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MASTER THESIS

AN ANALYSIS OF EU ENERGY SECURITY, SUSTAINABILITY AND AFFORDABILITY POLICIES

Ljubljana, November 2025 MARKO FRANC

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Abstract

This thesis analyzes the European Union's (EU) energy policies with a focus on three key pillars: energy security, sustainability, and affordability. The aim is to assess how EU policies address these dimensions and how the interconnections between them influence the overall effectiveness of the EU's energy framework.

The research is based on a review of relevant literature, EU legislative documents, and secondary data from official sources. The empirical analysis evaluates indicators of energy security, sustainability, and affordability across EU member states and compares the EU's position with the United States and China. The findings show that while the EU has made progress in diversifying its energy supply and increasing the share of renewable energy, substantial differences remain between Central-Western and Central-Eastern Europe. The results further demonstrate that measures to strengthen security and sustainability can create trade-offs with affordability, particularly evident during the energy price surge in 2022–2023. The thesis concludes that achieving a secure, sustainable, and affordable energy system requires coordinated EU-level action, investment in renewable energy and infrastructure, and strengthened cross-border cooperation. By addressing synergies and trade-offs among the three pillars, the EU can enhance resilience and move closer to its long-term energy policy goals.

Keywords*: EU energy policy, energy security, sustainability, affordability*

Sustainable Development Goals addressed: *SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action).*

Povzetek

Ta magistrska naloga analizira energetske politike Evropske unije (EU) s poudarkom na treh ključnih stebrih: energetski varnosti, trajnosti in dostopnosti. Namen naloge je oceniti, kako politike EU obravnavajo te dimenzije ter kako njihove medsebojne povezave vplivajo na celotno učinkovitost energetskega okvira EU.

Raziskava temelji na pregledu ustrezne literature, zakonodajnih dokumentov EU in sekundarnih podatkov iz uradnih virov. Empirična analiza ocenjuje kazalnike energetske varnosti, trajnosti in dostopnosti v državah članicah EU ter primerja položaj EU z Združenimi državami Amerike in Kitajsko. Ugotovitve kažejo, da je EU sicer dosegla napredek pri diverzifikaciji energetskih virov in povečevanju deleža obnovljivih virov energije, vendar ostajajo znatne razlike med srednjezahodno in srednjevzhodno Evropo. Rezultati dodatno kažejo, da lahko ukrepi za krepitev varnosti in trajnosti ustvarijo kompromise z dostopnostjo, kar je bilo posebej očitno med energetskim cenovnim skokom v letih 2022–2023. Naloga zaključuje, da doseganje varnega, trajnostnega in dostopnega energetskega sistema zahteva usklajeno delovanje na ravni EU, vlaganja v obnovljive vire energije in infrastrukturo ter okrepljeno čezmejno sodelovanje. Z obravnavo sinergij in kompromisov med tremi stebri lahko EU poveča odpornost ter se približa svojim dolgoročnim energetskim ciljem.

Ključne besede: *energetska politika EU, energetska varnost, trajnost, dostopnost*

Obravnavani cilji trajnostnega razvoja: *CTR 7 (Dostopna in čista energija), CTR 11 (Trajnostna mesta in skupnosti), CTR 12 (Odgovorna poraba in proizvodnja), CTR 13 (Podnebni ukrepi).*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AGSI - Aggregated Gas Storage Inventory

BTU – British thermal unit;

CBAM – Carbon Border Adjustment Mechanism;

CCR – Capacity Calculation Regions;

CDM – Clean Development Mechanism;

CEE – Central and Eastern European;

CWE – Central and Western European;

DES – Diversification of Energy Sources;

EC – European Commission;

ECSC – European Coal and Steel Community;

EE – Energy Efficiency;

EED – Energy Efficiency Directive;

EGD – European Green Deal;

ETS – Emission Trading System;

EU – European Union;

EU-27 – The 27 Member States of the EU after the UK's withdrawal in 2020;

EURATOM – European Atomic Energy Community;

GDP – Gross domestic product;

GHG – Greenhouse gas;

GIE – Gas Infrastructure Europe;

HDI – Human Development Index;

IEA – International Energy Agency;

JI – Joint Implementation;

JTF – Just Transition Fund;

KGOE – Kilograms of oil equivalent;

kWh – Kilowatt-hour

LNG – Liquefied Natural Gas;

MSR – Market Stability Reserve;

MWh – Megawatt-hour;

NECP – National Energy and Climate Plan;

NREAPs – National Renewable Energy Action Plans;

PCI – Projects of Common Interest;

RED – Renewable Energy Directive;

RES – Renewable Energy Sources;

RQ – Research Question;

RRF – Recovery and Resilience Facility;

SCF – Social Climate Fund;

SGT – Smart Grid Technologies;

SME – Small and medium sized companies;

USA – United States of America;

WEC – World Energy Council;

1 INTRODUCTION

Energy security, sustainability, and affordability have become the three central challenges of EU energy policy, driven by climate commitments, geopolitical disruptions, and volatile prices. Addressing these interlinked pillars is essential for ensuring a stable, clean, and affordable energy supply. The European Union (EU) faces a persistent energy policy trilemma: how to ensure security of supply, advance sustainability, and maintain affordability at the same time. These three objectives have become the foundation of EU energy policy and are increasingly interdependent. Energy security requires stable and diversified access to energy sources, supported by infrastructure and reserves to withstand external shocks (Bradshaw, 2013). Sustainability reflects the EU's binding commitments to reduce greenhouse gas emissions, expand renewable energy, and improve efficiency (Diesendorf, 2014). Affordability concerns the accessibility of energy for households and firms, with implications for competitiveness, social equity, and the risk of energy poverty (Gangale & Mengolini, 2019). Progress in one dimension often affects the others: renewable deployment can reduce import dependence and emissions but may raise short-term costs, while emergency measures for security can temporarily delay decarbonization. Understanding these trade-offs and synergies is essential for effective policy design.

The importance of these three pillars has been reinforced by recent developments. The European Green Deal set out the goal of climate neutrality by 2050, requiring a fundamental restructuring of energy production and consumption (European Commission, 2019). This transition was accelerated by the Russia–Ukraine war, which exposed the EU's reliance on Russian fossil fuels. In response, the Union launched the RePowerEU plan to diversify suppliers, strengthen storage, and expand renewables (European Commission, 2022). At the same time, energy prices in 2022–2023 reached unprecedented levels, with household electricity prices in some Member States more than doubling compared to 2020, raising urgent questions about affordability (Eurostat, 2025). These crises revealed that the trilemma is not a theoretical construct but a pressing political, economic, and social challenge.

Placed within a broader historical context, today's energy transition is the continuation of earlier shifts. The Industrial Revolution marked the dominance of coal, followed in the twentieth century by oil and natural gas, while nuclear energy further diversified supply. In the twenty-first century, technological progress and falling costs have enabled rapid growth of wind, solar, and other renewables. Unlike past transitions, however, the EU's current transformation is shaped not only by technology, but also by urgent climate targets, geopolitical shocks, and the social imperative of affordable energy (Siddi, 2023). This makes the balance between security, sustainability, and affordability more complex than ever before.

Purpose and objectives. Against this backdrop, the purpose of this thesis is to examine how the European Union has addressed the interlinked challenges of energy security, sustainability, and affordability, and to assess the effectiveness of its policies in balancing these three objectives. The objectives are threefold: (i) to identify and analyze the main EU policy frameworks related to each of the three pillars, (ii) to empirically compare the performance of Member States across security, sustainability, and affordability indicators, and (iii) to evaluate the interactions between the pillars, highlighting synergies, trade-offs, and policy implications. Together, these objectives ensure that the thesis is not only descriptive but also analytical, linking policy frameworks with observable outcomes.

Research questions. To operationalize these objectives, the study is guided by three research questions:

- RQ1: What are the main EU policies in the area of energy security, sustainability, and affordability?
- RQ2: How do EU countries compare in terms of energy security, sustainability, and affordability?
- RQ3: How are the three pillars of EU energy policy related?

These research questions are designed to ensure that the thesis systematically addresses the central challenges of EU energy policy. The first question establishes the policy context by identifying the main instruments and strategies adopted at the EU level. The second question provides an empirical dimension, comparing Member States' performance across key indicators of security, sustainability, and affordability. The third question integrates the analysis by examining the interlinkages between the three pillars, thereby highlighting potential trade-offs and synergies. Together, the questions form a coherent framework that connects the theoretical discussion, policy review, and empirical analysis.

Expected contribution. The contribution of this thesis is twofold. First, it provides a comprehensive and integrated overview of EU energy policy by systematically linking the three pillars of security, sustainability, and affordability, which are often studied in isolation. Second, by combining policy analysis with empirical data, it contributes to the academic and policy debate on how the EU can better manage trade-offs and exploit synergies in its energy transition. In doing so, the thesis offers insights that may support both scholarly understanding and practical policymaking in the field of European energy governance.

Methodology. To achieve these aims, the thesis relies primarily on secondary sources and publicly available data. The policy analysis reviews EU frameworks such as the European Green Deal, RePowerEU, the Renewable Energy Directive (RED), the EU Emissions Trading System (EU ETS), and affordability measures introduced in 2022–2023. The empirical analysis is based on datasets from Eurostat, EIA, IEA, Statista, and the European Environment Agency. Indicators include import dependency, diversification of supply, gas storage, renewable energy shares, emissions intensity, electricity and gas prices for households, and energy poverty metrics. The methodology applies descriptive and comparative analysis, focusing on both temporal dynamics and cross-country differences, with special attention to Central-Western Europe (CWE) and Central-Eastern Europe (CEE).

The reliance on secondary data is appropriate given the scope of the study and allows for comparability across Member States. It should be noted that during the preparation of this thesis, the generative artificial intelligence tool ChatGPT was used as an auxiliary aid. Its use was limited solely to improving the clarity, coherence, and academic tone of the text, as well as assisting in the structuring of chapters. The tool was also consulted to obtain suggestions for relevant academic literature, which were subsequently verified through official databases (Google Scholar, Scopus, Eurostat, IEA, EIA, etc.) before inclusion. All analyses, calculations, data interpretations, and arguments were independently conducted and verified by the author. The use of the tool was fully in accordance with the UL SEB Rules on Master's Theses and the Technical Guidelines for Written Works (2024).

Structure of the thesis. The thesis is structured into six chapters, of which four address the main objectives and constitute roughly 80% of the thesis. Following the introduction in Chapter 1, Chapter 2 reviews the conceptual foundations of energy security, sustainability, and affordability and surveys the relevant literature, defining the three pillars and explaining their interconnections. Chapter 3 analyses EU policy instruments for each pillar, focusing on the most important policies shaping the Union's energy framework. Chapter 4 presents the empirical assessment of EU Member States, comparing indicators across all three pillars in different regions and extending the comparison internationally. Chapter 5 synthesizes the findings, highlights limitations, and outlines implications for EU energy policy. Chapter 6 provides the conclusion, summarizing the main results, answering the research questions, and reflecting on the overall contribution. Finally, the thesis includes a comprehensive list of references, containing the literature and data sources used to address the research questions and analyses.

By starting with the trilemma and situating it within the EU's recent crises and historical context, this thesis provides a systematic and evidence-based assessment of how the Union has approached its energy challenges. It aims to contribute to both academic debate and policy discussions on how to balance the three central pillars of energy security, sustainability, and affordability in the years ahead.

2 RELATIONSHIP BETWEEN ENERGY SECURITY, SUSTAINABILITY AND AFFORDABILITY

This chapter provides a review of the academic literature on the three central pillars of EU energy policy: energy security, sustainability, and affordability. The aim is to define these concepts as they are understood in scholarly research, to present the main theoretical frameworks and methodological approaches, and to highlight the key debates and findings that shape contemporary energy studies. By grounding the analysis in established literature, the chapter develops the conceptual foundation required for the subsequent examination of EU policies (Chapter 3) and the empirical analysis of Member States (Chapter 4).

The review is structured in four parts. First, each pillar is examined separately: energy security is discussed with reference to frameworks such as diversification, import dependence, and system resilience; sustainability is defined in terms of environmental goals, life-cycle assessments, and trade-offs with cost and reliability; affordability is analyzed through indicators such as price levels, the share of energy costs in household income, and energy poverty measures. Second, the chapter addresses the interconnections between the three pillars, identifying both synergies and trade-offs as described in the literature. Recent literature also addresses the growing importance of renewable energy sources and the challenges posed by climate change. Strengthening policies across the three pillars is considered essential for building a resilient energy system in the EU. As Pascual and Elkind (2010) argue, a secure energy supply is a prerequisite for both economic stability and national security.

The purpose of this review is not to provide descriptive commentary, but rather to synthesize existing academic contributions and institutional reports in order to establish a theoretical and conceptual basis. This ensures that the subsequent chapters systematically address the research questions of the thesis with reference to recognized scholarly debates and evidence.

2.1 The importance of the three pillars of energy policy

Energy security, sustainability, and affordability are widely recognized in the literature as the three core dimensions of energy policy (Bradshaw, 2013). For the EU, their importance has been heightened by climate commitments, geopolitical instability, and recent market disruptions. A systematic review of these pillars is therefore required, beginning with energy security, which is often considered the foundation of the trilemma because of its direct implications for economic stability and the functioning of modern societies (Yergin, 2011; Cherp & Jewell, 2014).

2.1.1 Energy security

Energy security is often considered the most fundamental of the three pillars, since the stability of sustainability and affordability largely depends on the ability to ensure a reliable supply of energy. A widely used definition frames energy security as the uninterrupted availability of energy sources at affordable prices (Yergin, 2011). Building on this, Kruyt et al. (2009) conceptualize energy security through four dimensions: availability, accessibility, affordability, and acceptability. Winzer (2012) emphasizes that the concept should be understood as "the resilience of energy systems to disturbances," highlighting its multidimensional and dynamic nature. Similarly, Cherp and Jewell (2014) argue that energy security cannot be reduced to a single metric but must be seen as the capacity of energy systems to withstand risks and shocks.

Energy security matters because it underpins virtually all aspects of daily life — from lighting, heating, and transport to healthcare and digital communication. Disruptions in supply can quickly escalate into economic and social crises. For this reason, scholars often describe energy security as the foundation of the energy trilemma (Cherp & Jewell, 2011; Sovacool, 2012). As Pascual and Elkind (2010) note, a stable energy supply is a prerequisite for both economic stability and national security.

The literature identifies several frameworks and approaches for strengthening energy security. First, diversification of supply sources and technologies reduces dependence on single suppliers and increases system resilience (Kruyt et al., 2009; Ang, Choong & Ng, 2015). This is particularly important for the EU, where high import dependency creates structural vulnerabilities. Second, resilience of infrastructure — including storage facilities, interconnectors, and transmission grids — is essential to absorb shocks and avoid cascading disruptions (Cherp & Jewell, 2014). A third dimension is the recognition of new risks linked to the digitalization of the energy sector, where cyberattacks have emerged as a critical threat to energy security (Hiller & Russell, 2013).

Renewable energy also plays a growing role in debates on energy security. While some authors argue that variable renewables introduce new challenges for system reliability, others emphasize that renewables reduce import dependence and exposure to geopolitical risks (Sovacool, 2010; Ang et al., 2015). Within the EU, initiatives such as the Clean Energy for All Europeans package seek to enhance resilience by diversifying energy sources, promoting efficiency, and modernizing grids (European Commission, 2016).

In sum, the academic literature views energy security as a multidimensional and evolving concept, encompassing both traditional concerns about fossil fuel imports and emerging challenges such as digitalization and system flexibility. Its central role in the energy trilemma stems from its influence on both sustainability and affordability, making it a cornerstone for understanding EU energy policy.

2.1.2 Energy sustainability

Energy sustainability is the second central pillar of the energy trilemma and refers to the ability of energy systems to meet current needs without compromising the ability of future generations to meet theirs. Building on the broader definition of sustainable development in the Brundtland Report (Burton, 2010), Diesendorf (2014) defines energy sustainability as a system that provides reliable energy services while minimizing environmental harm, conserving resources, and supporting social well-being. The International Energy Agency (IEA, 2021) similarly frames sustainable energy as low-carbon, resource-efficient, and consistent with climate and environmental objectives. Recent approaches to measuring energy sustainability in the European Union emphasize multidimensional assessment frameworks. Brodny and Tutak (2025) applied a multi-dimensional measurement and approach to evaluate both energy sustainability across EU member states, highlighting significant disparities driven by renewable deployment and energy efficiency performance.

A crucial dimension of sustainability is the life-cycle assessment (LCA) of energy technologies, which evaluates not only operational emissions but also upstream and downstream impacts. For example, while wind and solar power have near-zero emissions during operation, their production and disposal phases involve material and land-use impacts (Turconi et al., 2013). Nuclear energy presents very low emissions but faces concerns regarding waste management and accident risks. Fossil fuels, even when used with carbon capture and storage, remain associated with high emissions and resource depletion (Sovacool et al., 2016).

The literature emphasizes that energy sustainability involves managing trade-offs. Expanding renewable capacity supports decarbonization but may create system challenges due to intermittency and the need for backup capacity (van den Bergh, 2013). Policies that increase sustainability can impose short-term economic costs, affecting both affordability and competitiveness. At the same time, as Biancalani et al. (2024) suggests, energy efficiency improvements are often seen as "no-regret" measures, simultaneously reducing emissions, costs, and import dependence.

In the EU context, sustainability has been placed at the center of energy policy through legislative frameworks such as the Renewable Energy Directive (RED), the EU Emissions Trading System (ETS), and the European Green Deal. These initiatives aim to accelerate the decarbonization of the energy system, increase renewable shares, and stimulate investment in low-carbon technologies (European Commission, 2019). At the same time, the policy debate highlights tensions between ambitious targets and the costs of implementation, which can affect affordability and public acceptance. Sustainability also entails social and developmental dimensions that shape how energy systems evolve. Yumashev et al. (2020) examined the relationship between the Human Development Index (HDI) and the quality and consumption of energy across countries, showing that sustainable energy transitions depend not only on environmental performance but also on improvements in human welfare and energy access.

In sum, the academic literature defines energy sustainability as a multidimensional concept that integrates environmental, economic, and social goals. It requires considering life-cycle impacts, managing trade-offs between climate objectives and system costs, and balancing long-term benefits with short-term challenges. Within the trilemma, sustainability strongly interacts with both security and affordability, reinforcing the need for policies that address all three pillars together.

2.1.3 Energy affordability

Energy affordability is the third core pillar of the energy trilemma and relates to the ability of households and firms to access energy at a reasonable cost. Boardman (2010) was one of the first to define affordability through the concept of fuel poverty, describing households that spend more than 10% of their income on energy services. Bouzarovski and Petrova (2015) expand this definition, highlighting that affordability encompasses not only price levels but also income distribution, housing quality, and access to modern energy infrastructure. In the EU context, Gangale and Mengolini (2019) note that affordability is increasingly analyzed through multiple indicators, including absolute and relative expenditure measures, as well as subjective assessments of energy poverty. Recent scholarship suggests that energy affordability cannot be separated from the broader context of energy poverty and social vulnerability. Bouzarovski, Thomson, and Cornelis (2021) outline a comprehensive research and policy agenda for confronting energy poverty in Europe, stressing the need for integrated approaches that combine price regulation, building efficiency, and targeted social measures.

The literature identifies several indicators for measuring affordability. These include: (i) nominal energy prices, both for electricity and natural gas; (ii) the share of energy expenditure in household income, which captures distributional effects; and (iii) energy poverty indices, such as the "10% rule" or the "Low Income High Costs" (LIHC) indicator widely used in the UK and adapted in EU studies (Gangale et al., 2019). Each of these approaches highlights different dimensions of affordability, from macro-level price dynamics to household-level vulnerability.

Energy affordability has become an increasingly salient issue in the EU, particularly during the 2022–2023 price crisis, when electricity and gas costs more than doubled in many Member States (Eurostat, 2025). Scholars emphasize that high prices affect not only household welfare but also industrial competitiveness, making affordability both a social and an economic concern (Bouzarovski, 2018). At the same time, policies aimed at improving sustainability, such as carbon pricing under the EU ETS, can increase short-term energy costs, thereby creating tensions between environmental objectives and affordability (Sovacool et al., 2016). The issue of energy affordability extends beyond individual energy prices to encompass broader questions of income inequality and social vulnerability. Dubois and Meier (2016) argue that energy inequality arises when low-income households face disproportionately higher energy burdens relative to their disposable income, making affordability a crucial dimension of social policy.

In this context, affordability is best understood as a multidimensional concept: it reflects market conditions (prices), socioeconomic factors (income distribution), and policy choices (taxes, subsidies, support schemes). Its importance in the trilemma comes from the fact that it acts as both as an outcome of energy policy and a constraint on its design. Ensuring affordable energy access is therefore not only a matter of protecting consumers but also a prerequisite for maintaining political support for the broader energy transition.

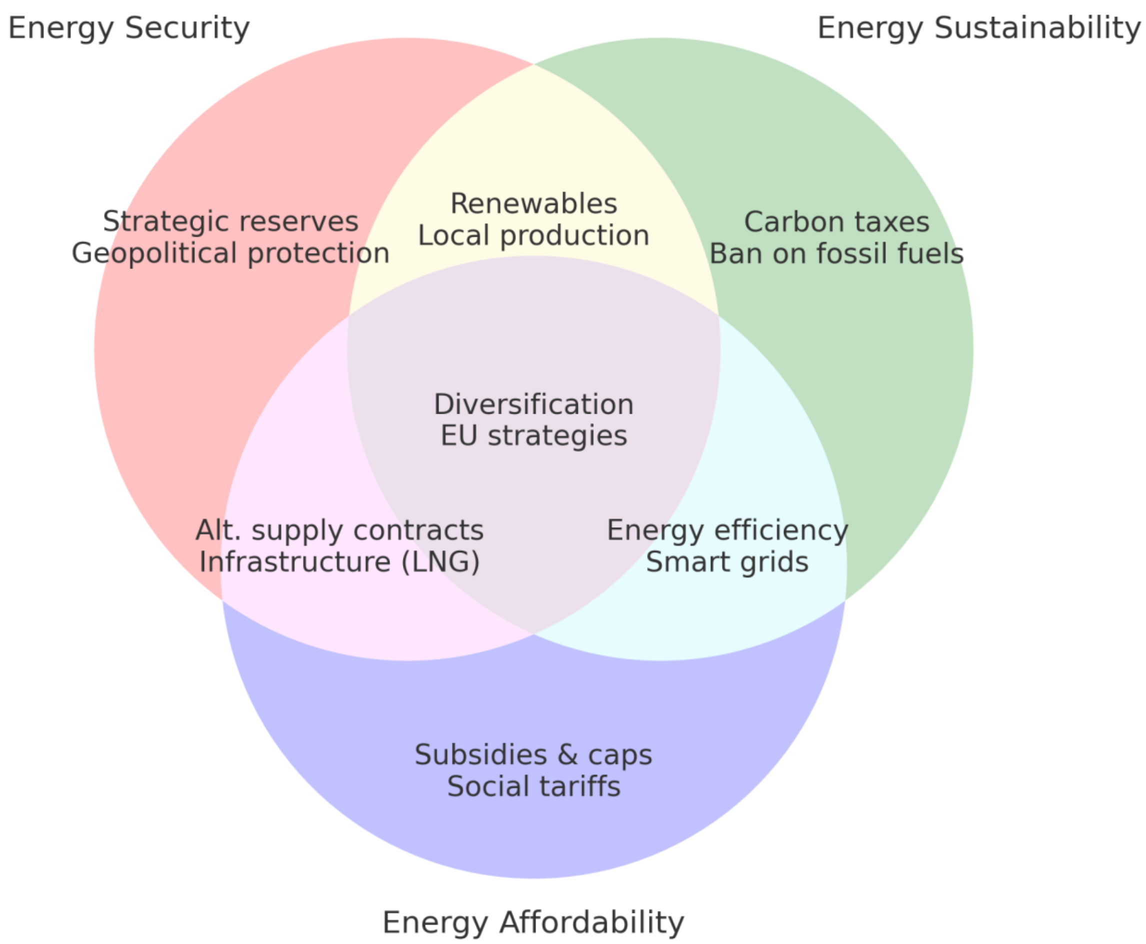
2.2 Correlation between the three pillars of energy policy

The three pillars of energy policy — security, sustainability, and affordability — cannot be understood in isolation. The literature consistently stresses that they are deeply interconnected, and that progress in one dimension often creates synergies or trade-offs with the others (Sovacool & Saunders, 2014; Goldthau & Sovacool, 2012). This interdependence has led scholars to describe the challenge of balancing the three objectives as the energy trilemma (World Energy Council, 2018).

Several studies highlight the potential synergies between sustainability and security. Expanding renewable energy reduces greenhouse gas emissions while simultaneously lowering dependence on imported fossil fuels, thereby strengthening energy security (Cherp & Jewell, 2014; Ang et al., 2015). Similarly, improvements in energy efficiency can reduce both emissions and import needs, producing benefits across all three pillars (Pérez-Lombard et al., 2008).

At the same time, the literature emphasizes important trade-offs. Policies aimed at accelerating decarbonization, such as carbon pricing under the EU Emissions Trading System (EU ETS), can increase short-term energy costs and raise affordability concerns (Sovacool et al., 2016). Likewise, emergency measures to safeguard energy security, such as building new LNG import terminals or subsidizing fossil fuel consumption in times of crisis, can slow progress toward sustainability targets (Stegen, 2023).

Figure 1: Synergies and trade-offs between energy security, sustainability, and affordability



Source: Own work based on Cherp & Jewell (2014); World Energy Council (2018); Sovacool (2016).

The interactions are therefore complex and context-dependent. Bouzarovski (2018) shows that affordability concerns are particularly acute for vulnerable households, where higher prices linked to sustainability policies can translate into energy poverty. On the other hand, failure to pursue sustainability measures increases long-term risks to both affordability (through price volatility of fossil fuels) and security (through dependence on unstable suppliers).

