to stakeholder expectations. Overall, energy strategy has evolved from a purely operational cost center into a strategic asset that supports risk management, competitiveness and corporate sustainability goals.

Beyond operational cost considerations, energy strategy is increasingly linked to firm valuation and investor expectations. Environmental, Social and Governance (ESG) criteria now play a

central role in capital allocation decisions, incentivizing firms to demonstrate measurable progress in reducing carbon emissions. Large technology companies such as Google, Microsoft and Amazon have responded by investing heavily in renewable energy assets and carbon-neutral strategies. These investments not only enhance corporate reputation but also function as risk management tools, reducing exposure to regulatory penalties and future carbon pricing mechanisms.

However, the increasing importance of sustainability-oriented energy strategies may also contribute to market concentration within the technology sector. Large multinational firms possess the financial resources necessary to invest in renewable energy projects, advanced energy management systems, and sustainability reporting frameworks. In contrast, smaller firms often face greater financial and organisational constraints, limiting their ability to adopt similar strategies. As a result, the transition toward sustainable and energy-intensive digital infrastructures may unintentionally reinforce competitive asymmetries within the technology business sector.

6.3.Strategic Responses by Technology Firms

In response to energy-related challenges, technology firms are increasingly integrating energy considerations into their strategic decision-making processes. This shift reflects a broader transition toward climate-aligned business models, in which firms seek to reconcile profitability with environmental sustainability. From a theoretical perspective, this evolution can be interpreted through the lens of the Resource-Based View (RBV), which suggests that firms can achieve sustained competitive advantage by developing valuable, rare and difficult to imitate capabilities. In this context, advanced energy management, renewable procurement strategies and energy - efficient infrastructure are emerging as strategic resources that differentiate leading technology firms from their competitors (Bolton & Kacperczyk, 2021).

At the same time, the Porter Hypothesis provides an additional explanatory framework, suggesting that well-designed environmental regulations can stimulate innovation and enhance

competitiveness. European climate policies, including carbon pricing and sustainability reporting requirements, have incentivized technology firms to invest in cleaner and more efficient energy solutions. Rather than merely complying with regulatory constraints, many firms are leveraging these pressures as opportunities to innovate, particularly in areas such as energy-efficient data centers, low-carbon cloud computing and sustainable supply chain management.

Strategically, firms are adopting a range of responses to mitigate energy-related risks. One key approach is the vertical integration of energy supply, where companies invest directly in renewable energy assets or enter long-term Power Purchase Agreements (PPAs) to secure stable and predictable energy costs. At the same time, geographic diversification has become very important, with firms locating data centers in regions characterized by lower energy costs, favorable regulatory environments and access to renewable energy resources. This strategy reflects the growing importance of energy availability as a determinant of digital infrastructure investment decisions (International Energy Agency [IEA], 2023).

Research indicates that efficiency improvements have significantly slowed the growth of energy consumption in the sector, despite rapid increases in digital demand. However, the continued expansion of artificial intelligence applications raises concerns that overall energy demand may continue to rise in the long term.

According to Microsoft's Environmental Sustainability Report (2023), these technologies have contributed to substantial improvements in energy efficiency and reductions in electricity consumption. Nevertheless, this example also highlights a broader tension within the technology sector: while technological innovation can improve operational efficiency and reduce emissions intensity, the rapid expansion of digital services may simultaneously increase overall energy demand. Consequently, firms face the challenge of balancing technological growth with sustainability objectives.

Furthermore, supply chain strategies are being reconfigured to reflect energy and sustainability considerations. Firms are increasingly requiring suppliers to meet specific environmental standards, effectively extending energy-related strategies beyond their direct operations. However, this shift may impose additional burdens on smaller suppliers, potentially exacerbating inequalities

within the technology ecosystem. As a result, strategic responses to energy challenges must balance efficiency, sustainability and inclusiveness.

Overall, the integration of energy considerations into corporate strategy represents a fundamental transformation in the technology business sector. Firms that successfully develop capabilities in energy management, regulatory adaption and technological innovation are more likely to achieve long-term competitive advantage. However, the effectiveness of these strategies depends on the ability to navigate trade-offs between cost, flexibility and sustainability in an increasingly complex and dynamic environment.