Overall, the academic debate suggests that the three pillars should not be treated as competing goals, but as interdependent dimensions of a resilient energy system. Policies that ignore one pillar often undermine the others. A comprehensive framework must therefore identify where synergies can be maximized and trade-offs carefully managed, ensuring that the EU's energy transition is not only environmentally sustainable, but also secure and socially equitable. These dynamics are summarized in Figure 1, which schematically presents the main areas where the three pillars overlap to generate synergies, as well as the points where pursuing one objective produces trade-offs for the others. In the following subsections, each pair of pillars is examined in more detail to highlight specific examples of these interactions.

2.2.1 Correlation between energy security and sustainability

The correlation between energy security and sustainability represents one of the most debated and multifaceted dimensions of the European energy trilemma. On the one hand, the two objectives are often presented as mutually reinforcing: investments in clean, domestically produced energy sources reduce dependence on imported fossil fuels, thereby enhancing supply security while also contributing to the decarbonization agenda (Cherp & Jewell, 2014; Sovacool, 2016). On the other hand, there are also inherent tensions, as certain sustainability measures may undermine energy security, especially in the short term, when the energy system still relies on carbon-intensive or imported backup solutions (Hughes, 2012; Winzer, 2012). This duality highlights why the literature frequently treats the link between security and sustainability as dynamic, context-dependent, and shaped by both technological choices and policy frameworks (Cherp & Jewell, 2011).

A central synergy highlighted in the literature is the expansion of renewable energy sources (RES). Greater deployment of solar, wind, hydro, and bioenergy strengthen sustainability by reducing carbon emissions while simultaneously lowering exposure to imported fossil fuels (Cherp & Jewell, 2011; Löschel et al., 2022). Several studies stress that decentralized renewable production, especially when combined with smart grids and digitalization, enhances resilience by diversifying the generation base and reducing the risks associated with centralized fossil infrastructure (IEA, 2021). In this sense, renewables are not only a climate strategy but also an instrument of geopolitical risk management.

Nuclear energy is another case where synergies can be observed. Although controversial in terms of waste management and social acceptance, nuclear power provides large-scale, low-carbon baseload capacity, reducing import dependency and supporting both decarbonization and supply adequacy (Sovacool, 2016). Similarly, sustainable bioenergy and emerging hydrogen technologies can both decarbonize and diversify energy systems, contributing to long-term resilience (European Commission, 2020).

Diversification more broadly is a recurring theme in the literature. A diversified mix of domestic and imported resources reduces exposure to disruptions from any single source or technology, thereby reinforcing security and sustainability simultaneously (World Energy Council, 2018). Unlike pure security measures such as strategic oil reserves, diversification that incorporates renewables, nuclear, and alternative fuels tends to align well with environmental goals (Cherp & Jewell, 2014). This argument directly connects with later policy discussions in Chapter 3, where initiatives such as RePowerEU explicitly link diversification with decarbonization.

Despite these synergies, numerous authors underline the trade-offs that arise when pursuing sustainability objectives. The phase-out of coal, for example, is central to the EU's decarbonization strategy, yet in several member states it has increased short-term reliance on natural gas imports, thereby creating new vulnerabilities to supply disruptions (Hughes, 2012; European Commission, 2022). The German Energiewende illustrates this dilemma: while the closure of coal and nuclear plants significantly reduced domestic carbon emissions, it also heightened dependence on Russian gas imports prior to 2022, exposing the country to geopolitical shocks.

Another prominent trade-off is linked to the intermittency of wind and solar power. Without sufficient investment in backup capacity, storage, and interconnections, the integration of variable renewables can undermine grid stability and reliability (Sovacool & Brown, 2010; IEA, 2021). The European experience shows that rapid renewable expansion without parallel investments in flexibility creates stress on system operators, especially during periods of low wind or sunlight. Similarly, large-scale deployment of intermittent renewables can require higher levels of reserve capacity, which may in turn prolong dependence on fossil fuels, at least during the transition phase (Cherp & Jewell, 2014).

Economic trade-offs are also significant. Carbon pricing and stringent environmental regulations, while central to sustainability, may raise production costs and lead to higher energy prices, indirectly affecting the affordability and security dimensions (Löschel et al., 2022). In energy-intensive industries, this can encourage relocation or reliance on imports from regions with lower environmental standards, paradoxically undermining both domestic security of supply and global sustainability.

Recent literature moves beyond the simple separation of "renewables as synergy" versus "intermittency as trade-off" by emphasizing the role of flexibility, storage, and demand-side measures. Flexibility in electricity systems—achieved through interconnections, demand-response, and system integration—is critical for reconciling high shares of renewables with stable supply (Löschel et al., 2022; IEA, 2023). Investment in storage technologies, from batteries to hydrogen, not only supports decarbonization but also provides additional buffers against supply shocks, reinforcing both pillars (European Commission, 2021a).

Demand-side management is another crucial mechanism. Policies that incentivize efficiency, behavioral change, and digital monitoring reduce overall consumption, lowering emissions while also decreasing vulnerability to external supply disruptions (Sovacool, 2016). This line of argument links directly to the affordability dimension but also strengthens the correlation between security and sustainability, as efficiency reduces both carbon footprints and import needs.

The correlation between security and sustainability is also shaped by social and equity considerations. As Sovacool (2016) argues, energy transitions that neglect distributional justice risk undermining both sustainability and security by eroding political support and creating social instability. Secure supply cannot be sustained if segments of the population are excluded from affordable and sustainable access. The literature on energy justice increasingly frames the trilemma as not merely technical but also normative, requiring policies that align climate goals with secure and equitable access to energy. This social dimension adds complexity but also enriches the understanding of synergies and trade-offs between security and sustainability.

A critical aspect of the debate is how these interactions are measured and evaluated. Indicators such as the share of renewables in gross final energy consumption, energy import dependency, system adequacy margins, storage capacity, and grid interconnection levels are widely employed to operationalize the relationship between security and sustainability (European Commissiona, 2021; World Energy Council, 2018). The World Energy Council's Trilemma Index, for instance, explicitly combines indicators of environmental sustainability and energy security, illustrating how countries perform in balancing the two.

The choice of indicators is not neutral: while high renewable shares are often seen as evidence of synergy, high dependence on intermittent sources without adequate flexibility may be interpreted as a trade-off. This points to the importance of integrated frameworks that account for both the benefits and risks of sustainability policies for energy security. The discussion of indicators here provides a foundation for Chapter 4, where empirical analysis compares EU member states across security, sustainability, and affordability dimensions.

In sum, the literature reveals that the correlation between energy security and sustainability is neither straightforwardly positive nor purely conflictual, but shaped by technology choices, policy frameworks, and social contexts. Renewables, nuclear energy, and diversification strategies represent clear synergies, while coal phase-outs, carbon pricing, and renewable intermittency highlight potential trade-offs. Flexibility, storage, and demand-side measures emerge as critical enablers that can transform trade-offs into synergies, while equity concerns underline the importance of social legitimacy. Finally, systematic measurement through indicators ensures that these conceptual debates can be linked to empirical assessment. This synthesis establishes a strong conceptual basis for subsequent chapters, where the policies (Chapter 3) and the empirical analysis of member states (Chapter 4) are examined in greater depth.

2.2.2 Correlation between energy security and affordability

The correlation between energy security and affordability is a central but contested theme in energy policy debates. Both concepts are politically sensitive: while governments prioritize secure supply to avoid disruptions, citizens and firms are highly sensitive to energy costs. Energy crises in the EU, particularly the 2008–09 gas dispute and the 2021–22 surge in prices, illustrate how closely security of supply is linked to affordability for households and industry (European Commission, 2022; IEA, 2025). The literature stresses that the relationship is dual in nature: in some cases, measures that strengthen security can also enhance affordability, while in others they impose significant short-term or distributional costs (Sovacool, 2016; Löschel et al., 2022).

One of the clearest synergies between security and affordability is diversification of supply. By reducing reliance on a single supplier or fuel, countries lower vulnerability to disruptions and price shocks (Cherp & Jewell, 2014). A diversified import structure reduces exposure to sudden geopolitical or market events, stabilizing prices for consumers. At the same time, diversification across fuels and suppliers increases competition, which may exert downward pressure on wholesale prices (Winzer, 2012). This synergy is particularly evident in the European gas sector, where the expansion of LNG infrastructure has enabled member states to access alternative suppliers and mitigate both price volatility and supply insecurity (European Commission, 2022).

Energy efficiency measures provide another strong synergy. By reducing overall demand, efficiency improvements lower import needs and enhance system resilience, while simultaneously reducing energy bills for households and firms (Sovacool, 2016). Demand-side management and smart grid technologies add flexibility to energy systems, enabling more efficient use of resources and further lowering costs (IEA, 2021). In this sense, efficiency policies act as a “no-regrets” strategy, strengthening both affordability and security.

Nevertheless, the literature also identifies important trade-offs. Large infrastructure projects designed to enhance security — such as cross-border pipelines, LNG terminals, or strategic storage facilities — often require significant upfront investment. While these projects may reduce vulnerability in the long term, they can increase costs for consumers in the short and medium term through tariffs or state subsidies (Hughes, 2012). Similarly, policies that subsidize domestic fossil fuel production to reduce import dependency may temporarily improve affordability but lock in carbon-intensive infrastructure, undermining sustainability and potentially leading to higher costs once carbon pricing is applied (Cherp & Jewell, 2014).

Price regulation is another contested tool. In some cases, governments cap retail energy prices to shield consumers from volatility. While this supports affordability in the short run, it can undermine investment signals for infrastructure and diversification, thereby weakening long-term security (Sovacool & Brown, 2010). Price caps during the 2021–22 energy crisis in Europe illustrate this tension: while they temporarily protected households, they created fiscal burdens and weakened incentives for demand reduction, complicating the security of supply challenge (IEA, 2023).

Market design plays a crucial role in shaping the balance between affordability and security. Liberalized markets were expected to deliver both lower prices and adequate investment in secure capacity. Yet the literature shows that markets alone may not guarantee sufficient investment in backup generation or storage, leading to concerns about reliability (Sovacool, 2016; Löschel et al., 2022). Capacity mechanisms, which compensate firms for maintaining reserve capacity, are often introduced to strengthen security. However, these mechanisms impose additional costs on consumers, raising questions about the affordability–security trade-off (European Commission, 2021b).

Distributional effects are increasingly emphasized in recent studies. Rising energy prices affect vulnerable households disproportionately, leading to energy poverty and social instability (Bouzarovski, 2021). Secure supply is not meaningful if large segments of the population cannot afford access to it. This has given rise to the concept of "just security," which combines resilience against external shocks with equitable affordability (Bouzarovski & Petrova, 2015). EU policies, such as the Social Climate Fund introduced under the Fit-for-55 package, reflect this concern by directly linking security of supply with measures to protect vulnerable consumers (European Parliament, 2021).

The debate also extends to industrial competitiveness. For energy-intensive industries, affordable and stable energy prices are critical for global competition. When security measures lead to higher prices, firms may relocate production abroad, a phenomenon known as carbon leakage. This not only undermines domestic industry but may also weaken security by increasing reliance on imported goods and shifting emissions outside the EU (Sovacool, 2010). Thus, the affordability–security nexus is not only a household issue but also a question of industrial policy and economic sovereignty.

From a long-term perspective, the correlation between affordability and security depends on the balance between short-term costs and long-term benefits. Investments in infrastructure, diversification, and efficiency often require higher costs upfront but reduce vulnerability and price volatility over time. The literature suggests that policies aligning short-term support for households with long-term structural measures are most effective in reconciling the two pillars (Cherp & Jewell, 2011; Girod, 2017). For instance, temporary subsidies can protect households during crises, but they should be combined with investments in efficiency and diversification to avoid perpetuating vulnerability.

Measurement and evaluation are key for understanding this relationship. Indicators commonly used include average household and industrial energy prices, volatility indices, import dependency ratios, and levels of strategic reserves (World Energy Council, 2018; European Commission, 2021b). Energy poverty indicators, such as the share of households unable to keep their home adequately warm, link affordability directly to security outcomes. At the same time, adequacy indicators, such as reserve margins and interconnection capacity, show how secure systems can reduce price volatility. The World Energy Council's Trilemma

Index illustrates how countries perform across both dimensions, revealing that high security does not always translate into high affordability, and vice versa.

In conclusion, the correlation between energy security and affordability is highly context-dependent. Synergies exist where diversification and efficiency measures reduce both vulnerability and costs, but trade-offs emerge when infrastructure, subsidies, or market interventions impose additional burdens. Distributional effects and industrial competitiveness further complicate the relationship, showing that affordability cannot be analyzed solely at the aggregate level. Ultimately, systematic use of indicators is essential for distinguishing between short-term and long-term effects, and for linking conceptual debates to the empirical analysis that follows in Chapter 4. This synthesis provides the necessary foundation for the subsequent examination of EU policy instruments in Chapter 3 and for the comparative evaluation of member states' performance in Chapter 4.

2.2.3 Correlation between energy sustainability and affordability

The relationship between energy sustainability and affordability is one of the most sensitive aspects of the energy trilemma, since it directly affects both environmental objectives and the welfare of households and firms. While sustainable energy transitions are essential for achieving long-term decarbonization, they often involve high upfront costs, raising concerns about affordability, particularly for vulnerable consumers (WEC, 2018; Bouzarovski & Petrova, 2015). The literature highlights that this relationship is not uniformly negative or positive but depends on time horizons, technological choices, and the design of accompanying policies (Brodny & Tutak, 2025).

Several studies emphasize that sustainability and affordability can be mutually reinforcing in the long run. As renewable energy technologies mature, their costs have fallen dramatically, with wind and solar now among the cheapest sources of new electricity generation in most regions (IEA, 2021). This reduces both emissions and wholesale electricity prices, especially when combined with competitive markets and cross-border integration (European Commission, 2021b). Energy efficiency policies provide another synergy, lowering energy demand while simultaneously reducing household bills and industrial production costs (Girod, 2017). In this sense, investments in efficiency and renewable sources can produce a "double dividend" of lower emissions and enhanced affordability.

Innovation and technological spillovers further strengthen this synergy. Early investments in clean technologies tend to generate cost reductions through learning effects, economies of scale, and global diffusion (van den Bergh, 2013). This dynamic has been evident in the rapid decline in the levelized costs of solar PV and wind over the past decade, which not only improves sustainability but also supports affordability across markets (IEA, 2023). In the longer term, sustainability policies can thus reduce exposure to fossil fuel price volatility, stabilizing household and industrial energy costs.

At the same time, the transition to sustainable energy systems is associated with important trade-offs. The most frequently cited is the high upfront investment cost of renewable deployment, grid expansion, and storage facilities. While these investments reduce costs over time, they can raise retail prices in the short and medium term as costs are passed on to consumers (Turconi, 2013.; van den Bergh, 2013). Carbon pricing mechanisms, such as the EU Emissions Trading System (ETS), are another example. Although they provide incentives for decarbonization, they also increase the cost of fossil-based electricity and heat, placing additional burdens on households and firms in the absence of adequate redistribution (Girod, 2017).

Subsidy design plays a crucial role in shaping affordability outcomes. Feed-in tariffs and renewable subsidies have accelerated decarbonization, but in several countries they initially led to higher retail electricity prices as costs were socialized among consumers (Sovacool, 2016). If poorly designed, such policies can have regressive impacts, disproportionately affecting low-income households that spend a larger share of their income on energy (Bouzarovski & Petrova, 2015). This highlights the importance of complementary measures to protect vulnerable groups, such as targeted social transfers, tax credits, or progressive tariff structures.

The equity dimension is increasingly central to the debate. The concept of energy poverty — defined as the inability of households to secure adequate energy services at affordable cost — connects sustainability directly with affordability and social inclusion (Bouzarovski & Petrova, 2015). A transition that neglects affordability risks undermining political support for sustainability policies, as public resistance grows when energy bills rise sharply. This tension has been observed in the "yellow vest" protests in France, where rising fuel taxes, introduced as a sustainability measure, triggered widespread social unrest (Sovacool, 2016). As a result, many scholars argue for a "just transition" that aligns decarbonization with equitable affordability, ensuring that sustainability does not come at the expense of social cohesion (European Parliament, 2021).

Market dynamics also influence the correlation between sustainability and affordability. While renewables reduce marginal costs of generation, their intermittency can increase price volatility, especially in wholesale markets with high renewable penetration and inadequate flexibility (Löschel et al., 2022). Investment in backup capacity, storage, and interconnections adds further costs that are often passed on to consumers. Conversely, fossil fuel price shocks, such as those observed in 2021–22, demonstrate how reliance on carbon-intensive energy undermines both affordability and sustainability simultaneously (IEA, 2023). This indicates that the relationship between sustainability and affordability cannot be reduced to simple trade-offs, but rather depends on the design of energy markets and supporting policies.

The temporal dimension is particularly important. Short-term affordability may suffer when sustainability measures raise costs through carbon pricing, subsidies, or infrastructure investment. However, long-term affordability improves as fossil fuel dependence decreases and clean technologies mature (Boardman, 2010). This duality is reflected in the EU's policy approach, which combines long-term decarbonization targets with short-term measures to protect vulnerable households, such as the Social Climate Fund under the Fit-for-55 package (European Parliament, 2021).

The academic debate also underlines the importance of measuring affordability and sustainability interactions through systematic indicators. Affordability is commonly tracked using household and industrial energy prices, energy expenditure as a share of income, and energy poverty indicators (World Energy Council, 2018; IEA, 2023). Sustainability is measured through indicators such as the share of renewables in gross final energy consumption, carbon intensity of energy supply, and emissions reductions. Linking these indicators highlights where synergies or trade-offs are strongest (Ürge-Vorsatz & Tirado Herrero, 2012). For instance, countries with high renewable shares but inadequate redistribution may score well on sustainability but poorly on affordability due to rising retail prices. Conversely, states with heavy fossil subsidies may achieve short-term affordability but undermine sustainability and increase long-term vulnerability.

This measurement perspective is essential for the empirical analysis in Chapter 4. By employing indicators such as electricity and gas prices, energy poverty rates, and renewable energy shares, it becomes possible to assess how member states perform in balancing affordability with sustainability. The World Energy Council's Trilemma Index again provides a useful benchmark, showing that very few countries achieve high scores in both dimensions simultaneously, underlining the inherent difficulty of reconciling the two pillars.

In conclusion, the relationship between sustainability and affordability is highly complex, shaped by time horizons, policy choices, and social contexts. While efficiency improvements, falling renewable costs, and innovation provide synergies, the transition also entails significant trade-offs related to investment costs, carbon pricing, and distributional impacts. Equity concerns are particularly central, as neglecting affordability risks undermining the legitimacy of sustainability policies. The correlation is therefore best understood not as a fixed trade-off but as a dynamic balance that shifts over time and across policy frameworks. By linking conceptual insights with measurable indicators, this discussion provides a solid foundation for the examination of EU policy instruments in Chapter 3 and the comparative empirical analysis in Chapter 4.

"Economic, environmental, and security considerations are interlinked within the energy sector. Achieving a balance between these three pillars is essential for a resilient and sustainable energy system. Policymakers must navigate these interconnections to create strategies that promote energy security, economic stability, and environmental sustainability concurrently" (Bradshaw, 2013). The three pillars of energy policy—security, sustainability, and affordability—are therefore deeply interconnected and mutually dependent. Effective energy policies must recognize both the synergies and the trade-offs among them. Only by understanding the properties and values of each pillar, as well as their interconnections, can policymakers design strategies that deliver a secure, sustainable, and balanced energy future.

Building on this conceptual framework of synergies and trade-offs, the next chapter examines how the European Union has translated these interconnections into concrete policies aimed at strengthening energy security, advancing sustainability, and safeguarding affordability.

3 EU ENERGY-RELATED POLICIES

In the previous chapters, the importance of the three energy pillars—security, sustainability, and affordability—was outlined, including their interdependence and the implications of external shocks for economic stability and the environment. Building on this theoretical framework, this chapter examines the European Union's (EU) policy measures designed to strengthen these pillars. The EU has long recognized that a secure, sustainable, and affordable energy system is essential for economic integration, social stability, and climate objectives (Bradshaw, 2013). Yet, given the heterogeneity of member states in terms of resources, consumption structures, and dependencies, formulating policies that balance the three pillars has been a continuous challenge (Cherp & Jewell, 2011; WEC, 2018). Coordinated integration of national energy strategies into a coherent EU framework remains central to achieving the Union's long-term objectives (Bradshaw, 2013).

The development of EU energy policy can be traced through successive stages shaped by geopolitical events, market transformations, and environmental imperatives. Following the devastation of World War II, efforts focused on rebuilding infrastructure and ensuring stable supplies, leading to the establishment of the European Coal and Steel Community (ECSC) in 1951 and the European Atomic Energy Community (EURATOM) in 1957—both aimed at pooling strategic resources and fostering energy cooperation (Yergin, 2011). The oil crises of the 1970s exposed Europe's vulnerability to external shocks, prompting diversification strategies and efficiency measures (Bradshaw, 2013). The 1990s marked a further milestone with the liberalization of energy markets, introducing competition and reshaping the role of national utilities (Goldthau & Sovacool, 2012).

From the early 2000s onward, environmental sustainability became a defining priority. The Renewable Energy Directive (RED) of 2009 established binding national targets to expand renewables in the energy mix, while the EU Emission Trading System (EU ETS), launched in 2005, introduced a cap-and-trade mechanism for greenhouse gas emissions (Diesendorf, 2014). In 2019, the European Green Deal was presented as a comprehensive framework to achieve climate neutrality by 2050, integrating climate, energy, and industrial policy (European Commission, 2019, 2020).

A critical reinforcement of these objectives came in 2021 with the Fit for 55 - package, a legislative suite designed to ensure a 55% reduction in greenhouse gas emissions by 2030. The package included revisions of the EU ETS, updates to the RED and Energy Efficiency Directive (EED), new standards for CO_2 emissions from vehicles, the Carbon Border Adjustment Mechanism (CBAM), and reforms in energy taxation, among other measures

(European Parliament, 2021). Together, these initiatives represented the most comprehensive attempt to align EU policy instruments with the Union's climate and energy objectives (European Commission, 2020).

Finally, the geopolitical rupture caused by Russia's invasion of Ukraine in 2022 underscored the persistent fragility of Europe's energy system. The RePowerEU plan, launched the same year, sought to reduce dependence on Russian fossil fuels through diversification of suppliers, accelerated renewable deployment, enhanced efficiency, and coordinated investment in cross-border infrastructure (European Commission, 2022; Siddi, 2023). RePowerEU further demonstrated the EU's effort to integrate security, sustainability, and affordability into a coherent framework in times of crisis.

This chapter therefore proceeds by examining policies systematically across the three energy pillars. Each subsection outlines the main measures, their objectives, primary contributions to the relevant pillar, secondary impacts on the other two, and critical reflections on their effectiveness and limitations. The chapter concludes with a synthetic overview of the policies, highlighting synergies, conflicts, and gaps that remain in the EU's approach to energy policy.

3.1 Policies in the area of energy security

Energy security has long been a central concern of EU energy policy, shaped by its dependence on external suppliers and the vulnerability of its infrastructure to geopolitical tensions and market shocks. The 2022 Russian invasion of Ukraine exposed the scale of these vulnerabilities, highlighting the risks associated with concentrated import structures and insufficient diversification. Within the EU framework, energy security is understood as the uninterrupted availability of energy sources at an affordable price, supported by diversity of supply, resilience of infrastructure, and sufficient reserves (Ang et al., 2015; Cherp & Jewell, 2011; Yergin, 2011). Over the past decade, the EU has adopted a series of measures aimed at reducing import dependency, strengthening interconnections, and ensuring resilience against crises. The following sections examine the most significant policies and initiatives designed to enhance security of supply, while also assessing their interactions with sustainability and affordability objectives.

3.1.1 REPowerEU project

The REPowerEU plan, launched by the European Commission in May 2022, represents the Union's immediate and most comprehensive response to Russia's invasion of Ukraine and the subsequent energy crisis (European Commission, 2022). Its overarching objective is to end EU dependence on Russian fossil fuels well before 2030 by diversifying energy imports, accelerating the deployment of renewable energy, strengthening energy efficiency, and expanding infrastructure for hydrogen and LNG. In parallel, the plan introduces stricter storage obligations and measures to simplify and smooth-out permitting for renewables, combining short-term crisis management with long-term strategic transformation of the European energy system.

From the perspective of energy security, REPowerEU directly addresses the EU's structural vulnerability: the high concentration of Russian gas imports, which accounted for roughly 40% of EU consumption prior to 2022 (Siddi, 2023). The plan's primary contribution lies in the diversification of supply sources and routes, expansion of LNG infrastructure, mandatory storage requirements, and reinforcement of cross-border energy networks. First, diversification of supply has been pursued through long-term LNG contracts with alternative suppliers such as the United States, Qatar, and Algeria, alongside the expansion of pipeline deliveries from Norway and the Southern Gas Corridor. These efforts reduce import dependency and improve resilience to geopolitical shocks (European Commission, 2022). Second, the construction of new LNG terminals in Germany, Greece, and the Baltic region — some completed within record time — has substantially expanded Europe's regasification capacity. This infrastructural build-out increases flexibility by enabling imports from the global LNG market, thus reducing reliance on a limited number of pipeline suppliers (IEA, 2023). Third, the plan introduced legally binding storage requirements, mandating that gas storage facilities be filled to 80% before the winter of 2022–23 and 90% in subsequent years. This measure significantly enhances seasonal security of supply and reduces vulnerability to price spikes caused by unexpected shortages (European Union, 2022). Finally, REPowerEU has reinforced investment in interconnectors and reverse-flow mechanisms across member states, strengthening cross-border solidarity and ensuring that diversified supplies can be distributed effectively throughout the internal energy market. Together, these measures directly enhance the three classical dimensions of energy security — availability, reliability, and resilience (Cherp & Jewell, 2011; Kruyt et al., 2009).