6.4.Sustainability Pressures and Regulatory Challenges

The European regulatory environment plays an important role in shaping how technology firms respond to energy and sustainability challenges (European Commission, 2021). Policies such as carbon pricing and mandatory sustainability reporting aim to accelerate the transition to a low-carbon economy. These include carbon pricing, renewable energy targets and mandatory sustainability reporting (European Commission, 2021). As a result, firms are increasingly required to measure, report and reduce their environmental impact.

One of the most important mechanisms within the European climate framework is the European Union Emissions Trading System (EU ETS), which places a financial cost on carbon emissions. By introducing a market-based carbon pricing mechanism, the EU ETS creates economic incentives for firms to invest in cleaner technologies, improve energy efficiency and transition toward renewable energy sources. From a theoretical perspective, this aligns with the Porter Hypothesis, which argues that well-designed environmental regulations can stimulate innovation and improve long-term competitiveness (Porter & van der Linde, 1995). However, while such regulations may encourage technological innovation and sustainability-oriented investments, they also increase short-term operational costs and regulatory complexity for firms operating in energy-intensive sectors.

Large technology companies are generally better prepared to respond to these pressures. They have the financial resources and technical expertise to invest in renewable energy, improve efficiency and comply with reporting requirements. In contrast, small and medium-sized enterprises (SMEs) often face greater difficulties. They may lack access to capital, specialized knowledge, or ability to manage complex regulatory processes. This can create an uneven playing field, where larger firms gain a competitive advantage.

Another key development is the introduction of stricter reporting frameworks, such as the corporate Sustainability Reporting Directive (CSRD). These rules require firms to provide detailed information about their environmental performance, including energy use and emissions. While this improves transparency and accountability, it also increases administrative burdens, especially for smaller firms.

Overall, European regulation is accelerating the transition toward sustainable business practices in the technology sector. However, it also creates challenges related to cost, compliance and market competition. The ability of firms to adapt to these regulations will play an important role in determining their long-term success.

6.5. Energy Security and Geopolitical Risks

Energy security has become a central concern for technology firms in Europe. The disruption of natural gas supplies and the resulting surge in energy prices exposed the structural dependence of European economies on imported fossil fuels. For technology firms, which rely heavily on stable and affordable electricity to support digital infrastructure such as data centers and cloud services, these disruptions have translated into increased operational risks and uncertainty.

The European response to the crisis, including initiatives such as REPowerEU plan, aims to reduce dependence on external energy suppliers while accelerating the deployment of renewable energy sources (European Commission, 2022). This policy shift is reshaping the strategic environment in which technology firms operate, as energy resilience and supply diversification become key

determinants of long-term competitiveness. Firms are increasingly required to align their energy strategies with broader geopolitical and regulatory developments, integrating risk assessment into their investment and location decisions.

In response, large technology companies are actively pursuing energy diversification strategies, including direct investments in renewable energy projects, geographically diversified data center infrastructure and participation in decentralized energy systems. For example, Amazon has become one of the world's largest corporate purchasers of renewable energy, securing energy supply through long-term contracts across multiple regions (Amazon, 2023). However, these strategies enhance resilience by reducing exposure to single-point supply disruptions, but they also involve significant capital expenditure and long planning horizons.

Geopolitical risks extend beyond energy supply alone. The increasing electrification of digital infrastructure raises concerns regarding grid stability, electricity market integration and cross-border energy dependencies within Europe. In addition, the transition toward renewable energy systems and advanced digital technologies has intensified global competition for critical raw materials such as lithium, cobalt and rare earth elements, which are essential for batteries, semiconductors and renewable energy technologies. According to the International Energy Agency (2023), demand for critical minerals is expected to increase substantially as countries accelerate decarbonization and digitalization strategies. This creates a dual dependency for technology firms: they are exposed not only to energy market volatility but also to geopolitical and supply chain risks associated with strategic resource competition.

Overall, energy security is no longer solely a macroeconomic or political issue but a core strategic challenge for the technology business sector. Firms must adopt integrated risk management approaches that account for geopolitical uncertainty, regulatory change and infrastructure constraints. While the transition toward renewable and decentralized energy systems offers opportunities to enhance resilience, it also requires long-term investment, strategic coordination and the ability to operate in an increasingly complex and uncertain global environment.

6.6. Structural and Technological Challenges

The integration of the energy sector and technology business sector is constrained by a series of structural and technological challenges that complicate the transition toward a more sustainable and digitalized economy. While technological innovation offers significant opportunities to enhance efficiency and flexibility, its large-scale implementation remains uncertain.

A central structure challenge is the growing mismatch between rapidly expanding digital demand and the relatively slow pace of energy infrastructure development. The increasing deployment of cloud computing, artificial intelligence (AI) and data-intensive applications is driving substantial growth in electricity consumption, particularly within data centers and digital networks. According to the International Energy Agency (IEA, 2023), global electricity demand from data centers, cryptocurrencies and AI-related applications is expected to rise significantly over the coming decade, placing additional pressure on already constrained electricity systems. However, the expansion of grid infrastructure, renewable generation capacity and transmission networks often lags behind this demand due to regulatory financial and technical barriers. This imbalance raises concerns regarding grid congestion, supply reliability and the ability of energy systems to support continued digital growth.

In addition, technological uncertainty represents a major constraint for both energy and technology firms. Although emerging solutions such as hydrogen, large-scale energy storage and smart grid technologies are frequently presented as key enablers of the energy transition, their commercial viability and scalability remain uncertain. For instance, while hydrogen is widely viewed as a promising solution for decarbonizing hard-to-abate sectors, its deployment is hindered by high production costs, limited infrastructure and unresolved regulatory frameworks (International Energy Agency [IEA], 2023). Similarly, energy storage technologies, while improving system flexibility, continue to face challenges related to cost, material availability and long-term performance (International Renewable Energy Agency [IRENA], 2022). As a result, firms must make strategic investment decisions in an environment characterized by incomplete information and evolving technological standards.

Another important issue is the “rebound effect”, whereby improvements in energy efficiency are partially or fully offset by increases in overall demand. In the context of the technology sector, advances in energy-efficient data centers and AI optimization can reduce energy consumption per unit of output. However, these gains may be outweighed by the rapid expansion of digital services, leading to an overall increase in total energy consumption. This dynamic shows a fundamental tension between technological progress and sustainability objectives, suggesting that efficiency improvements alone may be insufficient to achieve absolute reductions in energy use.

Furthermore, supply chain constraints introduce additional layers of complexity. The transition toward renewable energy systems and digital technologies depends heavily on critical raw materials such as lithium, cobalt and rare earth elements. These resources are geographically concentrated and subject to geopolitical risks, market volatility and environmental concerns. The International Energy Agency (IEA, 2023) emphasizes that demand for critical minerals could increase several-fold by 2040 under ambitious climate scenarios, raising concerns about supply security and price stability. This creates interdependencies between energy transition technologies and global resource markets, exposing firms to new forms of strategic risk.

Finally, institutional and organisational barriers further complicate the integration of energy and technology systems. Regulatory fragmentation across European markets, lengthy permitting processes for energy infrastructure and a shortage of specialized skills in both the energy and digital domains limit the speed and effectiveness of the transition. Firms must therefore navigate not only technological uncertainty but also complex governance structures and labor market constraints.

Overall, these structural and technological challenges highlight that the convergence of the energy and technology sectors is neither linear nor frictionless. While innovation remains a critical driver of transformation, its impact is mediated by infrastructure limitations, market dynamics and institutional constraints. Addressing these challenges will require coordinated action across public and private actors, as well as long-term investment strategies that balance technological ambition with economic and operational realities.

6.7.Future Outlook and Strategic Directions

The convergence of energy systems and digital technologies is expected to intensify over the coming decade, driven by the parallel acceleration of the European energy transition and the expansion of data-intensive digital services. The findings of this chapter suggest that this evolution will not be linear, but rather shaped by continuous interactions between technological innovation, regulatory pressure, and structural constraints within energy systems.

A key future trend is the increasing role of technology firms as active participants in energy markets rather than passive consumers. Large digital companies are likely to deepen their involvement in energy generation and procurement through long-term Power Purchase Agreements (PPAs), direct investment in renewable energy infrastructure, and the integration of energy management systems within digital operations. This shift reflects the growing strategic importance of energy security and price stability for maintaining competitiveness in data-driven industries.