The plan also generates important secondary impacts on sustainability and affordability. On the sustainability side, REPowerEU creates strong synergies by accelerating the expansion of renewable energy and energy efficiency investments. The plan raises the binding target for renewables to 45% of final energy consumption by 2030 and strengthens the Energy Efficiency Directive, thereby aligning short-term security measures with long-term decarbonization goals. In terms of affordability, the effects are more debatable. While diversification and infrastructure development impose significant upfront costs, particularly for member states with limited fiscal capacity, these measures may lower exposure to volatile fossil fuel markets over the longer term, stabilizing prices and protecting consumers from extreme fluctuations (Bradshaw, 2013; Sovacool & Goldthau, 2016).

A critical reflection reveals both achievements and challenges. REPowerEU demonstrates the EU's capacity to act rapidly and cohesively in response to crisis, embedding security objectives within a broader sustainability agenda. However, the distribution of costs remains uneven, with Eastern and Southern European countries bearing greater adjustment burdens due to their higher reliance on Russian supplies. Financing through the Recovery and Resilience Facility has provoked debate about fairness and long-term fiscal sustainability. Moreover, the large-scale expansion of LNG infrastructure raises the risk of carbon lock-in if facilities continue to operate beyond the transition period, potentially undermining the EU's climate neutrality objectives (Siddi, 2023). While diversification reduces dependence on Russia, it simultaneously increases reliance on other suppliers that may pose new geopolitical risks. This underscores the importance of complementary investment in domestic renewable generation, hydrogen development, and demand-side flexibility, which provide more durable forms of energy security (Sovacool & Brown, 2010).

In sum, REPowerEU constitutes a pivotal milestone in EU energy policy. Its immediate impact has been to enhance supply security by diversifying energy sources, expanding storage, and strengthening infrastructure. At the same time, it generates positive synergies with sustainability and mixed effects on affordability. The long-term success of the plan will depend on effective implementation, equitable cost-sharing among member states, and the EU's ability to reconcile urgent security measures with its enduring commitment to climate neutrality.

3.1.2 Strategic reserves and emergency response mechanisms

The establishment of strategic reserves and emergency response mechanisms has been one of the EU's core tools for safeguarding energy security. These measures are designed to ensure continuity of supply during disruptions caused by geopolitical crises, extreme weather events, or market instability. The framework is anchored in the Oil Stock Directive (2009/119/EC), which obliges member states to hold emergency oil stocks equal to at least 90 days of net imports or 61 days of average consumption, thereby creating a structural safeguard against global oil shocks (European Union, 2009). In the case of natural gas, the significance of reserves rose sharply after the 2022 Russian invasion of Ukraine. The EU responded by adopting Regulation (EU) 2022/1032, requiring member states to fill gas storage facilities to 80% before the 2022–23 winter and to 90% in subsequent years (European Union, 2022). These measures were reinforced by the Security of Gas Supply Regulation (2017/1938), which provides for solidarity mechanisms and cross-border coordination in case of emergency supply shortages (European Union, 2017). Taken together, these frameworks institutionalize a system of reserves and crisis response designed to strengthen the EU's resilience to sudden supply shocks.

From the perspective of energy security, strategic reserves and emergency mechanisms directly reinforce the dimensions of availability, reliability, and resilience (Cherp & Jewell, 2011; Ang et al., 2015). Strategic oil reserves have historically played a vital role in buffering member states against disruptions in global crude oil markets, such as during the Gulf crises of 1973 and 1991 or more recent OPEC production restrictions (Yergin, 2011). Gas storage has become particularly critical since 2022, when the EU was forced to compensate for the rapid decline of Russian pipeline supplies. The new storage regulation ensured that member states entered the 2022–23 winter with historically high gas reserves, which proved decisive in averting a systemic supply crisis. In addition to storage, emergency response mechanisms such as reverse-flow capabilities, solidarity clauses, and enhanced cross-border interconnectors have strengthened the Union's ability to manage asymmetric shocks across regions. These measures enable gas and electricity to be rerouted where needed most, preventing localized shortages from escalating into systemic crises. A further dimension of security relates to the protection of critical energy infrastructure. Incidents such as the 2022 Nord Stream pipeline explosions highlighted vulnerabilities to sabotage and hybrid threats. Similarly, cyberattacks on electricity grids and pipeline operators have underscored the need to treat cybersecurity as an integral part of energy security policy (Hiller & Russell, 2013). By addressing both physical and cyber risks, the EU's framework for strategic reserves and emergency response has evolved beyond resource availability to encompass broader systemic resilience.

The system also produces secondary impacts on sustainability and affordability. On the sustainability side, reliance on fossil-based reserves presents a trade-off with long-term climate objectives, as maintaining large oil and gas stocks risks prolonging hydrocarbon dependency. However, by providing stability during crises, these reserves create the operational flexibility necessary to integrate higher shares of intermittent renewable energy without jeopardizing system reliability (Bradshaw, 2013). In terms of affordability, reserves and emergency coordination can reduce extreme price volatility, protecting households and industry from sudden spikes in energy costs. For example, during the winter of 2022–23, the combination of filled gas storage and coordinated demand-reduction measures helped to stabilize wholesale prices across the EU (European Commission, 2024). At the same time, the maintenance of reserves entails substantial costs for member states, including storage infrastructure, operational expenses, and the opportunity cost of immobilized resources, which may ultimately be passed on to consumers.

A critical reflection highlights the strengths and limitations of these measures. On the positive side, mandatory oil and gas reserves have significantly increased the EU's preparedness for supply disruptions, while solidarity mechanisms and reverse-flow arrangements illustrate a stronger level of cross-border cooperation than in previous crises. Nevertheless, challenges persist. The effectiveness of reserves depends heavily on compliance, and prior to 2022 some member states had repeatedly failed to meet storage obligations, undermining the credibility of the system. Furthermore, the long-term reliance on fossil-based reserves risks creating path dependency, potentially slowing the structural shift toward renewables and demand-side flexibility (Sovacool & Saunders, 2014). The events of 2022 also demonstrated that while storage cushions short-term crises, it cannot replace the need for systemic diversification and decarbonization. Finally, the growing threat of hybrid and cyber warfare against energy infrastructure underscores a vulnerability that reserves alone cannot address, making it imperative to combine emergency mechanisms with stronger investment in grid resilience, digital security, and renewable-based flexibility (Hiller & Russell, 2013; Sovacool & Brown, 2010).

In sum, strategic reserves and emergency response mechanisms are indispensable instruments for reinforcing EU energy security. They ensure the availability of vital resources, provide resilience against crises, and stabilize energy prices during shocks.

However, their fossil-based nature, fiscal costs, and reliance on consistent member state compliance limit their long-term role. Their effectiveness will depend on how successfully they are integrated with broader measures aimed at diversification, renewable expansion, and systemic resilience.

3.1.3 Diversification of energy sources and infrastructure

Diversification of energy sources and the supporting infrastructure is a central strand of the EU's approach to energy security. Within the Union's policy architecture, diversification targets a reduction of import concentration and route risk by broadening the mix of fuels, suppliers, and physical entry points, while expanding cross-border infrastructure so that supplies can be reallocated when shocks occur (European Commission, 2016). In practical terms—this includes (i) shifting gas import portfolios away from a single dominant supplier through increased LNG access and alternative pipeline routes (e.g., the Southern Gas Corridor), (ii) accelerating domestic low-carbon generation to lower structural import dependence, and (iii) strengthening interconnection capacity and Projects of Common Interest (PCI) to move energy across borders when and where it is needed.

Framed against the definitional dimensions of energy security—availability, reliability, and resilience (Ang et al., 2015; Cherp & Jewell, 2011)—diversification acts on each. First, availability improves as the EU reduces supplier concentration risk: additional LNG access points and alternative pipeline corridors lessen exposure to unilateral cut-offs and transit disputes (Yergin, 2011; Bradshaw, 2013). Second, reliability increases through portfolio effects: a broader mix of fuels and origins reduces variance in supply conditions and price shocks arising from geopolitical or technical outages. Third, resilience is reinforced by network design: higher interconnection capacity, reverse-flow capabilities, and PCI investments enable rapid re-routing of volumes across member states, preventing local disruptions from becoming systemic. LNG reception capacity and the Southern Gas Corridor fit this logic well: both instruments expand the EU's set of feasible supply states and lower the probability that a single-supplier shock propagates through the system. Likewise, the cross-border infrastructure (interconnectors/PCI) operationalizes diversification by turning nominal access to alternative supplies into deliverable security—i.e., energy can actually reach constrained regions when needed. Together, these elements align with the claim that security improves when systems combine diverse inputs with flexible networks and transparent market rules (Sovacool & Saunders, 2014; Kruyt et al., 2009).

Diversification has sustainability synergies where it accelerates domestic low-carbon capacity and integrates variable renewables via stronger interconnections (reducing curtailment and facilitating balancing over larger areas), thereby lowering import dependence and emissions over time (Turconi et al., 2013; European Commission, 2019). On affordability, effects are mixed. In the near term, expanding LNG capacity and interconnectors entails significant capital costs and may transmit price signals from wider regional markets; over the medium term, portfolio diversification and deeper market integration tend to dampen extreme price spikes and reduce the cost of supply interruptions (World Energy Council, 2018; Bradshaw, 2013). This trade-off captures the upfront infrastructure and contracting costs versus lower volatility and crisis-time expenditures, which significantly affects energy affordability.

The policy logic is strong, but several constraints matter. First, infrastructure asymmetries—uneven interconnection density and PCI progress—mean benefits are not uniform across member states; peripheral regions can remain bottlenecked, limiting the crisis-sharing potential. Second, contracting and lock-in risks exist: long-term arrangements to secure diversified fossil supplies can conflict with forward decarbonization trajectories if not carefully time-bounded and aligned with the growth of domestic renewables (Siddi, 2023; Sovacool & Brown, 2010). Third, governance and coordination challenges persist: diversification delivers maximal security only when market coupling, capacity allocation, and transparency are consistent across borders (European Commission, 2016; Kruyt et al., 2009). Finally, while diversification reduces single-supplier leverage, it can reallocate geopolitical exposure rather than eliminate it, underscoring the need to pair external diversification with structural demand reduction and domestic clean generation.

Diversification of sources and infrastructure primarily strengthens EU energy security by lowering concentration risk and enabling system-wide flexibility. It creates clear sustainability synergies where it supports renewable integration and reduces import dependence, while affordability effects move from short-term cost pressures toward long-run volatility reduction. Its ultimate effectiveness hinges on closing infrastructure gaps, avoiding fossil lock-in, and coordinating market rules so that diversified options translate into deliverable security (Ang et al., 2015; Cherp & Jewell, 2011; European Commission, 2016; Sovacool & Saunders, 2014; Bradshaw, 2013).

3.2 Policies in the area of energy sustainability

Energy sustainability is a central pillar of EU energy policy, reflecting the Union's long-term commitment to climate neutrality, environmental protection, and intergenerational equity. Policies in this domain aim to reduce greenhouse gas emissions, expand the use of renewable energy, and improve efficiency, thereby ensuring that economic development is compatible with ecological limits. By accelerating the transition to a low-carbon economy, these measures contribute not only to mitigating climate change but also to promoting innovation, competitiveness, and social well-being (Diesendorf, 2014; van den Bergh, 2013).

The most comprehensive framework for EU sustainability policy is the Fit for 55 - package, adopted in 2021 to operationalize the European Green Deal's climate neutrality objective. Fit for 55 consists of 13 legislative proposals designed to cut greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels (European Commission, 2021a). Among these, the Renewable Energy Directive (RED III), the EU Emissions Trading System (ETS) reforms, and the European Green Deal (EGD) stand out as flagship measures that directly shape the Union's sustainability trajectory.

In line with the analytical framework established in Chapter 2, these policies will be assessed primarily for their contribution to sustainability — reducing emissions and enabling structural transformation of the energy system — while also considering their secondary impacts on security and affordability. The following subsections therefore examine RED, ETS, and the EGD as key elements of Fit for 55, evaluating their synergies, trade-offs, and implementation challenges across the wider energy trilemma.

3.2.1 Renewable Energy Directive

The Renewable Energy Directive (RED) has been the central legislative instrument for promoting renewable energy within the EU and forms a cornerstone of the Union's sustainability agenda. Adopted initially in 2009 as part of the Climate and Energy Package as Directive 2009/28/EC (European Union, 2009), it set legally binding national targets that collectively aimed for 20% of renewables in the EU's gross final energy consumption by 2020. This framework was revised with RED II as Directive EU 2018/2001 (European Union, 2018), which introduced a binding EU-wide target of 32% renewables by 2030. Most recently, under the Fit for 55 package, the directive was amended through RED III as Directive EU 2023/2413 (European Union, 2023), which raises the target to 42.5% by 2030, with a further indicative ambition of 45%. These successive revisions illustrate the EU's progressive tightening of its climate policy framework and highlight the role of RED as a flagship component of the Green Deal and Fit for 55 road-map (European Commission, 2019, 2021a).

From the perspective of energy sustainability, RED has been instrumental in driving decarbonization across member states. By providing binding targets and a long-term legal framework, it has significantly increased investment certainty in renewable technologies (van den Bergh, 2013). Mechanisms such as National Renewable Energy Action Plans (NREAPs), guarantees of origin, and support schemes (including feed-in tariffs and green certificates) have contributed to expanding renewable deployment across sectors including electricity, heating and cooling, and transport (Diesendorf, 2014). The results are visible: the EU's share of renewables increased from 12.5% in 2010 to about 24.5% in 2023 (European Commission, 2024). Nordic member states have emerged as frontrunners, with Sweden, Finland, and Latvia leading among member states. On the other side, larger economies such as Germany and France, while increasing their renewable share, have faced more difficulty in meeting their targets compared to the Nordic counties, underlining uneven progress across the Union. By setting progressively higher targets under RED III, the EU has reinforced the structural transformation of its energy system, ensuring that sustainability remains at the center of its policy framework (European Union, 2023).

The directive has also produced secondary impacts for security and affordability. On the security side, increased renewable deployment reduces dependence on imported fossil fuels, lowering vulnerability to geopolitical shocks and contributing to a more resilient energy mix (Bradshaw, 2013). On the affordability side, the effects are more complex. The expansion of renewables requires substantial upfront investments in generation and grid integration, costs which in the short term can translate into higher consumer prices or surcharges. At the same time, the rapid fall in the levelized costs of solar and wind energy has made renewables increasingly competitive, with long-term potential to stabilize prices and protect consumers from fossil fuel volatility (Turconi et al., 2013; IRENA, 2022). Distributional effects also matter: support schemes have occasionally been criticized for uneven cost-sharing, with vulnerable households disproportionately affected, highlighting the importance of instruments like the Social Climate Fund to offset these impacts.

A critical reflection underscores both achievements and ongoing challenges. The RED has been highly effective in providing a predictable legal framework for renewables, but implementation has been uneven. Some member states have struggled due to high administrative burdens, financing gaps, or delays in permitting, despite reforms under RED III aimed at streamlining procedures. Integration challenges persist as well, particularly regarding the balancing of intermittent renewables, the need for expanded cross-border interconnections, and investment in grid modernization (European Union, 2023). The heavy reliance on biomass in some member states has also raised ongoing debates regarding land use, biodiversity, and carbon accounting (Diesendorf, 2014). These challenges demonstrate that while RED has been indispensable in driving decarbonization, its long-term effectiveness depends on complementary measures addressing infrastructure bottlenecks, social fairness, and ecological safeguards.

In summary, the Renewable Energy Directive is the EU's most important legal instrument for advancing sustainability, driving the transition to a low-carbon economy through binding and progressively ambitious renewable targets. It has generated synergies with energy security by lowering import dependence and stabilizing supply, while creating affordability trade-offs in the short term due to infrastructure and support costs. Its overall success will depend on overcoming uneven national implementation, improving permitting and grid integration, and maintaining social acceptance as the Union moves towards its Fit for 55 and climate neutrality goals.

3.2.2 EU Emission Trading System (EU ETS)

The EU Emissions Trading System (ETS), established by the EU in 2003 as Directive 2003/87/EC (European Union, 2003) is the cornerstone of the Union's climate policy and its most significant market-based instrument for promoting sustainability. Launched in 2005, the ETS created the world's first large-scale carbon market, with the purpose of reducing greenhouse gas emissions in a cost-effective manner by placing a cap on total emissions and allowing trading of emission allowances. Subsequent reforms, including Directive (EU) 2018/410 (European Union, 2018) and the Fit for 55 revision - Directive (EU) 2023/959 (European Union, 2023), progressively strengthened the system by tightening the emissions cap, expanding sectoral coverage, and reducing free allocations. Together, these reforms illustrate the ETS's evolution into a central instrument for achieving the EU's 2030 climate targets and its long-term goal of climate neutrality by 2050 (European Commission, 2019, 2022).

From the perspective of energy sustainability, the ETS directly contributes to decarbonization by creating a price on carbon that incentivizes emission reductions across power generation, energy-intensive industries, and aviation. By gradually reducing the emissions cap, the ETS ensures absolute declines in greenhouse gas emissions between 2005 and 2023 (European Commission, 2024). The system's market-based design promotes efficiency by allowing reductions where they are cheapest, while revenues from allowance auctions finance low-carbon technologies, innovation, and just transition measures (van den Bergh, 2013; Diesendorf, 2014). The creation of the Market Stability Reserve in 2019 further improved sustainability by addressing allowance oversupply and stabilizing the carbon price, ensuring that the system provides credible and consistent signals for investment in renewables and efficiency (Yang, 2022). In this way, the ETS aligns economic incentives with environmental sustainability, embedding climate considerations into the functioning of the internal market.

The ETS also produces secondary impacts on energy security and affordability. On the security side, the system indirectly reduces fossil fuel dependence by encouraging investment in renewables and energy efficiency. However, the risk of carbon leakage—the relocation of carbon-intensive industries outside the EU—has long been a concern, which the EU now addresses through free allocations and the introduction of the Carbon Border Adjustment Mechanism (CBAM) as a complementary measure (Bradshaw, 2013). On the affordability side, the ETS has raised short-term energy costs, particularly in electricity and heating, as carbon prices are passed on to consumers. Nevertheless, revenues from allowance auctions are increasingly recycled into the Modernization Fund, Innovation Fund, and the forthcoming Social Climate Fund, which are designed to mitigate adverse distributional effects and support vulnerable households and regions (European Parliament, 2021). Over the longer term, by accelerating decarbonization and reducing exposure to volatile fossil fuel markets, the ETS is expected to stabilize prices and enhance affordability.

A critical evaluation underscores both the achievements and challenges of the ETS. The system has been effective in reducing emissions in covered sectors, with empirical evidence showing tangible results: Biancalani et al. (2024) estimate that ETS-covered industries reduced CO_2 emissions by approximately 15% between 2005 and 2020 relative to a counterfactual scenario, confirming its role as a measurable driver of decarbonization. Nevertheless, the ETS has faced recurring issues of allowance price volatility, uneven national impacts, and the continued reliance on free allocations, which have sometimes weakened its decarbonization incentives. Sectoral coverage also remains incomplete, as agriculture and much of transport are not yet included, though the Fit for 55 reform introduces a separate ETS II for buildings and road transport European Parliament. (2021). These limitations highlight that while the ETS is indispensable for advancing sustainability, it cannot operate in isolation. Its long-term success will depend on sustaining a robust and predictable carbon price, extending coverage, and ensuring fairness through redistributive mechanisms such as the Social Climate Fund, thereby reinforcing its role as a central pillar of the Fit for 55 strategy and the EU's climate neutrality pathway (van den Bergh, 2013; European Commission, 2022).

3.2.3 European Green Deal

The European Green Deal (EGD), introduced by the European Commission in December 2019 (European Commission – COM (2019) 640 final), is the Union's most comprehensive policy roadmap to embed sustainability across all sectors of the economy. Its targets are operationalized through the Fit for 55 - package of 13 legislative proposals adopted in 2021, which collectively update the EU's energy and climate framework to align with the 55% emissions reduction goal by 2030 compared to 1990 levels and its overarching goal to achieve climate neutrality by 2050 (European Parliament, 2021). The EGD functions as a strategic umbrella that aligns existing and new measures, including the Renewable Energy Directive, the EU Emissions Trading System reforms, the Energy Efficiency Directive, and the Carbon Border Adjustment Mechanism, into a coherent decarbonization pathway (European Commission, 2019, 2021a).

From the perspective of sustainability, the EGD's primary contribution lies in its systemic integration of climate objectives into the Union's economic and social framework. Unlike earlier packages, which were sector-specific, the EGD provides a holistic governance structure for the energy transition. It mainstreams sustainability into multiple policy domains: renewable energy expansion, energy efficiency, industrial decarbonization, sustainable mobility, and the circular economy. This broad coverage reflects the understanding that climate neutrality requires not only technological transformation, but also structural changes in production, consumption, and finance (Rosamond & Dupont, 2021). By setting a legally binding climate neutrality target, the EGD establishes long-term policy certainty that mobilizes both public and private investment in low-carbon infrastructure and innovation (European Commission, 2019). This is critical because sustainable transitions depend on credible long-term frameworks that reduce investment risk, particularly in emerging technologies such as hydrogen, carbon capture, and energy storage (Siddi, 2023). In addition, the EGD integrates social and territorial fairness through mechanisms such as the Just Transition Mechanism, acknowledging that sustainability must also encompass social inclusion and regional balance. In this way, the EGD operationalizes earlier academic insights on the need for innovation-led and systemic approaches to climate governance (van den Bergh, 2013; Diesendorf, 2014) within a concrete and enforceable policy framework.

The EGD also has secondary effects on the other two pillars. On the security side, by reducing fossil fuel demand and scaling up domestic renewable capacity, it contributes to lowering the EU's dependence on external suppliers, enhancing resilience against geopolitical risks and price shocks (European Commission, 2022; Siddi, 2023). On the affordability side, the transition entails significant investment needs and adjustment costs, but the Green Deal explicitly addresses these through fairness mechanisms such as the Just

Transition Mechanism (JTM) and the Social Climate Fund (SCF). These instruments are designed to support vulnerable households and carbon-intensive regions, mitigating short-term affordability pressures while ensuring social acceptance of the transition (European Parliament, 2021).

A critical reflection highlights both the transformative potential and the challenges of the Green Deal. Its comprehensive scope and legally binding targets mark a historic advance in EU climate governance, yet financing needs of over €1 trillion in the coming decade raise questions of burden-sharing between member states and private actors (European Commission, 2021a). Political interference is also visible, with disputes over the fairness of instruments such as CBAM and concerns from sectors like agriculture about stricter environmental standards. Furthermore, uneven administrative capacity among member states risks creating an implementation gap between targets and delivery (Rosamond & Dupont, 2021). These limitations indicate that while the EGD is indispensable for embedding sustainability across the EU economy, its long-term credibility will depend on consistent enforcement, sufficient financing, and sustained public support, confirming its role as the central framework for steering the EU towards climate neutrality (European Commission, 2019; European Parliament, 2021; Siddi, 2023).

3.3 Policies in the area of energy affordability

Energy affordability is a foundational pillar of EU energy policy, ensuring that households and businesses have access to energy at reasonable and predictable prices. The issue has gained particular urgency during recent energy crises, when volatile fossil fuel markets placed significant pressure on consumers. Affordability is not only an economic concern but also a social one, as high energy costs disproportionately affect low-income households, aggravating energy poverty and inequality across member states (Boardman, 2010; Bouzarovski, 2018). Consequently, the EU has introduced a range of policies and mechanisms to stabilize energy prices, protect vulnerable groups, and promote transparency in energy markets. Among the most important are the Energy Efficiency Directive, which reduces energy demand and thus lowers costs; the Social Climate Fund, designed to shield vulnerable households and micro-enterprises from the impacts of carbon pricing; and national-level price stabilization measures, including subsidies, tax reductions, and temporary caps, especially during the 2021–2022 energy crisis (Sgaravatti et al., 2023; European Commission, 2022). Together, these initiatives demonstrate that energy affordability is both a social imperative and an economic necessity, embedded in the EU's strategic framework and increasingly recognized as essential for maintaining social cohesion and political legitimacy (Gangale & Mengolini, 2019).

3.3.1 Energy Efficiency Directive

The Energy Efficiency Directive (EED), first adopted in 2012 as and subsequently revised in 2018 and recast in 2023 as part of the Fit for 55 - package as Directive (EU) 2023/1791

(European Union, 2023), is one of the EU's central instruments for reducing energy demand and controlling costs for households and businesses. Its overarching purpose is to improve energy efficiency across all sectors of the economy through binding targets, national action plans, and sectoral measures such as efficiency obligations for utilities, building renovation requirements, and standards for appliances and equipment (Girod, 2017). Under the most recent revision, the EU committed to a 11.7% reduction in final energy consumption by 2030 relative to baseline projections, positioning efficiency as the "first fuel" in the transition to a resilient and affordable energy system (European Commission, 2024).

From the perspective of affordability, the EED contributes directly by reducing energy demand and thereby lowering costs for households and businesses. One of its central objectives is to achieve large-scale energy savings by improving efficiency at every stage of the value chain, from production and transmission to end-use. To this end, the directive sets binding energy-saving targets for member states and requires energy companies to achieve annual savings through efficiency obligation schemes (European Union, 2023). For households, these measures have a tangible effect on monthly bills, particularly as energy price volatility has intensified in recent years. In the building sector, which accounts for nearly 40% of EU energy consumption, efficiency improvements have the greatest potential for reducing long-term costs. Regulations for minimum energy performance standards, alongside initiatives to support the renovation of inefficient buildings and the introduction of modern heating and cooling systems, are therefore critical for alleviating energy poverty and stabilizing household energy expenses (Pérez-Lombard, Ortiz, & Pout, 2008; Bouzarovski, 2018). For businesses, especially small and medium-sized enterprises (SMEs), the EED introduces requirements for regular energy audits and promotes efficiency investments that reduce operational costs and enhance competitiveness. The directive also empowers consumers by mandating more accurate billing information and promoting transparency in energy markets, enabling individuals and firms to make informed choices and benefit from lower prices where possible. These mechanisms collectively ensure that affordability is not left to market forces alone but actively supported through targeted policies that reduce energy bills, shield vulnerable consumers, and promote long-term economic resilience (European Commission, 2021b; Ürge-Vorsatz & Tirado Herrero, 2012). As part of the Fit for 55 - package, the recast EED elevates efficiency as the 'first fuel' of the transition, making it a cornerstone of both affordability and sustainability policies in the EU framework (European Union, 2023).