Regulatory frameworks within the European Union are expected to become more stringent and more integrated, particularly in relation to carbon reduction targets, sustainability reporting, and energy market integration. This will likely reinforce the strategic importance of compliance capabilities and sustainability performance as competitive differentiators within the technology sector.

However, future developments will remain constrained by structural limitations identified in Section 6.6. These include grid capacity bottlenecks, dependence on critical raw materials, and the uncertainty surrounding the scalability of emerging technologies such as hydrogen and large-scale energy storage. As a result, the pace of transformation will depend not only on technological progress, but also on institutional coordination and infrastructure development.

Overall, the future trajectory of the energy–technology relationship will be defined by a dual dynamic: increasing integration between the two sectors, and simultaneously growing complexity in managing their interdependencies. Firms that are able to develop adaptive strategies combining

technological innovation, energy flexibility, and regulatory foresight will be better positioned to maintain long-term competitiveness in this evolving environment.

6.8. Conclusion

This chapter has examined the economic, strategic and regulatory implications of the relationship between the energy sector and the technology business sector in Europe. The analysis showed that energy has become an important strategic factor for technology firms, affecting business costs, investment decisions and long-term competitiveness.

The chapter also shows that European policies, sustainability requirements and geopolitical developments are encouraging companies to invest in renewable energy, improve energy efficiency and make stronger their energy strategies. At the same time, technology companies continue to face challenges related to energy security, infrastructure limitations and the increasing demand for electricity.

Finally, the relationship between the energy and technology sectors is very important for the future of Europe. Successfully managing energy challenges while supporting innovation and sustainability will be essential for maintaining competitiveness and achieving the European Union's long-term energy and climate objectives.

7. Conclusion

This dissertation examined the changing energy landscape in Europe and its impact on the technology business sector. The study showed that the European energy transition is not only an environmental and political process, but also an economic and technological transformation that is reshaping industries, business models and market structures.

The analysis of the European energy market highlighted the importance of renewable energy expansion, market liberalization, digitalization and energy security within the broader framework of the European Union's climate and sustainability goals. At the same time, the study demonstrated that ongoing challenges such as price volatility, geopolitical tensions and dependence on external energy sources continue to affect the stability and competitiveness of European markets.

This dissertation also explored the growing relationship between the energy sector and the technology business sector. The findings showed that energy has become a strategic issue for technology companies rather than simply an operational requirement. Rising energy costs, sustainability pressures and stricter environmental policies are encouraging firms to invest in energy-efficient infrastructure, renewable energy solutions and digital energy management systems. In addition, technology companies are playing an active role in the transformation of the energy sector through innovation, digital services and smart technologies.

Overall, the study concludes that the relationship between energy and technology is becoming increasingly interconnected and interdependent. The energy transition creates both challenges and opportunities for technology business, requiring firms to adapt their strategies in order to remain competitive in a rapidly changing environment. At the same time, technological innovation will continue to play a critical role in supporting Europe's transition toward a more sustainable, secure and efficient energy future.

Finally, this dissertation highlights the need for continued investment in clean energy technologies, digital infrastructure and innovation-driven policies. Future research could further examine the long-term economic effects of the energy transition on technology firms, as well as the evolving role of emerging technologies in shaping sustainable energy systems.

7.1.Recommendations and Future Research

The research of this dissertation shows that the relationship between the energy sector and the technology business sector will continue to become more important in the future. For this reason,

policymakers and business should continue investing in renewable energy technologies, digital infrastructure and energy-efficient systems in order to support long-term sustainability and economic competitiveness.

Technology companies should focus on improving energy efficiency, adopting smart energy management systems and increasing the use of renewable energy sources in their operations. At the same time, stronger cooperation between governments, energy providers and technology firms will be necessary to support innovation and accelerate the energy transition.

Future research could examine the impact of energy market developments on specific technology industries, such as cloud computing, artificial intelligence, semiconductor production or data centers. In addition, further studies based on quantitative analysis, interviews or case studies could provide deeper insights into how technology firms respond to energy price volatility, sustainability pressures and changing regulatory environments.

8. REFERENCES

Amazon. (2023). Sustainability Report 2023.

Andrae, A. S. G. (2020). New perspectives on internet electricity use in 2030. *Energy and Sustainability*.

Andrae, A. S. G., & Edler, T. (2015). On global electricity usage of communication technology: Trends to 2030. *Challenges*, 6(1), 117–157.

Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2), 517–549.

Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies “Engines of growth”? *Journal of Econometrics*.

Catarinella, P., & Kram, S. (2025). *2019 European Green Deal: An ambitious project with lights and shadows*. In *Sustainable Green Infrastructure* (pp. 69–95). Springer.

Central Statistics Office Ireland (CSO). (2024). Data centres metered electricity consumption 2024: Key findings.

Centre for Economic Policy Research. (2023). Enablers of firms' use of digital technologies, technological innovation and digital transformation. CEPR.

Council of the European Union. (2023). Energy prices and security of supply.

Eurofound. (2023). SME digitalisation in the EU: Trends, policies and impacts.

European Commission (2021). Clean Energy for All Europeans Package.

European Commission Joint Research Centre (JRC). (2024). Energy consumption and sustainability of data centres in Europe. Publications Office of the European Union.

European Commission. (2019). The European Green Deal (COM/2019/640 final).

European Commission. (2020). A European strategy for data.

European Commission. (2020). Shaping Europe's digital future: Digital and green synergies.

European Commission. (2021). "Fit for 55": Delivering the EU's 2030 climate target on the way to climate neutrality.

European Commission. (2021). 2030 Digital Compass: The European way for the Digital Decade.

European Commission. (2021). Europe's Digital Decade: Digital targets for 2030. EUR-Lex.

European Commission. (2022). Proposal for a regulation establishing a framework of measures for strengthening Europe's semiconductor ecosystem (European Chips Act).

European Commission. (2023). Digital Economy and Society Index (DESI).

European Commission. (2023). Europe's Digital Decade.

European Commission. (2023). Renewable Energy Directive: Targets and rules.

European Commission. (2024). Digital Economy and Society Index (DESI).

European Commission. (2024). European partnerships under Horizon Europe: Digital, industry and space.

- European Commission. (2025). Energy prices and costs in Europe.
- European Commission. (n.d.). EU emissions trading system (EU ETS).
- European Investment Bank. (2023). Digitalization in Europe 2022–2023: Evidence from the EIB Investment Survey.
- European Parliament. (2022). Energy efficiency directive revision.
- European Parliament. (2023, September 15). Energy security: Solutions to current challenges.
- European Parliament. (2024). Solutions to electricity market price instability.
- European Parliament. (2025). Europe’s technological competitiveness and digital market structure.
- European Parliament. (2025, June 16). More coordinated and resilient electricity grids requested by Parliament.
- European Parliament. (n.d.). Energy policy: General principles.
- European Parliamentary Research Service. (2023). REPowerEU plan.
- European Union Agency for Cybersecurity (ENISA). (2019). What we do.
- European Union. (2022). Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 as regards corporate sustainability reporting. Official Journal of the European Union.
- European Union Institute for Security Studies. (2022). Brief 12: Strategic Autonomy.
- Eurostat. (2025). Digitalisation in Europe 2025.
- Eurostat. (2025). Electricity price statistics. European Commission.
- Eurostat. (2025). Gas price developments in Europe.
- Fang, X., Misra, S., Xue, G., & Yang, D. (2012). Smart grid — The new and improved power grid: A survey. *IEEE Communications Surveys & Tutorials*, 14(4), 944–980.
- Fatemi, A., Glaum, M., & Kaiser, S. (2018). *ESG performance and firm value: The moderating role of disclosure*. *Global Finance Journal*, 38, 45–64.

Google. (2023). Environmental Report 2023.

Gross, Robert, et al. (2018). The impact of renewable energy cost reductions. *Energy Policy*, 123, 682–699.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), 1645–1660.

Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. (2011). Smart grid technologies: Communication technologies and standards. *IEEE Transactions on Industrial Informatics*, 7(4), 529–539.

Halkos, G. (2018). *Effective energy commodities' risk management* (MPRA Paper No. 90781). Munich Personal RePEc Archive.

I Bieser, J. C. T., & Hilty, L. M. (2018). Assessing indirect environmental effects of information and communication technology (ICT): A systematic literature review. *Journal of Cleaner Production*, 198, 448–467. International Energy Agency (IEA). (2022). *Renewables 2022*.

International Energy Agency (IEA). (2014). *Technology roadmap: Energy storage*.

International Energy Agency (IEA). (2019). *The future of hydrogen: Seizing today's opportunities*.