The directive also has secondary impacts on security and sustainability. On the security side, reducing demand directly lowers import dependence, easing exposure to geopolitical risks in energy supply (European Commission, 2022). On the sustainability side, efficiency gains are critical for reducing emissions, since lower energy use translates into fewer carbon emissions even before accounting for renewables (Ürge-Vorsatz & Tirado Herrero, 2012). The EED therefore plays a bridging role between the three pillars, reinforcing synergies between affordability, sustainability, and security.

A critical reflection shows that while the EED has been instrumental in embedding energy efficiency into EU and national policy frameworks, its implementation has faced challenges. Progress has been uneven across member states, with financing gaps, administrative capacity, and weak enforcement slowing delivery (European Commission, 2021b). Energy efficiency improvements have often lagged behind targets, particularly in the building sector, where renovation rates remain below what is required. Moreover, upfront investment costs can discourage households and small firms, limiting the immediate affordability gains, despite long-term benefits. Nevertheless, the EED remains a cornerstone of EU affordability policy: it lowers energy bills, reduces import dependence, and cuts emissions, making it indispensable for achieving the objectives of the Fit for 55 package and reinforcing the EU's climate neutrality trajectory.

3.3.2 Measures to protect vulnerable consumers

Protecting vulnerable consumers has become a central priority of EU and national energy policies, particularly as volatile energy markets and rising prices have intensified energy poverty across the Union. Vulnerable households are disproportionately exposed to high energy costs and disconnection risks, which heightens inequality and undermines trust in the energy transition (Boardman, 2010; Bouzarovski, 2018). To address these challenges, the EU has strengthened consumer rights through the Clean Energy for All Europeans package (European Commission, 2016), which obliges member states to monitor and mitigate energy poverty via their National Energy and Climate Plans (NECPs). At the same time, emergency measures have been deployed in response to the 2021–2022 energy price crisis. The Commission's communication Tackling rising energy prices: a toolbox for action and support set out a menu of short- and medium-term policies—ranging from temporary price caps to targeted subsidies—that could be adopted at the national level to shield vulnerable households (European Commission, 2021b).

From the perspective of affordability, consumer protection measures directly reduce household and SME energy costs through a mix of social welfare systems, financial transfers, and rights-based instruments. National welfare systems continue to provide the bulk of support, including direct social assistance (36%), energy cost contributions (32%), social tariffs (20%), and targeted aid for elderly or vulnerable groups (Bouzarovski, 2018). These interventions are supplemented by energy allowances, vouchers, and tax reductions, which lower bills and ensure access to basic services (Sgaravatti et al., 2023). At the EU level, the Social Climate Fund (SCF), created under the Fit for 55 - package, represents a more structural response, financing measures to compensate vulnerable households and micro-enterprises for the costs of carbon pricing (European Parliament, 2021). Equally significant are consumer rights provisions: energy suppliers must provide clear contract terms, accurate billing, transparent tariff structures, and complaint mechanisms, enabling consumers to compare offers and avoid unfair practices (European Commission, 2016). By combining financial support with legal empowerment, these policies help stabilize budgets, prevent disconnections, and reinforce the social legitimacy of the energy transition (Gangale

& Mengolini, 2019). The framework also promotes contractual choice and flexibility, allowing consumers to select between different pricing models. For instance, households may opt for fixed-price contracts that guarantee predictable costs for basic energy needs, while also choosing dynamic pricing contracts for specific uses, such as charging electric vehicles during off-peak hours when electricity is cheapest (European Commission, 2021b).

The measures also produce secondary impacts on energy security and sustainability. On the security side, subsidies and price controls provide immediate relief but may encourage higher consumption, discouraging conservation and diversification. On the sustainability side, fossil fuel subsidies can undermine decarbonization objectives, but well-targeted schemes—such as building renovation grants, support for efficient appliances, or dynamic pricing contracts linked to renewables—can create synergies between affordability, sustainability, and security (Ürge-Vorsatz & Tirado Herrero, 2012). In this sense, the design of affordability measures determines whether they reinforce or hinder long-term policy objectives.

A critical reflection shows that while measures to protect vulnerable consumers have been indispensable in preventing a surge in energy poverty and safeguarding social stability, they also come with trade-offs. Bruegel estimates that EU governments allocated over €650 billion to affordability measures between 2021 and 2023, raising concerns about fiscal sustainability and uneven national capacities (Sgaravatti et al., 2023). Wealthier member states could provide generous support, while others offered more limited aid, increasing intra-EU disparities. Furthermore, reliance on subsidies risks distorting market signals and delaying investment in efficiency and renewable alternatives. Nevertheless, the introduction of the Social Climate Fund and the strengthening of consumer rights frameworks signal a shift toward more structural, long-term solutions that combine immediate relief with fairness and empowerment. Ensuring that such measures remain fiscally sustainable and consistent with security and sustainability goals will be key to maintaining public support for the EU's climate and energy transition (European Parliament, 2021; Bouzarovski, 2018).

3.3.3 Initiatives to stabilize and reduce energy prices

Ensuring stable and affordable energy prices has become one of the most pressing challenges in EU energy policy. Historically, energy prices were largely determined by oil supply and demand, but today they are influenced by a more complex interplay of factors, including the integration of renewables, market liberalization, geopolitical tensions, and global economic disruptions. This has made energy pricing significantly more volatile than in past decades, exposing consumers and businesses to sharp fluctuations. Recent crises have highlighted the urgency of EU initiatives to reduce volatility and protect affordability, positioning price stabilization at the center of the energy affordability agenda (European Commission, 2021b; Bouzarovski, 2018).

From the perspective of affordability, the most acute challenges arose from the surge in natural gas prices beginning in late 2021, driven by post-pandemic demand, and further culminated by the Russian invasion of Ukraine in 2022. In response, the EU took a series of measures aimed at mitigating the price shock. These included mandatory gas storage targets (in liquefied form - LNG), with Germany and other member states filling reserves during summer months to ensure winter supply, and the creation of the EU Energy Platform in 2022 to coordinate joint gas purchases for the 2023–2024 winter (European Commission, 2022). In 2023, this evolved into the Aggregate-EU mechanism, designed to strengthen collective bargaining power and reduce dependence on high-cost suppliers. Parallel initiatives sought to directly shield consumers, most notably the Regulation on an emergency intervention to address high energy prices, adopted in October 2022. This introduced temporary price caps, incentives to reduce electricity demand, and a solidarity contribution from fossil fuel companies, whose excess profits were redirected to struggling households and businesses. Together, these measures provided immediate relief from soaring prices, increased solidarity among member states, and laid the groundwork for a more resilient and integrated energy market (Sgaravatti, Tagliapietra, & Zachmann, 2023).

The initiatives also produced secondary impacts on energy security and sustainability. On the security side, joint purchasing and storage obligations enhanced resilience by reducing exposure to individual suppliers and strengthening solidarity mechanisms. However, price caps risk dampening incentives for energy savings, potentially raising demand in the short term (European Commission, 2022). On the sustainability side, measures that cap fossil fuel revenues and redirect funds toward affordability have the potential to align price stabilization with decarbonization goals, especially when combined with market reforms that promote competition and renewable deployment. Market integration and electricity market reform have already played a role in lowering wholesale electricity prices by increasing the share of renewables, highlighting how affordability and sustainability can reinforce each other (Ürge-Vorsatz & Tirado Herrero, 2012).

A critical reflection shows that these initiatives have been essential in maintaining affordability during unprecedented energy price shocks, but they are not without challenges. The large-scale fiscal interventions required to finance subsidies and compensation mechanisms strain public budgets and vary significantly across member states, raising concerns of unequal protection within the Union (Sgaravatti et al., 2023). Moreover, reliance on temporary market interventions risks distorting price signals and delaying structural adjustments needed for long-term resilience. Nevertheless, the combination of joint purchasing, storage coordination, and emergency interventions demonstrates the EU's capacity to act collectively in times of crisis. Looking ahead, the effectiveness of these measures will depend on their integration with broader energy market reforms and their ability to balance the three pillars of affordability, security, and sustainability in the long-term EU energy strategy (European Commission, 2022).

Table 1: Overview of EU Energy-Related Policies, Their Primary Pillar, and Secondary Impacts

Policy / Initiative	Primary Pillar	Secondary Impacts
REPowerEU project (2022)	Security	Sustainability (accelerates RES deployment); Affordability (mixed: high upfront costs, long-term price stability)
Strategic reserves and emergency response mechanisms	Security	Sustainability (temporary fossil reliance undermines RES); Affordability (prevents extreme price shocks)
Diversification of energy sources and infrastructure	Security	Sustainability (supports RES integration); Affordability (enhances market efficiency, lowers costs over time)
Renewable Energy Directive (RED III)	Sustainability	Security (reduces import dependence); Affordability (long-term stability, upfront investment costs)
EU Emissions Trading System (EU ETS)	Sustainability	Security (reduces fossil fuel reliance); Affordability (short-term cost increases, long-term stabilization via funds)
European Green Deal (EGD)	Sustainability	Security (diversification, reduced import dependency); Affordability (Just Transition Mechanism, Social Climate Fund)
Energy Efficiency Directive (EED)	Affordability	Security (reduces import needs); Sustainability (lowers emissions, complements renewables)
Measures to protect vulnerable consumers	Affordability	Security (subsidies can keep demand high); Sustainability (fossil subsidies undermine RES, but targeted measures create synergies)
Initiatives to stabilize and reduce energy prices	Affordability	Security (joint purchasing strengthens resilience); Sustainability (risk of fossil lock-in, but reforms redirect revenues toward clean energy)

Source: Own work based on European Commission (2016), European Commission (2021a) European Commission (2021b), European Commission (2022); Directive (EU) 2023/1791, Directive (EU) 2023/2413; European Parliament (2021); Boardman (2010); Bouzarovski (2018); Sgaravatti et al. (2023); Ürge-Vorsatz & Tirado Herrero (2012)

The analysis of EU policies across the three pillars of energy policy—security, sustainability, and affordability—shows how the Union has built a layered response to both immediate crises and long-term structural challenges. Each initiative has a primary focus, but also produces secondary impacts that create synergies and trade-offs. For instance, RePowerEU (European Commission, 2022) primarily strengthens energy security by reducing dependence on Russian gas, yet also accelerates renewables deployment and affects affordability through high upfront costs. Similarly, the Renewable Energy Directive (Directive (EU) 2023/2413) drives sustainability, but also contributes to security by reducing import reliance and to affordability through long-term price stability (Bouzarovski, 2018). Affordability-focused measures, such as the Energy Efficiency Directive (Directive (EU) 2023/1791), reduce consumer bills while also lowering emissions and imports (Boardman, 2010; Ürge-Vorsatz & Tirado Herrero, 2012).

However, significant tensions and gaps remain. Short-term affordability measures—such as subsidies, tax cuts, and price caps—have been indispensable in shielding consumers, yet they risk undermining sustainability by encouraging fossil fuel consumption (Sgaravatti, Tagliapietra, & Zachmann, 2023). Other evidence suggests that synergies are strongest between security and sustainability, particularly in renewables and efficiency, while affordability remains the most vulnerable pillar, as fiscal constraints and uneven national capacities create disparities across the Union (Bouzarovski, 2018; European Parliament, 2021). Table 1 summarizes the examined policies, their primary pillar of impact, and their secondary spillovers across the other two dimensions.

4 EMPIRICAL ANALYSIS OF THE ENERGY SITUATION IN THE EU

This chapter presents an empirical analysis of the European Union's energy situation along the three analytical pillars outlined in the theoretical and policy framework: energy security, energy sustainability, and energy affordability. The analysis is carried out consistently for the EU-27 Member States, which form the baseline country set across all subchapters. This approach ensures methodological comparability between pillars and avoids inconsistencies in coverage. For interpretive purposes, the analysis applies two segmentation lenses: a geographical grouping (CWE/CEE) in the domains of energy security and sustainability, and GDP-based income groups in the domain of affordability. These secondary groupings do not alter the common EU-27 base but provide additional analytical insight suited to the nature of each pillar.

The operationalization of indicators draws on widely accepted frameworks that conceptualize energy policy as a multidimensional issue (Brodny & Tutak, 2025; WEC, 2018). Energy security is evaluated through measures of import dependency, diversification, storage adequacy, and interconnection, reflecting the priorities of REPowerEU, the strategic reserves (EU) 2022/1032, and diversification initiatives reviewed in Chapter 3. Energy sustainability is captured through renewable energy penetration, greenhouse gas (GHG) intensity, and efficiency metrics, aligned with the Renewable Energy Directive (RED II and III), the EU Emissions Trading System (EU ETS), and the Energy Efficiency Directive (EED 2023/1791). Affordability is assessed through household energy prices, energy consumption per capita, and percentage of income spent on energy, reflecting both academic traditions (Boardman, 2010; Bouzarovski, 2018) and EU policy instruments such as the Social Climate Fund and national shielding measures (Bruegel, 2023).

The empirical analysis uses a compact but representative set of indicators:

- Energy security: overall and gas-specific import dependency; gas storage fullness before winter, and, where data permit, electricity generation diversity.

- Energy sustainability: share of renewables in gross final energy consumption; GHG emissions; and primary energy consumption or energy intensity as an efficiency metric.

- Energy affordability: average household energy prices in EUR/MWh (and where relevant, PPP-adjusted); energy consumption per capita; and percentage of income spent on energy.

Data are sourced primarily from Eurostat, complemented by the IEA, the US Energy Information Administration (EIA) and specialized policy datasets (e.g., Bruegel's energy price tracker, World Bank, etc.). All tables and figures follow a uniform design, with consistent units, labelled axes, numbering, and source notes, in line with the SEB LU technical guidelines (2024).

For each pillar, the analysis combines cross-sectional comparisons across Member States with trend analysis over the period 2015–2023 (or the closest feasible range), thereby capturing both structural differences and dynamic adjustments, particularly around the 2021–2022 energy crisis. Each subchapter concludes with a brief reflection that links observed patterns to the mechanisms and targets of EU energy policy in Chapter 3.

The remainder of the chapter is organized as follows. Section 4.1 analyses energy security across the EU-27, with interpretive insights from CWE and CEE segmentation. Section 4.2 examines energy sustainability, again with reference to regional divergences. Section 4.3 addresses affordability, supplementing EU-27 comparisons with GDP-based groupings to highlight socio-economic disparities. Finally, Section 4.4 provides an international comparison between the EU, the United States, and China, applying methodologically analogous indicators across the three pillars to situate EU performance in a broader global context.

4.1 Energy security in EU member states

Energy security remains a central dimension of the European Union's energy policy, particularly after the 2021–2022 supply crisis exposed Member States' vulnerabilities. In line with conceptual frameworks that define security through availability, accessibility, and resilience (Cherp & Jewell, 2011, 2014; Winzer, 2012; Sovacool & Brown, 2010), this section employs a consistent set of indicators across the EU-27. These measures are directly linked to the policy instruments reviewed in Chapter 3, including REPowerEU, the Gas Storage Regulation (EU) 2022/1032, and diversification and infrastructure initiatives.

The following indicators operationalize energy security for the EU-27:

1. Overall energy import dependency (%) – measures the share of net imports in gross available energy. A high dependency rate signals vulnerability to external supply disruptions and underpins the diversification agenda of REPowerEU.

2. Gas storage fullness (% of capacity on 1 November) – indicates preparedness for winter demand, serving as a direct output of the Gas Storage Regulation (EU) 2022/1032, which mandates filling targets across Member States.

3. Diversity of electricity generation (Shannon index, normalized) – measures balance in the generation mix, linking system adequacy and resilience to fuel shocks.

The analysis combines cross-sectional comparison of Member States for the most recent year available with trend analysis covering the period 2014–2023 (or 2019–2024 for storage data). This dual approach distinguishes structural country differences from dynamic adjustments following the 2021–2022 crisis. To highlight regional contrasts, results are also interpreted through a CWE vs CEE segmentation, given their historically different levels of Russian fuel dependency, infrastructure connectivity, and diversification options. Each indicator is discussed in light of the EU's security-oriented policies from Chapter 3, with a concluding reflection summarizing how empirical outcomes align with policy objectives.

4.1.1 Overall import dependency

Import dependency is a core indicator of energy security, as it captures the extent to which a country relies on external suppliers for its energy needs. According to Eurostat, it is defined as the share of net imports in gross available energy, expressed as a percentage of total supply. A high level of import dependency signals vulnerability to supply disruptions and price volatility, while a lower level reflects greater self-sufficiency and resilience. This measure is directly aligned with the objectives of the REPowerEU plan, which aims to reduce the Union's structural dependence on fossil fuel imports through diversification of supply sources and accelerated deployment of renewable energy (European Commission, 2022).

As we can see from Table 2, in 2023, import dependency among Central and Western European (CWE) Member States displayed substantial variation, ranging from less than one-third in Sweden and Finland to nearly complete reliance in Malta and Luxembourg. Countries with significant domestic generation capacities, such as Sweden and Finland with hydro, nuclear, and bioenergy, or France with nuclear power, exhibit much lower levels of import dependency.

Table 2: % of import dependency for CWE and CEE countries in 2023

Country	Import %	Country	Import %
Belgium	76.10	Bulgaria	39.72
Denmark	38.87	Czechia	41.68
Germany	66.38	Estonia	3.47
Ireland	77.90	Greece	75.60
Spain	68.42	Croatia	55.72
France	44.87	Cyprus	92.21
Italy	74.81	Latvia	32.73
Luxembourg	90.62	Lithuania	68.04
Malta	97.55	Hungary	62.06
Netherlands	70.45	Poland	48.02
Austria	61.05	Romania	27.86
Portugal	66.87	Slovenia	49.27
Finland	29.57	Slovakia	57.73
Sweden	26.39		
CWE	63.56	CEE	51.20
EU-27	58.27	EU - 27	58.27

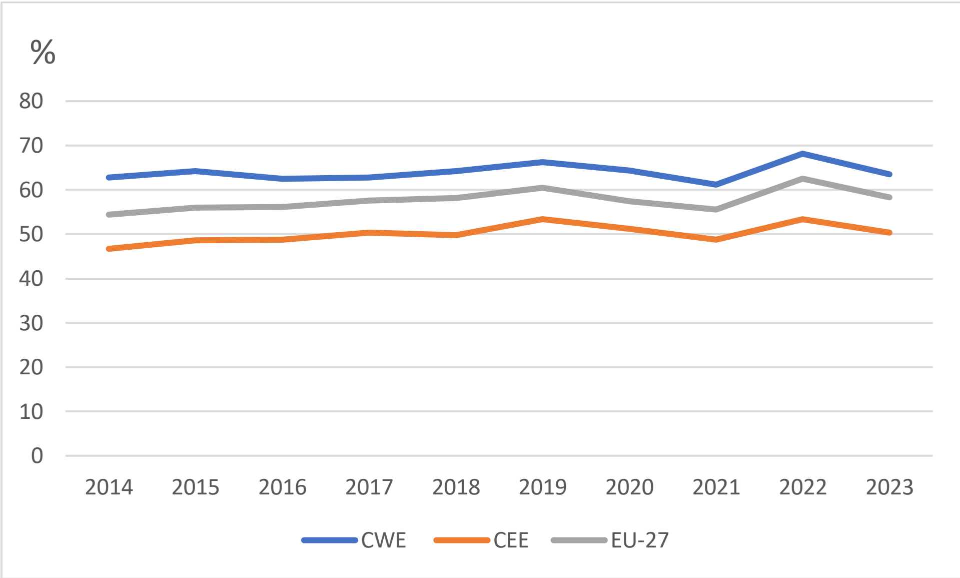
Source: Own work based on Eurostat (2024a)

By contrast, smaller states with negligible resource bases, including Malta, Luxembourg, and Ireland, are almost entirely reliant on external supply. Southern Member States such as Italy, Spain, and Portugal remain above the EU-27 average due to their continued reliance on imported oil and gas despite rapid growth in renewable capacity. The arithmetic mean for CWE countries reached 63.6 percent, compared with the Eurostat-reported EU-27 value of 58.3 percent. This outcome may appear counterintuitive, since CWE economies are often assumed to be more resilient, but the result is shaped both by methodological factors—the group average is a simple mean that gives small high-dependency states equal weight with larger economies—and by the structural reliance of several Western and Southern systems on imported fossil fuels. These results are consistent with the multidimensional approach to energy security highlighted in the literature, which emphasizes that vulnerability is determined not only by geographical location but also by the diversity of supply and the robustness of domestic energy systems (Ang et al., 2015; Cherp & Jewell, 2011, 2014; Winzer, 2012). Within CWE, those states with a diversified and low-carbon portfolio demonstrate greater resilience, while those lacking indigenous resources remain exposed to import risks, a pattern that reflects Sovacool and Brown's (2010) argument that energy security is inherently linked to structural diversity. The findings also connect directly with the EU's policy objectives. The REPowerEU plan, adopted in 2022, explicitly aims to reduce import dependency by diversifying suppliers and accelerating renewable deployment (European Commission, 2022). The 2023 results suggest that while some CWE states, particularly in Northern Europe, align with these objectives, others in Southern Europe continue to face elevated import reliance. Strategic reserves and emergency response mechanisms are especially important for smaller, highly dependent economies, while diversification of supply routes and infrastructure investment remain crucial for countries in

Southern Europe, in line with the principles set out in the Gas Storage Regulation (EU, 2022/1032) and the European Energy Security Strategy. Overall, the indicator demonstrates that import dependency in CWE is shaped by a mix of domestic generation capacity, supply diversity, and structural reliance on fossil fuels. Although the group average exceeds the EU-27 baseline, the heterogeneity across countries highlights uneven progress toward the objectives of REPowerEU and related security measures, underlining the need for continued investment in diversification and low-carbon domestic capacity.

Table 2 also shows the 2023, energy import dependency among Central and Eastern European (CEE) countries averaged 50.3 percent, which is notably lower than the Eurostat-reported EU-27 value of 58.3 percent. The variation across the group is striking. Estonia, with only 3.5 percent import dependency, and Romania, at 27.9 percent, reflect the continued role of domestic resources such as oil shale, coal, and indigenous oil and gas. Poland, at 48 percent, also benefits from a large coal base, which lowers its dependency rate relative to other Member States. By contrast, Cyprus (92.2 percent) and Greece (75.6 percent) are among the most import-dependent economies in the Union, owing to their limited indigenous energy resources and structural reliance on imported oil and gas. Lithuania, Hungary, and Slovakia also report values above 57 percent, consistent with their historical dependence on external supplies. At first sight, the fact that the CEE average lies below both the EU-27 baseline and the CWE average appears paradoxical, since this group is commonly perceived as more vulnerable to external shocks. The explanation lies in the methodological structure of the indicator and the composition of the energy mix. Several CEE states maintain low import dependency not because of high diversification or integration, but because they rely heavily on domestic fossil fuels, especially coal and oil shale. This pattern aligns with the literature's observation that energy security indicators may capture reduced import dependence while masking other vulnerabilities, such as unsustainability, inflexibility, or geopolitical exposure (Ang et al., 2015; Cherp & Jewell, 2014; Winzer, 2012). These results also resonate with the EU's policy agenda. The REPowerEU plan prioritizes a reduction in reliance on Russian fossil fuels, which historically dominated CEE imports (European Commission, 2022). Although dependency rates appear moderate for several CEE members, the persistence of fossil-heavy domestic production raises major sustainability challenges under the European Green Deal and creates cost risks through the EU Emissions Trading System. Strategic reserves and joint procurement mechanisms therefore remain crucial, particularly for highly exposed states such as Greece and Cyprus, while diversification of supply infrastructure, including LNG terminals and cross-border interconnections, continues to be a central element of EU security strategy (Regulation (EU) 2022/1032). Overall, the 2023 snapshot for CEE underscores the limitations of import dependency as a standalone indicator. While the group's average is below the EU-27 level, this is due more to reliance on domestic coal and oil shale than to structural resilience. In practice, CEE remains highly vulnerable to external supply risks, especially in gas markets, and faces long-term challenges in aligning security with sustainability.

Figure 2: 2014-2023 trend of % import dependency in the EU



Source: Own work based on Eurostat (2024a)

Figure 2 shows that between 2014 and 2023, the EU-27's import dependency remained relatively stable, fluctuating between 54 and 62 percent. Dependency increased gradually from 54.4 percent in 2014 to 60.5 percent in 2019, before dropping to 57.5 percent in 2020 as energy demand contracted during the COVID-19 pandemic. A further decline to 55.5 percent in 2021 was followed by a sharp increase in 2022 (62.5 percent), reflecting both the immediate disruptions of the Russian invasion of Ukraine and the Union's increased reliance on non-Russian suppliers. By 2023, dependency fell back slightly to 58.3 percent, suggesting the early impact of REPowerEU measures aimed at diversifying suppliers, expanding LNG imports, and accelerating renewable deployment (European Commission, 2022).

CWE countries consistently recorded dependency levels above the EU-27 average. Their values ranged from 62.6 percent in 2016 to a peak of 68.2 percent in 2022, before falling to 63.6 percent in 2023. This trajectory highlights the region's persistent reliance on imported oil and gas, even though several CWE members maintain substantial domestic low-carbon capacity (e.g., nuclear in France, hydro in Sweden and Finland). The rise in 2022 underlines how shocks in global energy markets amplified the vulnerability of high-import states such as Italy, Spain, and Belgium. By contrast, CEE countries recorded consistently lower import dependency, averaging around 47–53 percent. Their values increased gradually from 46.7 percent in 2014 to 53.3 percent in 2019, fell back to 48.8 percent in 2021, and rose again to 53.4 percent in 2022 before declining to 50.3 percent in 2023. This relative stability is largely due to the continued reliance on domestic fossil fuels such as coal, lignite, and oil shale, which suppress import needs but at the cost of higher carbon intensity and limited diversification.

The comparison illustrates a structural divergence: CWE appears more import dependent than the EU-27 as a whole, while CEE appears less dependent, though for different and less sustainable reasons. This supports the argument from the literature that import dependency must be interpreted cautiously, since lower dependency does not automatically translate into greater security if it relies on unsustainable domestic resources (Cherp & Jewell, 2011; Ang et al., 2015; Sovacool & Brown, 2010). For EU policy, the trend underscores that while REPowerEU has begun to moderate dependency, the underlying vulnerabilities of both regions persist, albeit in different forms.

4.1.2 Gas storage fulness

Gas storage levels are a key short-term indicator of energy security, as they reflect the ability of Member States to withstand supply disruptions and meet peak demand during the winter heating season. Adequate storage reduces vulnerability to external shocks by creating a buffer that ensures continuity of supply even when imports are constrained, thereby enhancing resilience and flexibility—two dimensions frequently highlighted in the literature as central to energy security (Cherp & Jewell, 2011; Ang et al., 2015; Yergin, 2011). In the EU context, the strategic importance of gas storage was underscored during the 2021–2022 energy crisis, when unusually low storage levels exacerbated market volatility and exposed the Union's dependence on Russian gas. In response, the EU adopted the Gas Storage Regulation (EU 2022/1032) as part of its emergency package under the REPowerEU plan. The regulation requires Member States to fill their storage facilities to at least 80 percent of capacity by 1 November 2022 and 90 percent in subsequent years, and extends solidarity mechanisms to those without storage infrastructure. This measure represents a cornerstone of the Union's strategic reserves and emergency response mechanisms, complementing efforts to diversify suppliers and reduce overall import dependency (European Commission, 2022). Tracking gas storage fullness on 1 November each year therefore provides a direct measure of compliance with EU policy targets and of the Union's progress in strengthening its energy security pillar.

The results in Table 3 show that gas storage levels in both CWE and CEE countries converged toward the EU-27 benchmark following the adoption of the Gas Storage Regulation (EU 2022/1032). In 2022, the first year of implementation, EU storage was filled to 94.9 percent by 1 November, already surpassing the mandatory 80 percent threshold. CWE countries recorded an average of 99.4 percent, with particularly high values in Portugal (109.3 percent of working capacity, due to capacity adjustments and LNG inflows) and Belgium (118.2 percent). CEE countries averaged 89.1 percent in 2022, with Latvia at just 57.7 percent reflecting limited infrastructure and high reliance on Russian supply, while other states such as Poland and Romania filled beyond 95 percent (Gas Infrastructure Europe [GIE], 2024).

By 2023, the 90 percent legal requirement had become fully operational, and compliance was near universal. The CWE average reached 99.9 percent, with Spain, Portugal, and the Netherlands all exceeding 99 percent. The CEE average increased to 97.7 percent, with Hungary, Poland, and Romania surpassing the EU average of 99.3 percent. Even Latvia, which had struggled in 2022, reached nearly 89 percent. This convergence illustrates the effectiveness of coordinated EU measures, including the joint gas purchasing platform and financial support for filling operations (European Commission, 2022).

Table 3: Gas storage fullness (%) on 1st November (2022-2024) in CWE and CEE countries

	% full				% full		
Country	**2022**	**2023**	**2024**	**Country**	**2022**	**2023**	**2024**
Belgium	118.16	102.46	98.19	Bulgaria	90.41	97.66	99.76
Denmark	99.27	96.44	75.09	Czechia	94.88	98.95	92.09
Germany	99.21	99.77	98.19	Estonia	/	/	/
Ireland	/	/	/	Greece	/	/	/
Spain	94.75	100.42	100.22	Croatia	97.03	96.95	91.24
France	100.12	99.84	95.42	Cyprus	/	/	/
Italy	95.45	98.93	98.53	Latvia	57.68	88.78	79.68
Luxembourg	/	/	/	Lithuania	/	/	/
Malta	/	/	/	Hungary	86.01	98.12	90.96
Netherlands	91.81	99.62	88.88	Poland	98.91	99.48	97.97
Austria	93.07	99.52	94.42	Romania	96.78	102.80	102.61
Portugal	109.25	107.15	102.92	Slovenia	/	/	/
Finland	/	/	/	Slovakia	91.29	98.86	94.76
Sweden	92.94	95.33	91.08				
CWE	99.40	99.95	94.29	CEE	89.12	97.70	93.63
EU-27	94.96	99.29	95.21	EU - 27	94.96	99.29	95.21

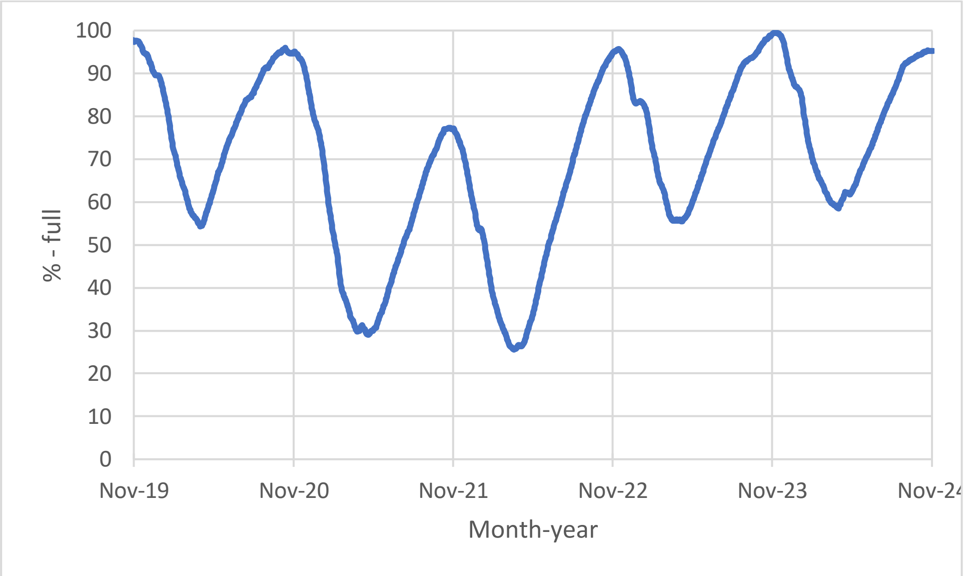
Source: Own work based on Gas Infrastructure Europe (2024)

The latest figures for November 2024 confirm continued compliance: CWE and CEE countries recorded averages of 94.3 and 93.6 percent respectively, closely aligned with the EU-27 benchmark of 95.2 percent. While some variation persists—such as lower levels in Latvia and Czechia—the overall pattern demonstrates that both regions have successfully institutionalized the annual filling requirement. These results support the view in the literature that strategic reserves enhance short-term resilience and flexibility in energy systems (Cherp & Jewell, 2011; Ang et al., 2015).

Taken together, the cross-country evidence confirms that the Gas Storage Regulation has delivered rapid and measurable gains for the Union's energy security. While countries without storage facilities, such as Ireland, Malta, Cyprus, Slovenia and others remain reliant on solidarity arrangements, the sharp rise in storage fullness across Member States underscores the role of coordinated EU-level intervention in mitigating supply risks after the 2021–2022 crisis.

Figure 3 shows the seasonal evolution of EU gas storage levels between November 2019 and November 2024. The cyclical pattern reflects the annual rhythm of injection during summer and withdrawal during winter.

Figure 3: Gas storage levels trend in the EU (2019-2024)



Source: Own work based on Gas Infrastructure Europe (2024)

The data highlight the precarious situation in 2021 and early 2022, when storage fell to unusually low levels of around 25–30 percent, exacerbating the Union's vulnerability as Russian pipeline flows declined. Following the adoption of the Gas Storage Regulation (EU 2022/1032) in July 2022, storage levels were filled to above 90 percent by November 2022 and again by November 2023 and 2024, demonstrating compliance with the new mandatory target. This sharp increase underscores the role of coordinated EU policy in reinforcing energy security, with strategic reserves serving as an effective emergency response mechanism to external supply shocks (European Commission, 2022). The trend confirms findings from the literature that resilience and flexibility are crucial components of energy security (Cherp & Jewell, 2014; Ang et al., 2015;), while also illustrating the capacity of EU institutions to translate policy into measurable outcomes within a short timeframe.

The evidence from both the cross-country and trend analyses demonstrates that the Gas Storage Regulation (EU 2022/1032) has significantly strengthened the Union's short-term energy security. In 2022, when the measure was first applied, some variation remained, particularly in CEE countries such as Latvia, but by 2023 and 2024 nearly all Member States with storage facilities had exceeded the 90 percent target. The EU-wide trend confirms that storage fullness before winter has stabilized well above historical averages, providing a reliable buffer against seasonal demand peaks and potential supply interruptions. While countries without storage remain reliant on solidarity arrangements, the overall outcome illustrates the effectiveness of coordinated EU-level intervention in reinforcing resilience. Nevertheless, the indicator also highlights the temporary nature of such measures: strategic reserves can mitigate short-term risks but must be complemented by diversification of supply and long-term demand-side measures to ensure lasting security (Cherp & Jewell, 2011; Ang et al., 2015).

4.1.3 Diversity of electricity generation

Electricity generation diversity is a critical element of energy security, as systems that rely heavily on a single fuel or technology are more vulnerable to supply shocks, price volatility, or technical disruptions. A diversified mix—including renewables, nuclear, and multiple fossil fuels—enhances resilience by reducing dependence on any one source. The literature emphasizes diversity as a central dimension of security, linking it to both system flexibility and long-term sustainability (Sovacool & Brown, 2010; Hughes, 2012). At the EU level, diversification has been a core policy priority, reinforced by the European Energy Security Strategy and embedded in the objectives of REPowerEU, which seeks to reduce dependence on Russian gas by accelerating renewable generation and strengthening interconnections (European Commission, 2022). Assessing generation diversity across Member States therefore provides insight into the effectiveness of diversification policies in enhancing security.

Table 4: Energy generation diversity (% from total generation) in CWE countries 2023

Country	Fossil fuels	Renewables	Nuclear	Other
Belgium	21.91	31.92	39.35	6.82
Denmark	10.67	82.32	0.00	7.02
Germany	39.32	46.78	1.41	12.49
Ireland	52.56	44.25	0.00	3.19
Spain	25.07	49.97	19.89	5.07
France	6.70	26.28	64.46	2.56
Italy	50.51	37.72	0.00	11.76
Luxembourg	3.36	91.38	0.00	5.26
Malta	85.70	13.18	0.00	1.12
Netherlands	45.05	44.59	3.28	7.07
Austria	10.96	83.90	0.00	5.14
Portugal	23.46	74.27	0.00	2.27
Finland	2.83	51.02	42.07	4.08
Sweden	0.18	68.57	29.18	2.07
CWE	27.02	53.30	14.26	5.42
EU-27	28.79	42.37	22.54	6.30

Source: Own work based on Eurostat (2025b)

As Table 4 shows, in 2023, the electricity generation mix across Central and Western European (CWE) countries displayed pronounced heterogeneity. France stands out with its strong reliance on nuclear power, where nearly two-thirds of generation originates from this source. By contrast, Austria, Denmark, and Portugal generate over 70% of their electricity from renewables, supported by hydro, wind, and solar resources. Germany and the Netherlands remain balanced systems with significant shares of both fossil fuels and renewables, reflecting their ongoing energy transitions.

At the other extreme, Ireland and Italy continue to rely heavily on fossil fuels, with over half of their electricity derived from these sources. The CWE regional average shows 53.3%

renewables, 27.0% fossil fuels, and 14.3% nuclear, which positions the region ahead of the EU-27 average in renewable deployment but somewhat below in nuclear share.

Table 5 illustrates that Central and Eastern European (CEE) countries reveal a more uneven picture. Estonia and Lithuania both generate more than three-quarters of their electricity from renewables, while Croatia, Romania, and Latvia also record renewable shares exceeding 50%. Nuclear energy remains central in Hungary, Slovakia, and Bulgaria, each producing over 35% of their electricity from this source. By contrast, Poland remains heavily dependent on fossil fuels (70%), underscoring the structural challenges of decarbonization in coal-intensive economies. The CEE regional average shows 41.4% renewables, 30.7% fossil fuels, and 18.5% nuclear, which places the region below the EU-27 average in renewable penetration but above in nuclear reliance. Overall, these cross-country patterns underscore how the EU's diversification strategy is materializing differently across regions.

Table 5: Energy generation diversity (% from total generation) in CEE countries 2023

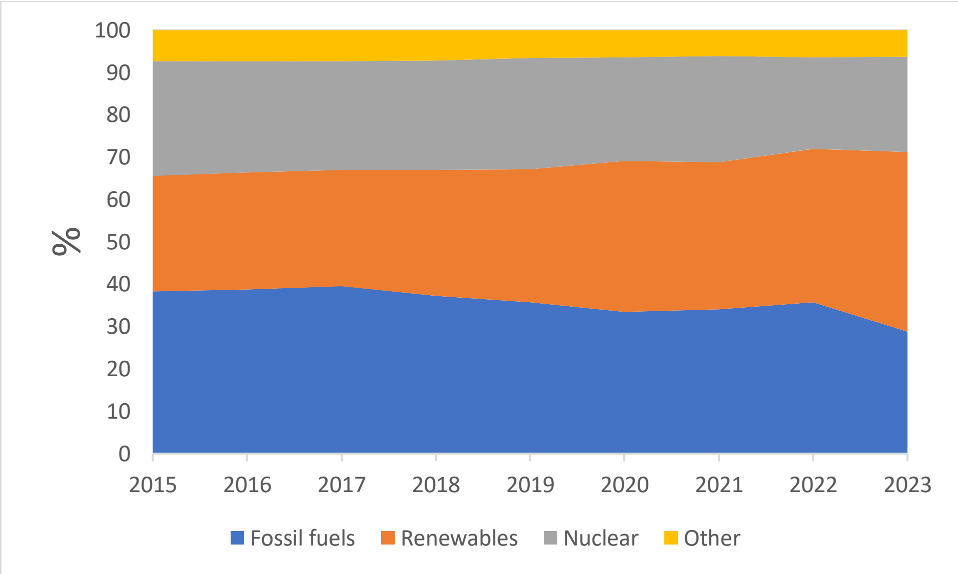
Country	Fossil fuels	Renewables	Nuclear	Other
Bulgaria	33.21	24.70	40.15	1.94
Czechia	43.64	12.28	39.49	4.58
Estonia	0.69	47.85	0.00	51.46
Greece	47.69	48.11	0.00	4.20
Croatia	29.69	68.14	0.00	2.17
Cyprus	50.42	19.50	0.00	30.08
Latvia	22.26	74.86	0.00	2.88
Lithuania	10.95	77.44	0.00	11.61
Hungary	27.55	25.09	44.78	2.58
Poland	69.95	27.12	0.00	2.93
Romania	29.53	49.68	19.30	1.49
Slovenia	20.55	40.99	35.29	3.17
Slovakia	12.92	22.07	61.31	3.70
CEE	30.70	41.37	18.49	9.45
EU-27	28.79	42.37	22.54	6.30

Source: Own work based on Eurostat (2025b)

This confirms the literature's argument that diversity in the energy mix enhances resilience but also depends strongly on national resource endowments and institutional pathways (Ang et al., 2015; Sovacool & Brown, 2010). The variation also reflects the uneven implementation of EU-level policies such as the Renewable Energy Directive, the Green Deal, and REPowerEU (European Commission, 2019, 2022), with frontrunners moving ahead while laggards remain constrained by historical infrastructure and socio-economic factors.

Figure 4 illustrates the evolution of the EU-27 electricity generation mix between 2015 and 2023. During this period, the share of fossil fuels in power production declined by nearly 10 percentage points, from 38.3% in 2015 to 28.8% in 2023, reflecting both the gradual coal phase-out and the reduction in natural gas generation after the 2021–2022 energy crisis.

Figure 4: Electricity production diversity (% from total) from 2015-2023 in the EU



Source: Own work based on Eurostat (2025b)

By contrast, renewables expanded steadily from 27.3% to 42.4%, making them the single largest source of electricity in 2023. Nuclear power fell from 27.1% to 22.5%, mainly due to phase-outs in Germany and operational challenges in France, while the share of other sources (non-renewable waste, imports, and minor categories) remained relatively stable at around 6%. The trend underscores a structural shift in the EU electricity system toward greater diversification and lower carbon intensity. This development supports the literature that links energy mix diversity with enhanced resilience (Cherp & Jewell, 2011; Ang et al., 2015; Sovacool & Brown, 2010) and reflects the implementation of EU policy initiatives such as the Renewable Energy Directive, the European Green Deal, and REPowerEU (European Commission, 2019; 2022). The growing role of renewables indicates progress toward policy targets, yet the declining share of nuclear and persistent fossil fuel dependence highlights the continued need for investment in flexible capacity, storage, and cross-border interconnections to secure long-term energy security.

Taken together, the cross-country and trend analyses show that the EU-27 electricity mix has become more diversified since 2015, with renewables overtaking fossil fuels as the largest source by 2023. However, substantial regional disparities remain: while several CWE countries already rely on renewables for the bulk of their generation, many CEE states continue to depend heavily on fossil fuels or nuclear. This uneven progress highlights both the achievements of EU-level policies such as the Renewable Energy Directive and REPowerEU, and the persistent challenges of aligning national pathways with common diversification goals.

The analysis of energy security indicators has shown that while the EU has made progress in reducing import dependency, strengthening strategic gas reserves, and diversifying electricity generation, these improvements remain uneven across Member States. Structural differences between CWE and CEE countries persist, reflecting distinct resource endowments, infrastructural legacies, and policy approaches. At the EU-27 level, the overall trend points toward greater resilience and reduced vulnerability to external shocks (Cherp & Jewell, 2011, 2014; Ang et al., 2015), but the continued reliance on fossil fuels and the varied pace of diversification underline the limits of security measures in isolation (Sovacool & Brown, 2010). Energy security, however, cannot be considered separately from the Union's broader sustainability agenda. Many of the same policies designed to enhance security—such as the European Energy Security Strategy and the REPowerEU Plan (European Commission, 2022)—also target emissions reductions, renewable deployment, and the green transition. To capture this dimension, the next section (4.2) examines the EU's progress on energy sustainability, focusing on indicators that reflect the effectiveness of decarbonization policies, the deployment of renewables, and the alignment with long-term climate goals.

4.2 Energy sustainability in EU member states

Energy sustainability represents one of the central pillars of the European Union's long-term energy policy framework, as it addresses the dual challenge of reducing greenhouse gas (GHG) emissions while fostering a transition to renewable and efficient energy systems. The empirical analysis in this section aims to evaluate how EU member states perform in terms of sustainability and how their progress reflects the policy measures discussed in Chapter 3. The analysis is structured around three key policy instruments of the EU's sustainability agenda, each operationalized through a measurable indicator:

1. Renewable Energy Directive (RED) – assessed through the share of renewable energy in gross final energy consumption. This indicator directly reflects compliance with the binding renewable targets established in Directive 2009/28/EC and recast in Directive (EU) 2018/2001, most recently revised in Directive (EU) 2023/2413. Tracking renewable penetration offers insights into how member states are aligning with the EU's decarbonization pathway (European Union, 2009; 2018; 2023).

2. EU Emissions Trading System (EU ETS) – evaluated by examining greenhouse gas emissions from the energy sector. As the EU ETS is the cornerstone of EU climate policy (European Union, 2003; European Union, 2018; Biancalani et al., 2024), declining emissions in ETS-covered sectors demonstrate the effectiveness of market-based mechanisms in internalizing the costs of carbon.

3. European Green Deal and Fit for 55 package – captured through the energy intensity of the economy (energy consumption per unit of GDP). This indicator measures the degree to which economic growth has been decoupled from energy consumption, a central ambition of the European Green Deal (European Commission, 2019; European Commission, 2021a).

Lower energy intensity suggests that structural changes and efficiency improvements are taking effect, in line with the EU's climate-neutrality objective.

By organizing the analysis around these three indicators, this chapter ensures methodological consistency and a direct link between the EU's sustainability policies and their measurable outcomes. For each indicator, the analysis will combine trend analysis for the EU-27 as a whole and cross-country comparisons between Central-Western Europe (CWE) and Central-Eastern Europe (CEE). In doing so, the chapter provides a systematic assessment of how EU member states are progressing towards the targets of a sustainable, low-carbon energy system.

4.2.1 Share of renewable energy in total consumption

The share of renewable energy in gross final energy consumption represents the most direct indicator of compliance with the Renewable Energy Directive (RED), first adopted in 2009 and subsequently revised in 2018 and 2023. The Directive established binding national targets for renewable penetration, requiring the EU to achieve at least 20% of final energy consumption from renewable sources by 2020, and later raising the ambition to 32% by 2030 (Directive 2009/28/EC; Directive (EU) 2018/2001). With the most recent revision, the EU has further committed to a 42.5% share by 2030, marking a central step in the transition towards climate neutrality (Directive (EU) 2023/2413). Monitoring the evolution of this indicator is essential, as it not only demonstrates progress towards legal obligations but also reflects broader structural changes in the EU's energy system. A higher renewable share contributes to reducing greenhouse gas emissions, diversifying energy supply, and strengthening energy sustainability, thereby reinforcing the synergies between the three pillars of EU energy policy (European Union, 2023; Diesendorf, 2014).

To that extent, table 6 displays the share of renewable energy in gross final energy consumption across Central-Western European (CWE) and Central-Eastern European (CEE) countries in 2023. In CWE countries, the renewable share in 2023 averaged 28.8%, clearly above the EU-27 mean of 24.6%. This reflects the strong progress of frontrunners such as Sweden (66.4%), Finland (50.8%) and Denmark (44.4%), which demonstrate the feasibility of achieving high levels of renewable penetration in line with RED objectives. These countries benefit from favorable natural endowments (hydropower in Sweden and Finland, wind resources in Denmark) as well as long-standing policy commitments to decarbonization. At the same time, some of the largest CWE economies, including Germany (21.6%) and France (22.3%), remain close to or below the EU average, illustrating the challenge of scaling renewable deployment in more complex energy systems. Belgium (14.7%) and Luxembourg (14.4%) perform the weakest in the group, underscoring that not all Western European states are on a converging trajectory towards the 2030 target (Directive (EU) 2023/2413).

Table 6: Share of renewable sources in total energy consumption in CWE and CEE countries 2023

Country	%	Country	%
Belgium	14.74	Bulgaria	22.55
Denmark	44.40	Czechia	18.59
Germany	21.56	Estonia	40.95
Ireland	15.25	Greece	25.27
Spain	24.85	Croatia	28.05
France	22.28	Cyprus	20.21
Italy	19.59	Latvia	43.22
Luxembourg	14.36	Lithuania	31.93
Malta	15.08	Hungary	17.12
Netherlands	17.42	Poland	16.56
Austria	40.84	Romania	25.78
Portugal	35.16	Slovenia	25.07
Finland	50.75	Slovakia	16.99
Sweden	66.39		
CWE	28.76	CEE	25.56
EU-27	24.56	EU-27	24.56

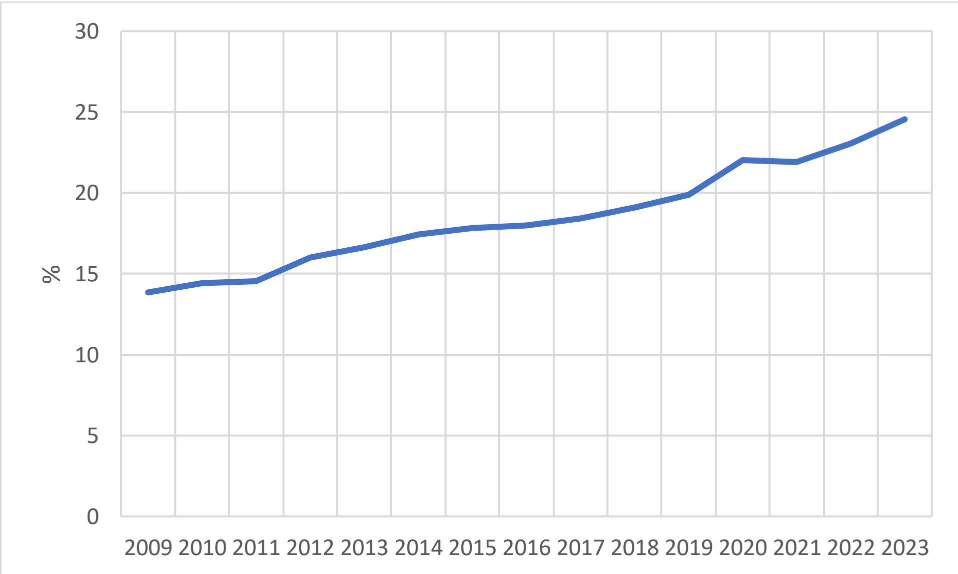
Source: Own work based on Eurostat (2025f)

The picture in CEE countries is more mixed, with an average of 25.6% in 2023—slightly above the EU-27 total but below the CWE mean. High shares in Latvia (43.2%), Estonia (41.0%) and Lithuania (31.9%) highlight the potential of Baltic states to align with RED milestones, particularly through biomass and wind integration (Eurostat, 2025). By contrast, Poland (16.6%), Hungary (17.1%) and Slovakia (17.0%) remain significantly behind, reflecting their slower transition away from coal-dominated systems and more limited renewable infrastructure. Slovenia (25.1%) and Croatia (28.1%) stand close to the EU average, illustrating incremental progress but not yet a transformative shift. These differences underline the role of EU funding mechanisms, such as the Recovery and Resilience Facility and cohesion funds, in supporting CEE states' renewable expansion (European Commission, 2024).