International Energy Agency (IEA). (2017). *Digitalisation and Energy*.

International Energy Agency (IEA). (2021). *Digitalisation and Energy*.

International Energy Agency (IEA). (2023). *Critical Minerals Market Review 2023*.

International Energy Agency (IEA). (2023). *Electricity 2023: Analysis and forecast to 2025*.

International Energy Agency (IEA). (2023). *Electricity Market Report 2023*.

International Energy Agency (IEA). (n.d.). *Data centres and data transmission networks*.

International Energy Agency (IEA). (n.d.). *Smart grids*.

- International Energy Agency (IEA). (2021). Net Zero by 2050: A Roadmap for the Global Energy Sector.
- International Energy Agency (IEA). (2022). Electricity Market Report 2022.
- International Energy Agency (IEA). (2023). World Energy Outlook 2023.
- International Energy Agency. (2020). Energy technology perspectives 2020.
- International Energy Agency. (2020). World energy Outlook 2020.
- International Energy Agency. (2022). Electricity market report – July 2022.
- International Energy Agency. (2023). World energy outlook 2023.
- International Energy Agency. (2025). World energy investment 2025: European Union.
- International Energy Agency. (n.d.). Data centres and data transmission networks.
- International Energy Agency. (n.d.). Digitalization and energy systems.
- International Renewable Energy Agency (IRENA). (2018). Corporate sourcing of renewable energy: Market and industry trends.
- International Renewable Energy Agency (IRENA). (2021). Renewable power generation costs in 2020.
- International Renewable Energy Agency (IRENA). (2022). World energy transitions outlook 2022.
- International Renewable Energy Agency (IRENA). (n.d.). Digitalisation.
- International Renewable Energy Agency. (2024). Renewable power generation costs in 2023.
- Lange, S., Pohl, J., & Santarius, T. (2020). Digitalization and energy consumption: Does ICT reduce energy demand? *Ecological Economics*, 176, 106760.
- Madani, S., Tavasoli, A., Khoshtarash Astaneh, Z., & Pineau, P.-O. (2025). Large Language Models integration in Smart Grids. *arXiv*.

- Mendicino, L., Menniti, D., Pinnarelli, A., & Sorrentino, N. (2019). *Corporate power purchase agreement: Formulation of the related levelized cost of energy and its application to a real life case study*. Energy Policy, 129, 979–990.
- Microsoft. (2023). Environmental Sustainability Report.
- Organisation for Economic Co-operation and Development (OECD). (2021). Assessing the economic impacts of environmental policies. OECD Publishing.
- Organisation for Economic Co-operation and Development (OECD). (2020). OECD digital economy outlook 2020.
- Organisation for Economic Co-operation and Development (OECD). (2024). OECD Digital Economy Outlook 2024 (Volume 1).
- Organisation for Economic Co-operation and Development. (2020). European Union 2020.
- Polzin, Friedemann, et al. (2019). Mobilizing private finance for renewable energy. Energy Policy.
- Pompili, S. (2021). Europe’s quest for digital sovereignty: The GAIA-X case study. Istituto Affari Internazionali.
- Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. Journal of Economic Perspectives, 9(4), 97–118.
- Safari, A., Daneshvar, M., & Anvari-Moghaddam, A. (2024). Energy intelligence: A systematic review of artificial intelligence for energy management. Applied Sciences, 14(23), 11112.
- Van Ark, B. (2016). The productivity paradox of the new digital economy. Centre for the Study of Living Standards
- World Energy News. (2025). EU natural gas storage levels in 2025.
- Georgiadou, A. (2022). Πράσινη ανάπτυξη και ελληνική ενεργειακή πολιτική [Master’s thesis, Δημοκρίτειο Πανεπιστήμιο Θράκης].
- Mavromatis, G. (2017, May 23). Η ιστορική εξέλιξη της ενεργειακής πολιτικής της Ευρωπαϊκής Ένωσης.

Author's Statement:

I hereby declare that, in accordance with article 8 of Law 1599/1986 and article 2.4.6 par. 3 of Law 1256/1982, this thesis/dissertation is solely a product of personal work and does not infringe any intellectual property rights of third parties and is not the product of a partial or total plagiarism, and the sources used are strictly limited to the bibliographic references.