These disparities illustrate both the achievements and challenges of the Renewable Energy Directive (Directive 2009/28/EC; Directive (EU) 2018/2001; Directive (EU) 2023/2413). While many member states have successfully integrated renewables beyond the 2020 target, others continue to lag behind, raising questions about the feasibility of meeting the revised EU-wide goal of 42.5% by 2030. The results also demonstrate how RED has driven a structural shift across both Western and Eastern Europe, though the pace of adoption remains uneven and shaped by domestic energy mixes and capacities (European Commission, 2024). It should be noted that the EU-27 average of 24.6% is not a simple arithmetic mean of country values but a weighted average, calculated on the basis of each member state's gross final energy consumption. As a result, larger energy consumers with below-average renewable shares, such as Germany, France, and Poland, exert a downward pull on the EU total, which explains why the EU-27 figure does not fully align with the regional averages presented above (Eurostat, 2025f). These results are consistent with the findings of Brodny and Tutak (2025), who also identified notable disparities in sustainability performance across EU member states, particularly between Central-Eastern and Western Europe.

Figure 5 illustrates the evolution of the share of renewable energy in gross final energy consumption in the EU-27 between 2009 and 2023. The share increased from 13.9% in 2009 to 24.6% in 2023, demonstrating a steady upward trajectory over the period (Eurostat, 2025). The EU surpassed its initial RED target of 20% in 2020, although progress briefly stagnated in 2021. The acceleration in recent years reflects the combined effects of the RED recast (Directive (EU) 2018/2001), the launch of the European Green Deal (European Commission, 2019), and subsequent policy support mechanisms, including the Recovery and Resilience Facility.

Figure 5: Share of renewables (%) in total energy consumption in the EU from 2009-2023



Source: Own work based on Eurostat (2025f)

With a new binding target of 42.5% renewables by 2030 (Directive (EU) 2023/2413), the current trajectory highlights significant achievements while underscoring the need for continued structural transformation of the EU energy system.

In sum, the evolution of the share of renewable energy in gross final consumption demonstrates the significant progress achieved under the Renewable Energy Directive since its adoption in 2009. The EU-27 exceeded its 2020 target, reaching 24.6% by 2023, thereby confirming the Directive's effectiveness as a driver of renewable deployment (Directive 2009/28/EC; Directive (EU) 2018/2001). Nevertheless, the cross-country comparison reveals substantial regional disparities, with Northern and Nordic states substantially outperforming the EU average, while several large energy consumers in both CWE and CEE continue to lag behind. These uneven outcomes underscore the persistent challenge of aligning national trajectories with the EU-wide 2030 target of 42.5% renewables (Directive

(EU) 2023/2413). Overall, the indicator confirms that the RED has been instrumental in fostering renewable energy uptake, though its success remains conditional on stronger convergence across member states (European Commission, 2024; Diesendorf, 2014).

4.2.2 Greenhouse gas emissions

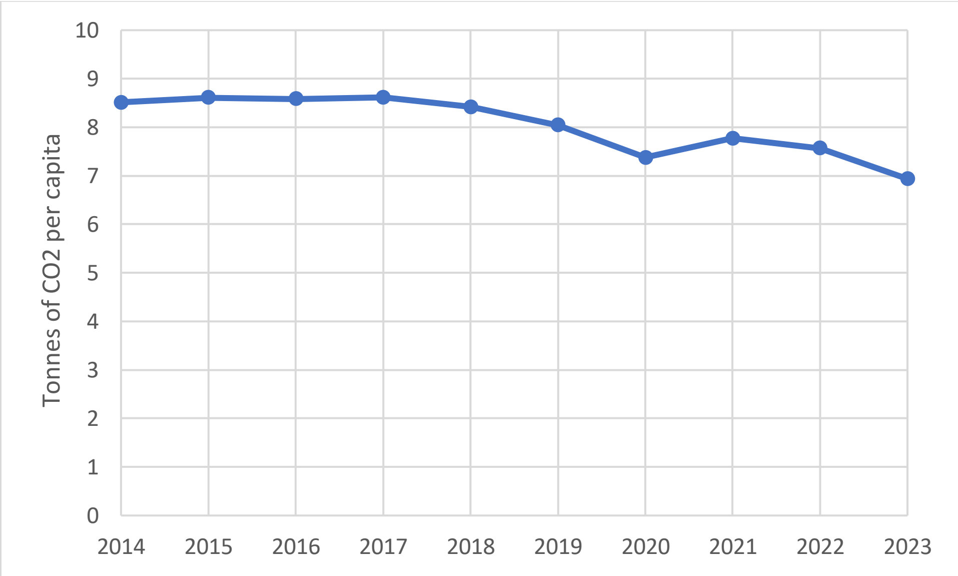
Greenhouse gas (GHG) emissions from the energy sector serve as a central indicator of the EU's progress toward sustainability and decarbonization. The EU Emissions Trading System (EU ETS), established in 2005 and consolidated through Directive 2003/87/EC and its subsequent amendments (Directive (EU) 2018/410; Directive (EU) 2023/959), remains the cornerstone of EU climate policy. By placing a price on carbon, the ETS incentivizes emission reductions in the power and industrial sectors, which together account for nearly half of the EU's total GHG output (European Commission, 2021a).

Empirical analysis of emissions in the energy sector therefore provides a direct measure of how effectively the ETS has driven decarbonization over time. Since the launch of Phase III in 2013, and especially with the tightening of the cap and introduction of the Market Stability Reserve, verified emissions have shown a steady downward trend (Biancalani et al., 2024). Tracking this development is crucial for assessing whether the EU is on course to meet the Green Deal's overarching goal of climate neutrality by 2050 (European Commission, 2019).

Figure 6 presents the evolution of EU-27 per capita greenhouse gas (GHG) emissions between 2014 and 2023. During this period, emissions declined from 8.5 to 6.9 tonnes of CO_2-equivalent per person, representing an overall reduction of almost 20%. The trajectory was relatively stable between 2014 and 2018, when emissions fluctuated around 8.5 tCO_2-eq per capita. A marked decline began in 2019, followed by a sharp drop in 2020 (7.4 tCO_2-eq) that reflected the economic slowdown and reduced energy demand caused by the COVID-19 pandemic. While emissions temporarily rebounded in 2021, they resumed a downward trajectory in 2022 and reached their lowest point in 2023, consistent with the acceleration of structural decarbonization trends (European Commission, 2021a; Biancalani et al., 2024).

While emissions temporarily rebounded in 2021, they resumed a downward trajectory in 2022 and reached their lowest point in 2023, consistent with the acceleration of structural decarbonization trends (European Commission, 2021a; Biancalani et al., 2024). These results highlight the central role of the EU Emissions Trading System (EU ETS) in driving emissions reductions, particularly since the start of Phase III in 2013 and the subsequent tightening of the emissions cap and strengthening of the Market Stability Reserve. In combination with the broader framework of the European Green Deal and the emergency measures introduced under REPowerEU in response to the Russian invasion of Ukraine, the ETS has contributed to a sustained decline in per capita emissions across the Union. The overall trend therefore demonstrates progress toward the EU's legally binding objective of reducing net GHG emissions by at least 55% by 2030 compared to 1990 levels (Directive (EU) 2023/959; European Commission, 2019).

Figure 6: EU-27 GHG emissions per capita from 2014-2023



Source: Own work based on Eurostat (2025d)

Table 7 presents greenhouse gas (GHG) emissions per capita in Central-Western European (CWE) and Central-Eastern European (CEE) countries in 2023. The values are expressed in tonnes of CO_2-equivalent per person and exclude LULUCF, ensuring consistency with the scope of EU climate policy. The EU-27 average, calculated as a population-weighted figure, stood at 6.9 tCO_2-eq per capita and serves as the benchmark for comparison. The results highlight pronounced regional disparities. In CWE, several large economies such as Germany (8.1 t) and the Netherlands (8.1 t) remain above the EU average, while Luxembourg (11.7 t) and Ireland (10.3 t) record the highest levels in the group. By contrast, countries with relatively decarbonized energy systems, such as Sweden (4.2 t), France (5.5 t) and Portugal (5.0 t), perform significantly below the EU average. This diversity within CWE reflects the coexistence of fossil-fuel-dependent systems and low-carbon mixes dominated by nuclear and renewables. In CEE, the variation is equally striking. Coal-dependent economies such as Poland (9.5 t) and Czechia (9.4 t) exhibit emissions well above the EU benchmark, underlining the continuing challenge of phasing out carbon-intensive energy production. Conversely, countries such as Latvia (5.3 t) and Romania (5.4 t) fall below the EU average, benefiting from higher shares of hydropower, biomass, and other renewable sources. Other states, including Hungary (5.7 t) and Slovakia (6.7 t), cluster closer to the EU-27 mean.

Overall, the cross-country comparison confirms that while the EU-27 is reducing its emissions in aggregate, the distribution of progress remains uneven. High-performing countries demonstrate the feasibility of low per capita emissions under the EU ETS framework, whereas coal-intensive economies continue to lag, highlighting the importance of targeted support mechanisms under the European Green Deal and related policies (European Commission, 2019; Directive (EU) 2023/959; Biancalani et al., 2024). These cross-country differences also reflect the link between energy system quality and socio-economic development emphasized by Yumashev et al. (2020).

Table 7: GHG emissions per capita in CWE and CEE countries 2023

CWE	GHG emission	CEE	GHG emission
Belgium	8.30	Bulgaria	7.00
Denmark	6.60	Czechia	9.40
Germany	8.10	Estonia	7.90
Ireland	10.30	Greece	6.90
Spain	5.60	Croatia	6.60
France	5.50	Cyprus	8.90
Italy	6.50	Latvia	5.30
Luxembourg	11.70	Lithuania	6.20
Malta	4.10	Hungary	5.70
Netherlands	8.00	Poland	9.50
Austria	7.50	Romania	5.40
Portugal	5.00	Slovenia	7.00
Finland	7.40	Slovakia	6.70
Sweden	4.20		
EU-27	6.94	EU-27	6.94

Source: Own work based on Eurostat (2025d)

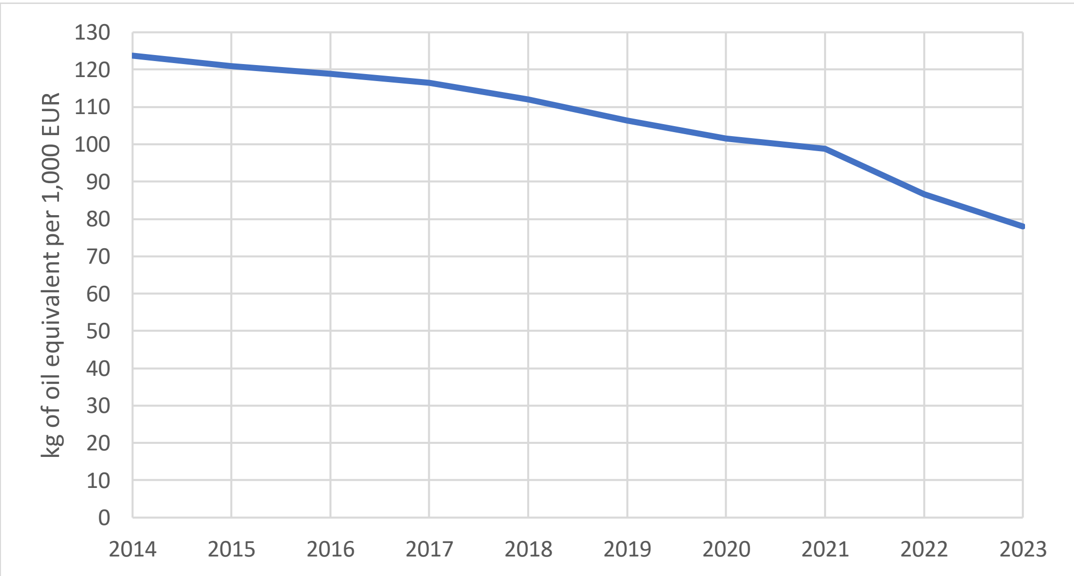
Overall, the cross-country comparison confirms that while the EU-27 is reducing its emissions in aggregate, the distribution of progress remains uneven. High-performing countries demonstrate the feasibility of low per capita emissions under the EU ETS framework, whereas coal-intensive economies continue to lag, highlighting the importance of targeted support mechanisms under the European Green Deal and related policies (European Commission, 2019; Directive (EU) 2023/959; Biancalani et al., 2024). These cross-country differences also reflect the link between energy system quality and socio-economic development emphasized by Yumashev et al. (2020).

In conclusion, the analysis of GHG emissions per capita demonstrates that the EU has achieved substantial reductions over the past decade, with EU-27 emissions falling from 8.5 tCO_2-eq per capita in 2014 to 6.9 t in 2023. This trajectory reflects the impact of the EU ETS, reinforced by successive reforms, higher carbon prices, and complementary measures introduced under the European Green Deal and REPowerEU. Nevertheless, the cross-country comparison highlights persistent disparities. While several CWE and CEE states already emit below the EU average, others—particularly coal-dependent economies—remain well above it. This unevenness underscores the dual challenge facing EU climate policy: sustaining the overall downward trend while ensuring convergence among member states. The ETS thus continues to act as both a driver of collective decarbonization and a source of distributional pressures that require balancing through complementary instruments such as the Just Transition Mechanism (European Commission, 2019; Directive (EU) 2023/959; Biancalani et al., 2024).

4.2.3 Energy intensity of the economy

The energy intensity of the economy, measured as gross inland energy consumption per unit of GDP, serves as a key indicator of the European Union's progress in decoupling economic growth from energy use. A lower energy intensity implies that the economy generates more output with less energy input, reflecting improvements in efficiency, structural economic change, and a shift toward less carbon-intensive energy sources. This indicator is directly linked to the objectives of the European Green Deal and the Fit for 55 - package, which aim to accelerate energy efficiency improvements and promote a sustainable growth model consistent with climate neutrality by 2050 (European Commission, 2019; European Commission, 2021a). By reducing energy intensity, member states not only lower emissions but also improve affordability and security, highlighting the synergies among the three pillars of EU energy policy.

Figure 7: Energy intensity of GDP in PPS in EU-27 from 2014-2023



Source: Own work based on Eurostat (2024b)

To assess how the EU economy has progressed in decoupling growth from energy consumption, Figure 7 illustrates the evolution of EU-27 energy intensity between 2014 and 2023. It's shows results based on the EU-27's energy intensity of GDP, measured in kilograms of oil equivalent per 1,000 EUR in PPS. The values declined consistently from 123.7 in 2014 to 78.0 in 2023, representing a reduction of over one third within a decade. This downward trajectory indicates a significant improvement in the efficiency of energy use relative to economic output. The sharpest decreases occurred after 2020, coinciding with the implementation of the European Green Deal and the subsequent Fit for 55 - package, which reinforced the role of energy efficiency as a cornerstone of the EU's decarbonization pathway (European Commission, 2019; European Commission, 2021a). The results confirm that structural economic change, technological progress, and targeted policy interventions have been effective in reducing energy intensity at the aggregate EU level. While the EU-27 - time trend demonstrates a steady decline in energy intensity, the cross-country comparison for 2023 reveals significant disparities among member states, with some economies already well below the Union average and others remaining far above it.

Table 11 presents the energy intensity of the economy in Central-Western European (CWE) and Central-Eastern European (CEE) countries in 2023, measured in kilograms of oil equivalent per 1,000 EUR of GDP in purchasing power standards (PPS).

Table 8: Energy intensity of GDP in PPS in CWE and CEE countries from 2023

CWE	**kg of oil eq.**	**CEE**	**kg of oil eq.**
Belgium	105.51	Bulgaria	110.27
Denmark	57.79	Czechia	101.21
Germany	69.58	Estonia	105.81
Ireland	34.19	Greece	84.13
Spain	76.19	Croatia	78.49
France	85.75	Cyprus	81.55
Italy	65.53	Latvia	91.23
Luxembourg	61.55	Lithuania	76.62
Malta	139.49	Hungary	88.07
Netherlands	84.17	Poland	86.97
Austria	75.68	Romania	53.96
Portugal	70.13	Slovenia	82.27
Finland	150.12	Slovakia	109.63
Sweden	102.88		
EU-27	78	EU-27	78

Source: Own work based on Eurostat (2024b)

A lower value indicates that less energy is required to generate economic output, reflecting higher levels of efficiency and decoupling between growth and energy use (European Commission, 2019; European Environment Agency, 2021). The EU-27 average stood at 78, but considerable variation exists across member states, shaped by their economic structures, energy mixes, and industrial legacies. Within CWE, values range from 34 in Ireland to 150 in Finland. Ireland stands out as an outlier on the low side. Its exceptionally low energy intensity is less a result of superior energy efficiency policies than of its specific economic structure, which is dominated by high-value-added sectors such as pharmaceuticals, ICT, and financial services, where output is large relative to energy consumption (FitzGerald, 2020). Luxembourg (61.6) follows a similar pattern, as its GDP is heavily influenced by finance and services. By contrast, Finland (150.1) records the highest energy intensity in the Union, driven by the importance of energy-intensive industries such as pulp and paper, metals, and chemicals (IEA, 2022). Other CWE countries, including France (65.5) and Italy (65.5), report below-average values due to diversified economies with substantial service sectors and the contribution of nuclear power (in France) to stable and efficient energy use.

Germany (69.6) and Austria (75.7) are close to the EU average, reflecting the persistence of large industrial sectors despite progress in efficiency improvements. CEE countries display a similarly wide range. Romania (53.9) achieves one of the lowest intensities in the Union, supported by significant hydropower resources, moderate energy demand, and structural economic changes since EU accession (World Bank, 2023). Lithuania (76.6) and Croatia (78.5) also perform close to or below the EU average. By contrast, several CEE countries remain highly energy intensive: Slovakia (109.6), Bulgaria (110.3), and Estonia (105.8). In Slovakia and Bulgaria, the persistence of coal and heavy industry contributes to higher ratios of energy use relative to GDP, while Estonia's reliance on oil shale, one of the most carbon-intensive fuels, explains its high value (Siddi, 2020). Poland (97.0) and Czechia (101.2) also remain above the EU average, underlining the ongoing challenge of decarbonizing coal-dependent economies.

Overall, the cross-country distribution of energy intensity demonstrates that the geography of efficiency does not neatly follow the CWE/CEE divide. Some CEE states, such as Romania and Lithuania, already outperform larger CWE economies, while certain CWE members (Belgium, Finland, Netherlands) remain relatively inefficient. The indicator therefore highlights the importance of both national energy mixes and economic structures in shaping progress toward EU-wide efficiency targets. As underscored in the European Green Deal and the Fit for 55 - package, reducing energy intensity is a cornerstone of achieving climate neutrality by 2050, yet the disparities evident in 2023 confirm the need for targeted support and convergence mechanisms to ensure that all member states can follow a sustainable trajectory (European Commission, 2019; European Commission, 2021a). In conclusion, the steady decline of EU-27 energy intensity confirms that the European Green Deal and Fit for 55 - package have reinforced the trend of decoupling energy use from economic growth. Nevertheless, the cross-country comparison demonstrates that progress is uneven, with some member states already achieving low-intensity economies, while others continue to rely on energy-intensive structures. These disparities underscore the importance of EU-level instruments, such as cohesion funding and the Recovery and Resilience Facility, in supporting lagging regions and ensuring convergence in energy efficiency improvements.

The empirical analysis of energy sustainability in the EU highlights both the progress achieved and the challenges that remain in aligning with the objectives of the Renewable Energy Directive (RED), the EU Emissions Trading System (ETS), and the European Green Deal. Across all three indicators—renewable energy consumption, greenhouse gas (GHG) emissions, and energy intensity—the EU-27 demonstrates clear progress toward a more sustainable energy system, though significant disparities persist among member states. The analysis of the share of renewables in gross final energy consumption confirms the effectiveness of the RED as a driver of renewable deployment. The EU-27 not only surpassed its 2020 target of 20% but reached 24.6% in 2023, moving closer to the new binding target of 42.5% by 2030 (Directive 2009/28/EC; Directive (EU) 2018/2001; Directive (EU) 2023/2413). However, patterns are uneven in the implementation of RED across the Union and there are structural differences in energy mixes (Diesendorf, 2014; European

Commission, 2019). The second indicator, GHG emissions per capita, reveals that EU-27 emissions declined from 8.5 tCO_2-eq in 2014 to 6.9 t in 2023, reflecting a reduction of nearly 20%. This trend has been shaped both by structural reforms under the ETS, which tightened caps and raised the carbon price (Directive 2003/87/EC; Directive (EU) 2018/410; Directive (EU) 2023/959), and by broader policies such as the European Green Deal and REPowerEU (European Commission, 2019, 2022; Biancalani et al., 2024). While the aggregate trajectory is encouraging, the cross-country comparison shows persistent differences. Finally, the analysis of energy intensity demonstrates that the EU has made substantial progress in decoupling energy consumption from economic growth. EU-27 energy intensity fell from 123.7 kgoe/1,000 EUR (PPS) in 2014 to 78.0 in 2023, a reduction of more than one third. Yet, again, the distribution across countries is uneven just as with the previous two indicators. In summary, the three indicators confirm that EU-wide sustainability policies have been effective in shifting the Union's energy trajectory toward a more sustainable model. However, national disparities persist, with a clear divide between frontrunners and laggards. These differences highlight the need for complementary EU funding and support mechanisms, such as cohesion funds and the Recovery and Resilience Facility, to ensure convergence (European Commission, 2021a, 2024). As the EU advances its decarbonization agenda, sustainability cannot be considered in isolation; the parallel challenge of safeguarding energy affordability for households and businesses forms the focus of the next section.

4.3 Energy affordability in EU member states

Energy affordability forms the third pillar of the EU's energy policy framework, addressing whether households can meet basic energy needs without disproportionate financial burdens. The empirical analysis in this section evaluates affordability outcomes in EU member states and links them directly to the policy measures presented in Chapter 3.

The analysis is structured around three indicators, ordered to mirror the affordability-related policy instruments:

1. Energy Efficiency Directive (EED) – evaluated through average energy consumption per capita (MWh). Lower consumption indicates progress toward efficiency goals and reduced demand pressures.

2. Measures to protect vulnerable consumers – captured through the share of income spent on energy (%). This indicator reflects the financial stress borne by households and the effectiveness of targeted protection schemes.

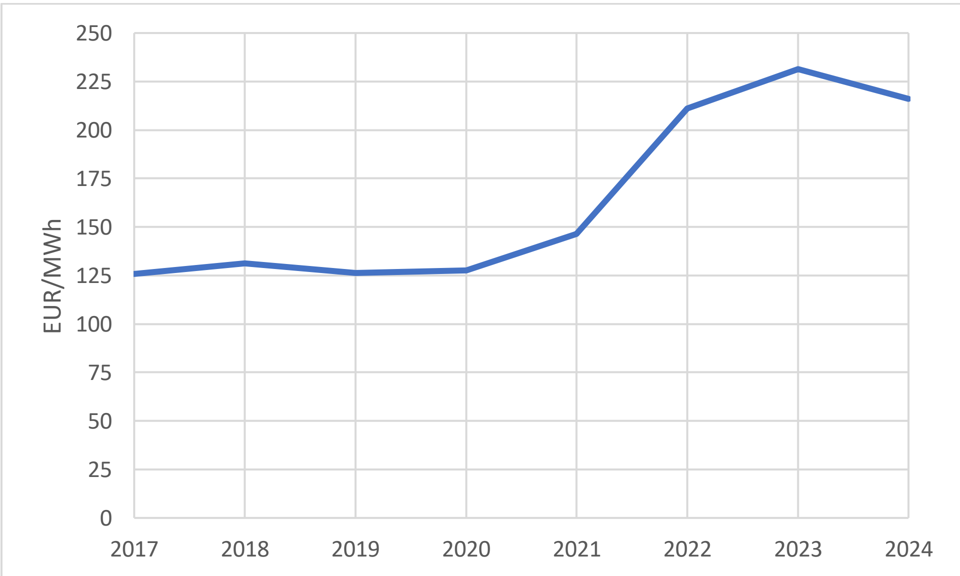
3. Initiatives to stabilize and reduce energy prices – assessed through average household energy prices (EUR/MWh), indicating the impact of market interventions and emergency measures on end-user prices.

This thesis approaches the concept of energy affordability primarily from the household perspective, focusing on social and energy poverty dimensions. The analysis therefore examines how energy costs affect households' ability to secure adequate energy services without compromising other essential expenditures. While energy affordability can also be examined from an industrial or macroeconomic perspective—particularly in relation to business competitiveness and production costs (see e.g., Dubois & Meier, 2016)—this dimension exceeds the analytical scope of the present research and is only briefly acknowledged here for contextual completeness. To ensure methodological consistency, the analysis combines two complementary perspectives. First, a time-trend analysis (2014–2023) of EU-27 averages traces the evolution of affordability, including the 2021–2022 price shock. Second, a cross-country comparison (2019–2023) groups Member States by GDP per capita to highlight structural differences between higher- and lower-income economies (see, e.g. Thomson, Snell, & Bouzarovski, 2017). Together, these analyses provide a systematic assessment of how EU policies have shaped affordability across the Union.

4.3.1 General trends in energy prices in the EU

The time-trend analysis of energy affordability in the EU-27 is presented through two indicators: average household electricity prices and final household energy consumption per capita. Together, they reflect the dual impact of price developments and demand-side adjustments on affordability. Electricity prices are reported in EUR/MWh for the standard Eurostat household consumption band of 2,500–4,999 kWh annually, excluding taxes and levies, while household final energy consumption is expressed in MWh per capita, converted from kilograms of oil equivalent (kgoe).

Figure 8: Average household electricity prices in EU-27 (2017-2024)

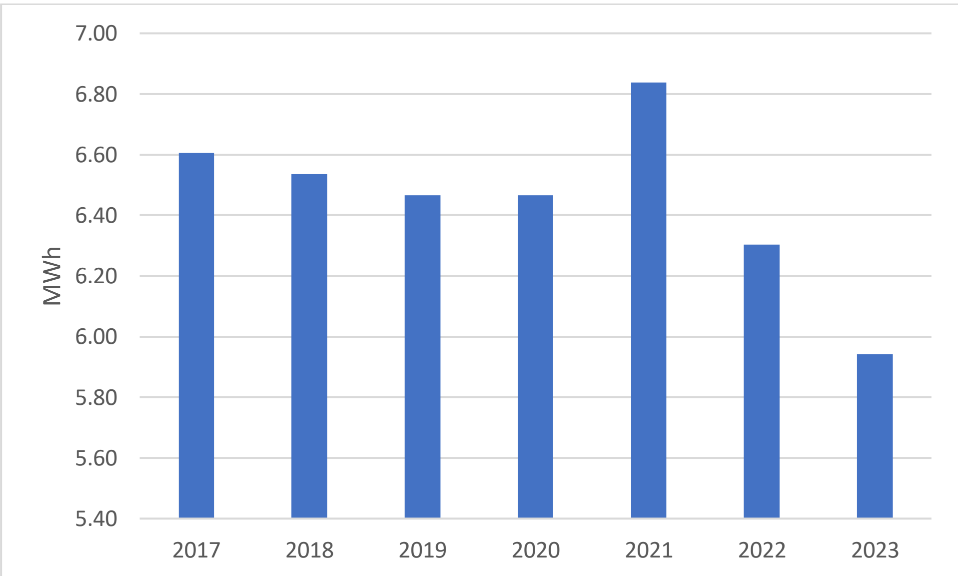


Source: Own work based on Eurostat (2025a)

As Figure 8 shows, between 2017 and 2020, average household electricity prices in the EU-27 remained relatively stable, fluctuating between 125 and 131 EUR/MWh. This period of stability corresponds to a time of steady market conditions and relatively low volatility in global energy prices (European Commission, 2021b). In 2021, however, prices began to rise sharply, reaching 146 EUR/MWh, before accelerating further to 231 EUR/MWh in 2023 (Eurostat, 2025). This dramatic increase of nearly 60% over two years reflects the combined impact of reduced Russian gas supplies, surging global energy prices, and heightened market uncertainty following the outbreak of the war in Ukraine (Siddi, 2023; Tagliapietra et al., 2023). Preliminary data for 2024 indicate a decline to 216 EUR/MWh, suggesting that EU interventions — including the Energy Prices Toolbox, joint gas purchasing through the EU Energy Platform, and measures under REPowerEU — helped to stabilize markets and ease affordability pressures, even though prices remained well above pre-crisis levels (European Commission, 2021b; Bruegel, 2023). This trajectory illustrates both the vulnerability of EU households to external shocks and the partial effectiveness of EU stabilization measures.

Electricity prices are important when trying to determine the impact of market interventions and emergency measures, however progress toward efficiency goals and reduced demand pressures largely reflects on total energy consumption (Boardman, 2010). Figure 9 gives a clear look into household final energy consumption.

Figure 9: Final energy consumption in households in EU-27 (2017-2023)



Source: Own work based on Eurostat (2025c)

While prices surged, household energy consumption in the EU-27 displayed an opposite trend. Between 2017 and 2020, consumption declined modestly from 6.61 to 6.47 MWh per capita, consistent with improvements in household efficiency and structural demand reductions encouraged by the Energy Efficiency Directive (EED) (European Union, 2018; Girod, 2017). In 2021, consumption rose to 6.84 MWh per capita, a temporary increase likely driven by colder-than-average winters and the rebound in household energy use after the COVID-19 lockdowns (Eurostat, 2025). However, in 2022 and 2023, consumption fell sharply to 5.94 MWh per capita, the lowest level in the observed period. This decrease reflected both price-induced demand reductions — as households curtailed usage in response to the affordability crisis — and targeted EU and national measures promoting conservation and efficiency (European Commission, 2022).

Taken together, the two indicators show how the affordability challenge evolved in the EU-27. The surge in prices between 2021 and 2023 directly undermined affordability, increasing the financial stress on households, while the simultaneous drop in consumption partially mitigated the burden. These outcomes underscore the interaction between supply-side stabilization measures and demand-side efficiency policies. They also highlight the continued importance of consumer protection instruments to address the distributional impacts, which are further examined in the cross-country analysis.

4.3.2 Cross country comparisons in energy prices in the EU

This section turns to the final pillar of the trilemma, energy affordability, which is assessed through a cross-country comparison for the period 2019–2023. Member States are grouped into high-, medium-, and low-GDP per capita categories, reflecting the central role of income capacity in determining affordability outcomes (Thomson, Snell, & Bouzarovski, 2017; Bouzarovski, 2018). The analysis is based on three indicators drawn from Eurostat (2025):

1. Average electricity price (EUR/MWh), excluding taxes and levies, for the household consumption band of 2,500–4,999 kWh annually.

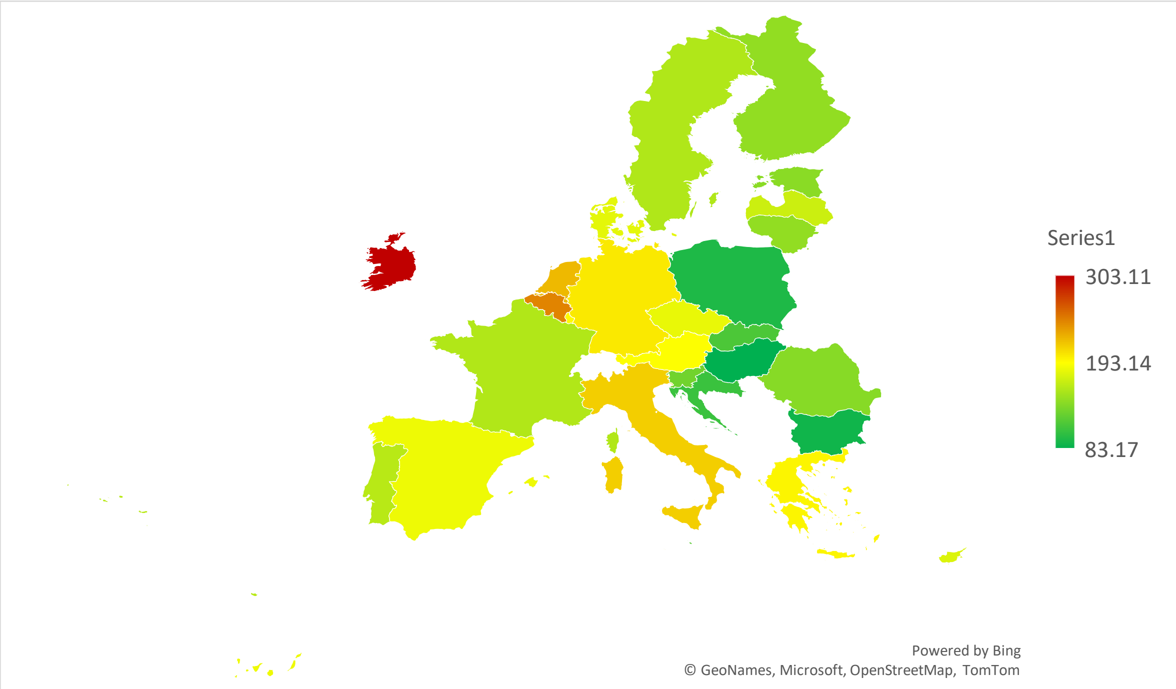
2. Energy consumption per capita (MWh), converted from kilograms of oil equivalent (kgoe) to ensure comparability with other energy indicators.

3. Share of income spent on energy (%), calculated as the annual electricity bill relative to GDP per capita, serving as a proxy for affordability.

Gas prices are excluded, as gas coverage varies across Member States and would reduce comparability, whereas electricity is universal. GDP per capita is used as a proxy for disposable household income, consistent with prior studies of energy poverty (Thomson, Snell, & Bouzarovski, 2017). By combining these three indicators, the cross-country analysis offers the most direct picture of affordability differences across the EU. Unlike the EU-27 time-trend, which highlighted the general trajectory of prices and consumption, these tables allow for a distributional perspective, showing how the affordability burden diverges sharply between high-, medium-, and low-income Member States.

Figure 10 provides a geographical overview of average household electricity prices across the EU during 2019–2024. Clear spatial differences are visible, with Ireland and several Western European states recording the highest prices, while most Central and Eastern European countries maintained lower nominal price levels. However, as the subsequent tables illustrate, affordability cannot be assessed by prices alone but requires linking costs to household income levels and consumption. The group of high-GDP per capita countries presents an interesting paradox in terms of energy affordability. Electricity prices in this group as shown in Table 9 are among the highest in the EU, with Ireland (303 EUR/MWh) and Belgium (246 EUR/MWh) standing out, compared to France (160 EUR/MWh) and Finland (145 EUR/MWh) at the lower end (Eurostat, 2025). These elevated prices reflect both higher generation costs and, in some cases, more liberalized market structures (European Commission, 2020). However, the affordability burden, measured as the share of income spent on electricity, remains relatively low in this group, ranging from just 1.6% in Luxembourg to 4.3% in Belgium. This is a direct consequence of the high GDP per capita levels that cushion households from energy poverty risks despite high nominal prices, confirming the literature that affordability depends as much on income capacity as on price levels (Thomson, Snell, & Bouzarovski, 2017).

Figure 10: Average household electricity prices in the EU, 2019–2024 (EUR/MWh)



Source: Own work based on Eurostat (2025a)

Energy consumption per capita in this group is also considerably higher than in medium- and low-GDP groups, with Finland (11.8 MWh per capita) and Sweden (8.2 MWh per capita) recording the highest values. This reflects structural factors such as larger dwellings, colder climates, and energy-intensive lifestyles in Northern and Western Europe. Despite higher absolute consumption, the affordability burden remains low because of income effects, showing how GDP levels mediate vulnerability.

From a policy perspective, this indicator aligns with the Energy Efficiency Directive (EED), which seeks to reduce household energy demand. High-GDP countries often implement advanced efficiency standards and benefit from modernized housing stocks, which help mitigate consumption levels even when lifestyles and climates push demand upward (European Union, 2018). The indicator on share of income spent on energy directly reflects the EU's measures to protect vulnerable consumers. In this group, the indicator confirms that affordability risks are generally limited, with only Belgium (4.3%) approaching the levels typically seen in medium-GDP countries. This suggests that consumer protection policies are less decisive in high-GDP Member States, as high incomes alone ensure affordability. However, the sharp rise in prices during 2021–2022 still required EU-wide interventions, such as the Energy Prices Toolbox (European Commission, 2021b), demonstrating that even wealthy Member States were not immune to the crisis.

Table 9: Average energy price, consumption and percentage of income in high GDP EU member states (2019-2023)

Country	Energy price (EUR/MWh)	Energy consumption per capita (MWh)	GDP per capita (EUR)	Price of energy per year (EUR)	% of income
Luxembourg	194.70	8.53	103,924	1,661.18	1.60
Ireland	303.11	6.60	82,778	1,999.62	2.42
Denmark	181.38	8.47	56,336	1,537.01	2.73
Netherlands	223.25	5.94	49,552	1,325.66	2.68
Sweden	159.26	8.16	47,976	1,299.56	2.71
Austria	192.29	9.03	44,952	1,736.86	3.86
Finland	145.93	11.75	43,578	1,714.53	3.93
Germany	202.53	7.93	42,760	1,606.87	3.76
Belgium	246.09	7.47	42,634	1,839.03	4.31
France	159.69	6.70	36,570	1,069.76	2.93

Source: Own work based on Eurostat (2025a); Eurostat (2025c); Eurostat (2025e)

Overall, the high-GDP group illustrates that electricity prices alone do not determine affordability. Despite facing some of the EU's highest prices and highest consumption levels, these Member States maintained relatively low affordability burdens, thanks to strong income buffers. This underlines the importance of linking price and consumption indicators to income levels when assessing affordability, and it demonstrates how EU policies — from the EED to price stabilization initiatives — interact differently across income groups.

The group of medium-GDP per capita countries (ranging from approximately €18,600 in Lithuania to €30,900 in Malta) as shown in Table 10, is characterized by much greater diversity in affordability outcomes. Electricity prices in this group vary widely, from 121 EUR/MWh in Malta to 214 EUR/MWh in Italy (Eurostat, 2025). Several Member States in this group, such as Italy, Spain, and Cyprus, faced prices above 175 EUR/MWh, levels comparable to high-income states. Yet others, including Slovenia and Portugal, maintained much lower prices, closer to 130–160 EUR/MWh. This dispersion reflects structural factors such as energy mix, reliance on imports, and the degree of market liberalization. Despite relatively moderate price levels in some states, the affordability burden is higher than in the high-GDP group. On average, households in this category devote between 2.5% and 6.6% of their income to electricity, with Czechia (6.6%) and Estonia (5.4%) standing out as cases of affordability stress. By contrast, Malta presents an extreme outlier, with households spending less than 1% of their income on electricity. This is largely due to low consumption (2.4 MWh per capita) and extensive state interventions to shield consumers from energy costs, including price regulation and subsidies (Bruegel, 2023). This demonstrates how measures to protect vulnerable consumers can decisively alter affordability outcomes when effectively implemented. Household consumption per capita in this group generally falls between 3 and 8 MWh, with Estonia (8.3 MWh) and Czechia (7.8 MWh) at the higher end, and Spain (3.5 MWh) and Malta (2.4 MWh) at the lower end. This reflects both climatic conditions and structural energy demand patterns.

Table 10: Average energy price, consumption and percentage of income in medium GDP EU member states (2019-2023)

Country	Energy price (EUR/MWh)	Energy consumption per capita (MWh)	GDP per capita (EUR)	Price of energy per year (EUR)	% of income
Italy	214.41	6.00	30,882	1,286.25	4.17
Malta	121.07	2.42	30,678	293.47	0.96
Cyprus	177.45	4.54	26,920	804.91	2.99
Spain	185.80	3.51	26,028	651.79	2.50
Slovenia	131.95	5.99	23,862	790.91	3.31
Estonia	142.71	8.26	21,738	1,178.78	5.42
Czechia	183.77	7.75	21,686	1,423.85	6.57
Portugal	162.54	3.32	20,922	539.47	2.58
Lithuania	146.07	6.25	18,664	913.23	4.89

Source: Own work based on Eurostat (2025a); Eurostat (2025c;) Eurostat (2025e)

Importantly, the higher consumption countries within this group also face higher affordability burdens, as incomes are not sufficient to absorb both high demand and elevated prices. The Energy Efficiency Directive (EED) plays a central role here, as its objective of reducing household energy use is particularly relevant in medium-income Member States where efficiency gains could significantly ease affordability pressures (European Union, 2018; Girod 2017). The medium-GDP group highlights the uneven effectiveness of EU affordability policies. In Malta and, to some extent, Spain and Portugal, affordability risks remain low thanks to lower consumption levels or strong national interventions. In contrast, in Estonia and Czechia, high prices and high consumption translate into severe affordability burdens, underscoring the vulnerability of these Member States. This variation confirms findings in the literature that affordability is not only shaped by market prices but also by the interaction of income levels, demand, and targeted policy interventions (Thomson, Snell, & Bouzarovski, 2017; Bouzarovski & Petrova, 2015).

Overall, the medium-GDP group demonstrates that affordability outcomes are far more heterogeneous than in the high-GDP countries. While some Member States successfully shielded households from price shocks, others experienced burdens that rival those of low-GDP countries. This underlines the continued need for EU-level coordination of consumer protection policies, alongside structural improvements in energy efficiency.

Table 11 shows the results for the countries with the lowest GDP per capita in the EU. The nominal electricity prices (2019–2023 average, excluding taxes and levies) are in general lower than those in the high- and medium-GDP groups, with values such as 83 EUR/MWh in Hungary, 90 EUR/MWh in Bulgaria and 96 EUR/MWh in Poland, compared to 198 EUR/MWh in Greece and 171 EUR/MWh in Latvia (Eurostat, 2025). Despite these relatively modest nominal prices, the share of income devoted to electricity is the highest in this group, reaching 7.29% in Latvia, 5.59% in Romania, and 5.19% in Greece, while the lowest share is 3.5% in Bulgaria. This clearly shows that affordability problems in low-GDP states are less a matter of price levels and more a reflection of limited purchasing power and household vulnerability to energy costs (Bouzarovski, 2018; Thomson, Snell, & Bouzarovski, 2017).

Table 11: Average energy price, consumption and percentage of income in low GDP EU member states (2019-2023)

Country	Energy price (EUR/MWh)	Energy consumption per capita (MWh)	GDP per capita (EUR)	Price of energy per year (EUR)	% of income
Slovakia	115.85	5.76	18,066	666.72	3.69
Greece	197.59	4.57	17,370	902.20	5.19
Latvia	170.77	7.01	16,406	1,196.76	7.29
Hungary	83.17	7.05	15,400	586.51	3.81
Poland	96.11	6.54	15,154	628.37	4.15
Croatia	108.22	6.86	14,594	742.28	5.09
Romania	141.22	4.85	12,248	684.49	5.59
Bulgaria	90.06	3.97	10,216	357.81	3.50

Source: Own work based on Eurostat (2025a); Eurostat (2025c); Eurostat (2025e)

Energy consumption per capita also varies considerably, ranging from 3.97 MWh in Bulgaria to more than 7 MWh in Hungary and Latvia. The northern members of this group (Latvia, Poland, Hungary) display systematically higher consumption due to climate conditions, which in turn raises the share of income spent on energy, despite lower unit prices. Southern members (Greece, Croatia, Bulgaria) consume less, but affordability burdens remain high because of comparatively low GDP per capita. These findings highlight the continuing relevance of the Energy Efficiency Directive (EED), which aims to lower household demand through efficiency gains and renovations—policies especially important in countries where high consumption and low incomes intersect (European Union, 2018). Finally, the 2021–2023 energy crisis amplified these affordability pressures. Some governments responded with administrative price caps, subsidies or tax reductions, such as Hungary's regulated tariffs, which partly explain its relatively low-income share (3.81%) despite high consumption. Others, like Greece, faced both high wholesale prices and delayed implementation of protection measures, which resulted in affordability burdens above 5% (European Commission, 2022; Bruegel, 2023). This underlines the uneven effectiveness of EU-level stabilization measures (Energy Prices Toolbox, EU Energy Platform, REPowerEU), which sought to reduce household exposure but could not offset structural differences in income and consumption across member states.

In conclusion, the low-GDP group illustrates how energy affordability is strongly dependent on household income levels and energy demand patterns, rather than prices alone. Policies aimed at vulnerable consumers and price stabilization are crucial here, but without sustained improvements in energy efficiency and household incomes, these countries will remain the most exposed to affordability risks.

The cross-country analysis of energy affordability reveals strong structural inequalities across the EU. While high-GDP countries faced some of the highest nominal electricity prices and highest consumption levels, their households devoted only 1–4% of income to electricity thanks to stronger purchasing power (Eurostat, 2025). Medium-GDP countries displayed greater heterogeneity: affordability burdens were moderate in states such as Malta and Spain, but reached 5–6% in Czechia and Estonia, reflecting both higher consumption levels and limited income capacity (Eurostat, 2025; Bruegel, 2023). The most severe affordability pressures were observed in low-GDP Member States, where households spent up to 7% of income on electricity despite facing some of the lowest nominal prices. This confirms that energy affordability is driven primarily by income capacity and consumption patterns, rather than by nominal prices alone, and that EU measures to protect vulnerable consumers and stabilize prices have had uneven effectiveness (Bouzarovski, 2018; Thomson, Snell, & Bouzarovski, 2017; European Commission, 2021b; European Commission, 2022). The disparities observed among EU member states correspond with the structural energy poverty challenges highlighted by Bouzarovski, Thomson, and Cornelis (2021), particularly regarding the unequal exposure of households to rising energy costs. The observed regional disparities in household energy expenditure ratios mirror the patterns of energy inequality identified by Dubois and Meier (2016), confirming that affordability challenges are most pronounced among lower-income households in Central and Eastern Europe.

This completes the empirical analysis of the three pillars of the EU's energy trilemma. Energy security, examined in Section 4.1, showed how import dependency and diversification efforts have reshaped the Union's exposure to supply shocks, particularly following the Russian invasion of Ukraine (Siddi, 2023; Eurostat, 2025). Energy sustainability, analyzed in Section 4.2, highlighted progress in renewable deployment, emissions reduction, and energy intensity, reflecting the combined effect of the Renewable Energy Directive, the EU ETS, and the European Green Deal (European Union, 2018; European Commission, 2019; European Commission, 2021a). Energy affordability, as shown here, remains the most unequal of the three pillars, exposing structural divides between higher- and lower-income Member States (Bouzarovski & Petrova, 2015). Taken together, the three pillars confirm that while EU policies have achieved notable progress in enhancing resilience, decarbonization, and partial affordability relief, tensions and trade-offs remain. Measures designed to secure supply and accelerate the green transition often risk short-term affordability impacts, while affordability protections may dilute incentives for efficiency and decarbonization (Ang et al., 2015; Tagliapietra, Zachmann & Sgaravatti, 2023). These dynamics underscore the need for policy coherence and solidarity mechanisms across Member States (Girod, 2017).

While the preceding analysis focused on intra-EU variation, it is equally important to situate the EU's performance in a broader international context. The following section therefore compares the EU's position with that of the United States and China, two other major energy consumers whose approaches to security, sustainability, and affordability differ markedly (IEA, 2023).

4.4 International comparison of the EU with the USA and China

This section extends the empirical analysis beyond the European Union by positioning the EU's energy performance against two major global players, the United States and China. The aim is to provide an international perspective that situates the EU's achievements and challenges in a broader global context. Such a comparison is important, as it highlights not only intra-European dynamics but also the EU's relative standing in terms of energy security, sustainability, and affordability—the three pillars that structure this thesis (World Energy Council, 2018).

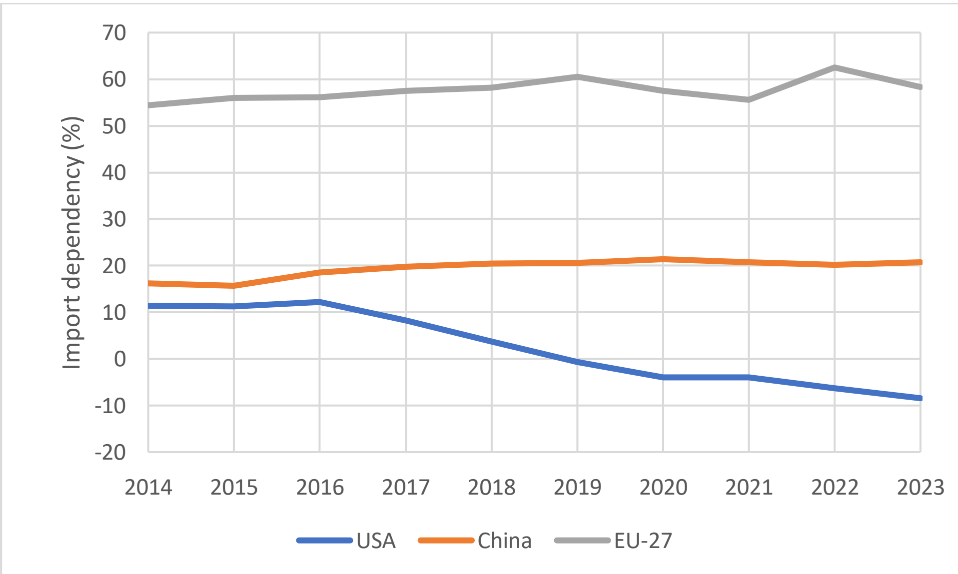
The analytical framework follows the same methodological logic as in the preceding subchapters. For each pillar, one representative indicator is selected: import dependency for energy security, the share of renewables in electricity generation for energy sustainability, and household electricity prices for energy affordability. These indicators were chosen because they are widely reported in international statistics, comparable across regions, and capture the most policy-relevant dimensions of each pillar (WEC, 2018). Data is drawn primarily from Eurostat, the International Energy Agency, the U.S. Energy Information Administration, and the World Bank, complemented by other reputable international sources where necessary. For each indicator, two types of analysis are presented. First, a cross-sectional snapshot compares the EU, the USA, and China in the most recent year with available data, illustrating the relative positioning of each. Second, a time-trend analysis tracks developments over the past decade, highlighting convergence, divergence, or structural differences in trajectories (Sovacool & Brown, 2010). This dual approach ensures both a static and dynamic perspective on the EU's performance. By embedding the international comparison into the same three-pillar, indicator-based framework used in the EU analysis, the section ensures methodological consistency and coherence. The findings allow readers to assess whether the EU's progress in implementing its energy policies translates into a stronger global position, or whether gaps remain when measured against other leading economies (Bradshaw, 2013; Goldthau & Sovacool, 2016). In doing so, the chapter not only broadens the scope of the analysis but also provides insights into the global relevance of EU energy strategies.

4.4.1 Energy security: Import dependency in the EU, USA and China

Import dependency is one of the most established indicators of energy security, as it measures the share of a country's energy needs covered by foreign supplies (Ang et al., 2015; Winzer, 2012). Eurostat defines it as the ratio of net imports (imports minus exports) to gross available energy (Eurostat, 2024). This metric is widely used in both academic and policy contexts because it provides a direct measure of vulnerability to external supply shocks and geopolitical risks (Cherp & Jewell, 2014; Sovacool & Brown, 2010). For this international comparison, import dependency was chosen as the core indicator of energy security because comparable data is available for the EU, the USA, and China, allowing for both a time-trend and cross-country analysis.

Figure 11 shows the development of import dependency for the EU, USA, and China over the last decade (until 2023 where data was available). The EU's values remained consistently high, ranging from 54% in 2014 to more than 62% in 2022, before settling at 58.3% in 2023. This confirms the Union's structural reliance on external suppliers, discussed in Section 4.1, and highlights its persistent vulnerability to external shocks such as the 2022 gas crisis (European Commission, 2022).

Figure 11: Trends in import dependency of the EU, USA, and China, 2014–2023 (%)



Source: Own work based on Eurostat (2024a); U.S. EIA (2025); IEA (2024)

By contrast, the USA moved in the opposite direction: dependency fell steadily from around 11% in 2014 to negative values after 2019, reaching –8.4% in 2023. Negative values indicate that the country exported more energy than it imported, a shift driven by the shale oil and gas boom and the rapid expansion of liquefied natural gas (LNG) exports (EIA, 2025). China followed a different trajectory, with dependency increasing moderately from 16% in 2014 to 21% in 2023. The comparatively low figure, relative to the EU, is explained by China's vast domestic coal production, which reduces its aggregate reliance on imports even though its dependency on oil alone exceeds 70% (IEA, 2024).

Table 12 illustrates the differences in 2023 more clearly: the EU recorded an import dependency of 58.3%, compared to 20.8% in China and –8.4% in the USA. These results underline the EU's weaker position relative to both global peers. The USA has achieved energy independence, with its net exporter status shielding it from supply disruptions and giving it additional leverage in international markets (Goldthau & Sovacool, 2012). China's moderate aggregate dependency is significantly lower than the EUs, although it conceals a more vulnerable position in oil and gas. For the EU, the comparison is unfavorable: despite diversification strategies and initiatives such as the REPowerEU plan (European Commission, 2022), it remains far more reliant on imports than either of the other two major economies.

Table 12: Cross-country comparison of import dependency in 2023 (%)

Country	EU-27	USA	China
% of net imports	58.27	-8.44	20.77

Source: Own work based on Eurostat (2024a); U.S. EIA (2025); IEA (2024)

Taken together, these results show that the EU's structural dependence on external suppliers has not been reduced in relative terms when compared with the USA and China. The USA's shift to a net exporter position underscores how domestic resource development — particularly unconventional oil and gas — can transform a country's energy security profile (Yergin, 2011; EIA, 2025). China's moderate overall dependency is explained by its large coal production, but its heavy reliance on oil and gas imports demonstrates hidden vulnerabilities (IEA, 2024; Yang et al., 2022). By contrast, the EU remains significantly more import dependent, with values above 55% throughout the past decade (Eurostat, 2024).

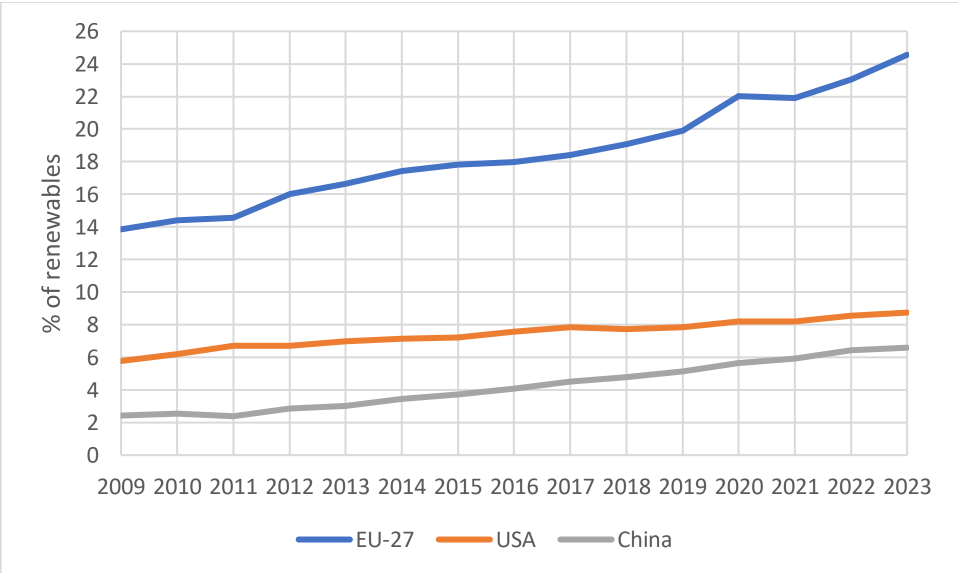
This comparison highlights the EU's relative weakness in global perspective. Despite extensive policy measures such as the REPowerEU plan, which aimed to diversify supply sources and accelerate renewables deployment (European Commission, 2022), the Union has not yet achieved a reduction in overall import dependency comparable to the structural changes observed in the USA or the balancing effect of coal in China. As identified in Chapter 3, the EU's reliance on imports leaves it exposed to geopolitical shocks, as illustrated by the 2022 energy crisis (European Commission, 2022). The international comparison therefore suggests that, while policy initiatives mitigate risks, the EU remains in a structurally weaker position than its global peers, which has important implications for both its energy strategy and its geopolitical standing (Bradshaw, 2013; Sovacool & Brown, 2010).

4.4.2 Energy sustainability: Share of renewables in the EU, USA and China

Energy sustainability reflects the extent to which energy systems transition towards low-carbon and environmentally sound pathways (Diesendorf, 2014; van den Bergh, 2013). Among various possible measures, the share of renewable energy in gross final energy consumption is selected here as the primary indicator for international comparison. This choice is motivated by its policy relevance, comparability across countries, and central role in the EU's legislative framework. The Renewable Energy Directive (European Union, 2018, 2023) and the European Green Deal (European Commission, 2019) both set binding targets for renewable deployment, making this indicator a direct measure of policy implementation and progress.

The share of renewables is also widely reported for the USA and China, which allows for a consistent time-trend and cross-country comparison. The USA, while lacking binding federal targets, has seen renewables grow through market-driven investments and state-level initiatives (EIA, 2025). China, by contrast, has combined rapid industrial expansion with large-scale state-driven investments in solar, wind, and hydropower, making it the world leader in absolute renewable capacity (IEA, 2024). Comparing these trajectories with the EU highlights both the effectiveness of its policy-driven approach and the structural challenges it faces in maintaining leadership. Other sustainability indicators, such as greenhouse gas emissions and energy efficiency, were analyzed in the EU context in Section 4.2. While not examined in detail here, they generally confirm the trends observed in renewable deployment: the EU's policy framework has delivered greater relative progress than the USA but faces increasing competition from China in absolute terms (IEA, 2024; Eurostat, 2025). Figure 12 presents the development of the share of renewables in gross final energy consumption between 2009 and 2023.

Figure 12: % of renewables in final energy consumption in the EU, USA and China



Source: Own work based on Eurostat (2025f); U.S. EIA (2025); IEA (2024)

The EU shows a steady and significant increase, rising from 13.9% in 2009 to 24.6% in 2023, an improvement of more than 10 percentage points. This growth reflects the impact of successive Renewable Energy Directives and national support schemes that have promoted the uptake of wind, solar, and biomass (European Union, 2018; European Commission, 2019). The USA also recorded growth, but at a much slower pace: renewables increased from 5.8% in 2009 to 8.7% in 2023. This reflects the absence of binding federal-level renewable targets, with progress largely driven by state-level initiatives and market competitiveness rather than national policy (Sovacool & Brown, 2010; Bradshaw, 2013). China, meanwhile, started from a very low base of 2.4% in 2009 and rose to 6.6% in 2023. This tripling of its renewables share reflects massive state-led investments in hydro, wind, and solar capacity, which have made China the world's largest market for renewable energy in absolute terms, even though the share of renewables in its energy consumption remains relatively low due to the dominance of coal (IEA, 2024; Yang et al., 2022).

A comparison of the most recent year underscores the divergence between the three economies. Table 13 shows that in 2023, the EU's renewable share of 24.6% was almost three times higher than China's 6.6% and nearly three times higher than the USA's 8.7%. This outcome highlights the EU's continued global leadership in renewables penetration, supported by binding policy frameworks and long-term decarbonization targets. By contrast, the USA, despite strong growth in renewable capacity, continues to lag in relative terms, reflecting the persistence of fossil fuels in its energy mix (EIA, 2025). China, although far behind the EU in relative share, is notable for its sheer scale of renewable capacity additions. Its renewable share remains modest because of the overwhelming role of coal in its domestic production, but in absolute terms China now installs more renewable capacity each year than the EU and USA combined (Eurostat, 2025; IEA, 2024).

Table 13: % of renewables in final energy consumption in the EU, USA and China 2023

Country	% of renewables
EU-27	24.56
USA	8.74
China	6.59

Source: Own work based on Eurostat (2025f); U.S. EIA (2025); IEA (2024)

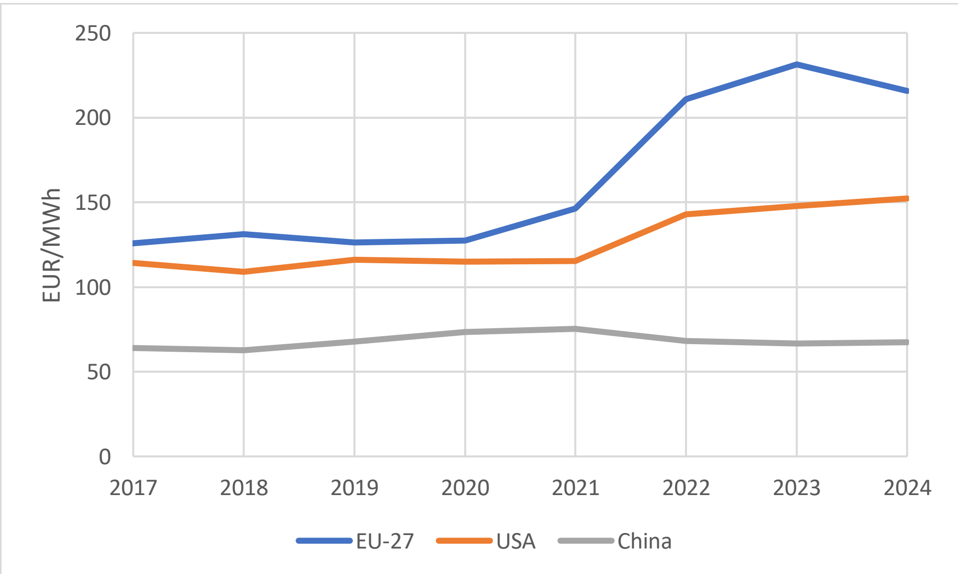
Overall, the comparison demonstrates that the EU remains a global leader in the share of renewables in final energy consumption, a direct outcome of its binding policy framework under the Renewable Energy Directive and the European Green Deal (European Union, 2018; European Commission, 2019). The USA's slower progress reflects its reliance on market forces and fragmented state-level policies (Sovacool & Brown, 2010), while China's position illustrates how rapid industrial deployment of renewables can coexist with a coal-dominated energy system (IEA, 2024). For the EU, the findings confirm that its sustainability policies have delivered measurable results in international perspective, but also that maintaining leadership will require sustained efforts, as both the USA and China are expanding their renewable capacity rapidly.

4.4.3 Energy affordability: Household Electricity Prices in the EU, USA, and China

Affordability is a crucial dimension of energy policy, as it reflects the extent to which households and businesses can secure reliable access to energy services at reasonable cost

(Bouzarovski, 2018). High energy costs place a disproportionate burden on lower-income households and can exacerbate social inequality, while stable and affordable prices are essential for maintaining competitiveness and social cohesion (European Commission, 2021b). For the international comparison, the average household electricity price is selected as the primary indicator of affordability. This measure is both widely available and directly relevant to consumer welfare, making it the clearest representation of affordability across different economies. It is also strongly linked to policy interventions, such as energy price caps, subsidies, and market reforms, which were particularly prominent during the 2021–2022 energy crisis (European Commission, 2022; IEA, 2023). Two additional indicators, energy consumption per capita and the share of household income spent on energy, complement the analysis by providing context. Higher per capita consumption, as observed in the USA, may mitigate the effect of lower prices, while the income share spent on energy highlights structural differences in vulnerability between households in the EU, USA, and China. These supporting measures will be briefly considered in the reflection, while the main analysis focuses on electricity prices as the most comparable and policy-relevant measure of affordability. The data in Figure 13 reveals strikingly different affordability dynamics across the three economies. In the EU, household electricity prices remained relatively stable between 2017 and 2020, fluctuating around 125–130 EUR/MWh, before rising sharply to 146 EUR/MWh in 2021 and peaking at 231 EUR/MWh in 2023. This surge reflects the combined effects of the global energy crisis, triggered by Russia's invasion of Ukraine, soaring natural gas prices, and the EU's structural dependence on imports (Siddi, 2023; European Commission, 2022). Although emergency measures such as the Energy Efficiency Directive and the Council Regulation on reducing energy demand (European Union, 2023) were introduced to contain household costs, prices remained historically high in 2022–2023, only slightly easing in 2024 (215 EUR/MWh).

Figure 13: Household electricity prices in the EU, USA and China from 2017-2024



Source: Own work based on Eurostat (2025a); U.S. EIA (2025); IEA (2024)

In contrast, U.S. household prices exhibited far greater stability. Between 2017 and 2021, prices hovered around 110–116 EUR/MWh, increasing gradually to 152 EUR/MWh in 2024. This reflects the USA's position as a net energy exporter (EIA, 2025), which shielded domestic consumers from global supply shocks. While U.S. households did experience higher prices after 2021, the increase was more gradual than in the EU, due to abundant domestic gas and electricity production and the absence of heavy taxation on electricity bills. China presents a markedly different case. Residential tariffs, regulated by the government, remained largely stable between 2017 and 2019 at around 63–68 EUR/MWh, rising modestly to 75 EUR/MWh in 2020–2021, before falling back to 66–67 EUR/MWh by 2022–2024 (IEA, 2024). These values are significantly lower than in both the EU and USA, reflecting China's longstanding policy of subsidizing residential consumers and cross-subsidizing household tariffs through higher industrial rates (IEA, 2024; Yang et al., 2022). The lack of sharp fluctuations illustrates how state-led control of electricity prices insulates households from international energy market volatility, albeit at the cost of reduced market efficiency and persistent reliance on coal.

Table 14: Household electricity prices in the EU, USA and China 2024

Country	Price EUR/MWh
EU-27	215.90
USA	152.26
China	67.47

Source: Own work based on Eurostat (2025a); U.S. EIA (2025); IEA (2024)

Table 14 shows that in 2024 the affordability gap between the three economies was stark. EU households faced an average of 216 EUR/MWh, compared with 152 EUR/MWh in the USA and only 67 EUR/MWh in China. Thus, EU households paid over 50% more than U.S. households and more than three times as much as Chinese households for electricity. These differences reflect structural and policy choices: the EU's reliance on liberalized markets with high integration of gas-linked marginal pricing exposed households directly to wholesale price spikes (European Commission, 2022), whereas the U.S. benefited from domestic energy abundance, and China relied on tariff regulation and subsidies to shield households.

Overall, the international comparison highlights the EU's relative vulnerability in terms of affordability. Despite targeted policies like the EGD, those to protect vulnerable consumers (European Commission, 2019) and temporary interventions such as price caps and demand reduction measures (European Union, 2023), European households faced much higher electricity costs than their U.S. and Chinese counterparts during the energy crisis. The contrast with the USA underlines the advantages of energy self-sufficiency and domestic production (EIA, 2025), while the comparison with China illustrates how regulated tariffs can stabilize household prices but conceal broader sustainability and efficiency challenges (IEA, 2021). For the EU, the findings suggest that ensuring affordability requires not only short-term crisis interventions but also structural reforms in electricity market design, as envisaged in the European Green Deal and the ongoing reforms to the electricity market framework (European Commission, 2019, 2023).

Taken together, the international comparisons across the three pillars demonstrate that the EU remains structurally more dependent on energy imports, has achieved higher shares of renewables, but faces considerable challenges in affordability relative to the USA and China. These findings are discussed in greater detail in Chapter 5, where the implications of the three-pillar comparison are synthesized.

5 DISCUSSION OF RESULTS

This chapter synthesizes the empirical findings to assess the European Union's relative position on the energy trilemma—security, sustainability, and affordability—and to interpret cross-pillar trade-offs in light of the policy framework reviewed earlier. The international comparison adopts the same indicator logic used in Chapter 4: import dependency (security), share of renewables (sustainability), and household electricity prices (affordability), ensuring methodological coherence between the EU-27 analysis and the EU–USA–China benchmark (Sections 4.1–4.4).

Across the past decade, the EU remained structurally import dependent (roughly mid-50s to low-60s %), reflecting enduring exposure to external supply shocks despite accelerated diversification after 2022. By 2023 the EU's import dependency still stood at ≈58%, underscoring persistent vulnerability highlighted in Section 4.1 and during the gas crisis. In contrast, the USA crossed into net exporter territory after 2019 (–8.4% in 2023), a shift linked to unconventional oil and gas and the rise of LNG exports. China recorded a moderate aggregate dependency (~21% in 2023) because large domestic coal output depresses the aggregate ratio, even as oil reliance remains high. These levels create a stark ranking: EU ≫ China > USA (in absolute import dependence).

Crisis-era strategic reserves materially raised Europe's short-term resilience—gas storage fullness before winter now stabilizes well above historic norms under Regulation (EU) 2022/1032—but storage is inherently a temporary buffer and cannot substitute for structural diversification and demand-side measures. The literature and your evidence converge on this point: resilience and flexibility are indispensable, yet long-run security hinges on diversification and efficiency.

These findings are consistent with the multidimensional understanding of energy security proposed by Sovacool and Brown (2010) and Ang et al. (2015), who emphasize the interaction between diversification, resilience, and dependency indicators. The observed improvements in LNG infrastructure and diversification policies in the EU reflect these theoretical dimensions in practice. From a policy perspective, the EU's security tools—REPowerEU, strategic reserves, and diversification of supply and infrastructure—are correctly targeted and have delivered measurable, short-term improvements; however, they have not yet reduced overall import dependency to levels comparable with the USA, nor do they offset China's coal-based buffer in the aggregate indicator. This mirrors the theoretical caution that import dependency, while policy-salient, is an imperfect proxy that must be interpreted with fuel-specific nuance.

On sustainability, the EU's policy-driven model (RED II/III, EU ETS, European Green Deal, Fit-for-55) has yielded higher renewable shares and a structurally more diversified electricity mix than a decade ago, with renewables overtaking fossil generation by 2023 at EU-27 level. Still, regional asymmetries remain (CWE ahead; several CEE systems anchored in legacy fossil/nuclear), showing that common EU targets meet heterogeneous national constraints. The results also align with the conceptual frameworks discussed by Brodny and Tutak (2025) and Yumashev et al. (2020), confirming that EU member states differ significantly in the balance between environmental and socio-economic aspects of sustainability. Countries with higher renewable shares and energy efficiency performance demonstrate the multidimensional sustainability trends described in the literature.

Internationally, the USA has recorded steady, market-led gains (significant state-level action; rising RES shares), yet it trails the EU on relative penetration. China is the global leader in absolute RES capacity and has made rapid progress, but its system remains coal-intensive, so its share metric lags the EU even as its scale rivals or surpasses others. As Section 4.4 argued, comparing RES shares (policy alignment) and levels (system scale) together clarifies why the EU leads on relative decarbonization, while China's absolute additions have global weight.

The cross-pillar message is consistent with theory: diversification and renewables support security in the medium term by reducing import needs and price exposure, but the pace and composition of the transition differ by resource endowments and institutions, producing uneven outcomes across Member States and between global peers.

The affordability comparison is unambiguous. EU household electricity prices were stable pre-2020 (~125–130 EUR/MWh), then surged in 2022–2023 amid wholesale gas price spikes and import shocks, easing slightly in 2024 yet remaining historically high. The U.S. profile shows lower, smoother increases over 2017–2024, consistent with abundant domestic supply and lower tax components. China's regulated residential tariffs held low and stable, insulating households from international volatility but at the cost of market efficiency and with continuing coal reliance.

The cross-sectional 2024 snapshot crystallizes this gap: EU ≈ 216 EUR/MWh, USA ≈ 152 EUR/MWh, China ≈ 67 EUR/MWh. Hence, EU households paid >50% more than U.S. households and over three times China's average. These differences reflect structural choices: a liberalized, gas-linked marginal pricing model in the EU; resource abundance and lower tax incidence in the USA; and administered tariffs in China. Emergency EU measures (price caps, demand reduction, shielding of vulnerable consumers) blunted the shock but could not fully offset structural exposure.

Within the EU-27, Chapter 4 also showed pronounced distributional inequalities (share of income spent, consumption patterns), confirming that affordability is driven at least as much by income and demand as by nominal prices—hence the importance of targeted transfers, efficiency, and market design reforms. The disparities in household energy expenditure and price trends observed in the analysis mirror the patterns of energy inequality highlighted by Dubois and Meier (2016) and the policy concerns outlined by Bouzarovski, Thomson and Cornelis (2021). These findings reinforce the argument that affordability remains both a social and policy challenge in ensuring just energy transitions.

Read together, the three pillars yield a clear comparative picture:

- Security: The EU made operational gains (storage, diversification) but remains structurally import dependent versus a net-exporter USA and a coal-buffered China. Security advances that focus on buffers (storage) are necessary but transitory; lasting convergence requires sustained diversification and demand reduction.

- Sustainability: The EU's policy-led approach delivers higher RES shares and falling fossil intensity, validating the RED/ETS/EGD architecture, though unevenly across Member States. The USA advances more incrementally; China advances rapidly in scale but remains coal-intensive.

- Affordability: Crisis exposure left EU households facing much higher prices than U.S. and especially Chinese households. Shielding tools were helpful but uneven, reinforcing the case for efficiency, targeted social protection, and electricity market design reform to decouple retail bills from gas-driven wholesale spikes.

These results echo the literature's warning that the trilemma is not a zero-sum game but involves dynamic trade-offs and sequencing: measures that accelerate decarbonization and reduce import exposure can, in the short run, elevate prices; conversely, broad affordability shields can attenuate incentives to save energy or invest in clean capacity. The policy task is to coordinate instruments so that short-term protection does not derail long-term security and sustainability goals.

Three implications follow:

1. Deepen structural diversification beyond storage: sustain REPowerEU's supplier diversification, accelerate cross-border infrastructure, and lock-in demand-side gains (efficiency, electrification) to compress import needs durably.

2. Stay the course on RED/ETS/EGD while targeting laggards: heterogeneity in Member State starting points requires tailored support (investment, flexibility assets, interconnection) to close regional gaps without slowing EU-level progress.

3. Reinforce affordability through design, not only transfers: combine targeted consumer protection with market-design reforms that limit gas-to-power pass-through during stress, while investing in efficiency to reduce baseline exposure.

International figures in Section 4.4 are based on Eurostat/IEA/EIA/Statista with harmonized units; China's household series includes transparent approximations for early years and administered tariff considerations, as documented in the figure/table notes. Results are therefore comparable for the intended purpose (trend and ranking), with caveats already stated in Chapter 4.

The EU leads on relative sustainability and has strengthened operational security, but remains more import dependent and less affordable for households than the USA—and far less affordable than tariff-regulated China. The direction of travel is correct; the challenge is one of pace and coherence, ensuring that crisis protections and structural reforms jointly deliver a secure, sustainable, and affordable energy system.

6 CONCLUSION

This thesis set out to examine the European Union's energy policy through the three pillars of the energy trilemma—security, sustainability, and affordability—guided by the three research questions.

The analysis of EU legislation and strategies (Chapter 3) showed that the EU has built a comprehensive framework addressing all three pillars. In the field of energy security, the most relevant initiatives are REPowerEU, the development of strategic reserves, and the diversification of supply sources and infrastructure. For sustainability, the central policies are the Renewable Energy Directive (RED II/III), the EU Emissions Trading System (ETS), and the European Green Deal, all of which underpin binding decarbonization targets. Regarding affordability, the Energy Efficiency Directive (EED), measures for vulnerable consumers, and recent interventions such as coordinated gas purchases and temporary price caps form the key policy instruments. While each policy primarily targets one pillar, the review demonstrated that many also have cross-pillar effects, creating both synergies and tensions. The empirical analysis (Chapter 4) revealed a mixed picture across Member States. In energy security, Central and Western European countries have advanced diversification and LNG integration, whereas several Central and Eastern European states remain heavily reliant on Russian fossil fuels. In sustainability, most Member States increased their renewable shares, with the EU average reaching nearly 25% in 2023, but progress is uneven, and coal remains significant in some CEE systems. In affordability, European households faced record-high electricity prices in 2022–2023, with notable differences between countries depending on tax systems, income levels, and policy interventions. Overall, the EU demonstrated progress, but unevenly across regions and indicators, confirming that national structural and geopolitical factors still condition outcomes.

The evidence confirms that the three pillars are deeply interconnected, as highlighted in the theoretical discussion (Chapter 2). Synergies arise when diversification and renewables enhance both security and sustainability, while affordability benefits in the longer term from lower import dependence. Trade-offs occur when decarbonization policies raise short-term prices, or when affordability measures dilute incentives for efficiency. The EU's experience shows that pursuing one pillar in isolation is insufficient; balanced coordination is required. The international comparison with the USA and China reinforced this conclusion: the EU leads in sustainability but lags in affordability and remains import dependent, whereas the USA leverages domestic resource wealth to excel in security and affordability, and China combines massive renewable deployment with low regulated tariffs but remains heavily coal dependent.

The contribution of this thesis lies in integrating theoretical, policy, and empirical perspectives into a coherent framework that clarifies how the EU performs relative to its own goals and to global peers. By using harmonized indicators and publicly available data, the thesis provides transparency and comparability. Its limitations arise mainly from data availability and comparability (Eurostat, EIA, IEA, Statista use different definitions), and from the reliance on a limited number of indicators to represent broad policy areas. These limitations were mitigated by consistent methodology and transparent caveats, but they nonetheless suggest caution in interpreting some year-to-year differences.

Future studies should expand the scope by incorporating additional affordability indicators (e.g. energy poverty metrics, industrial price competitiveness), exploring sector-specific dynamics, and assessing the impact of new technologies such as hydrogen, energy storage, and digitalization. For policy, the findings highlight three priorities for the EU: (1) deepen structural diversification and demand-side efficiency to reduce import dependency, (2) sustain leadership in renewables while supporting laggard Member States, and (3) redesign electricity markets to improve affordability while maintaining decarbonization incentives. Coordinating these dimensions will be essential for achieving the EU's long-term climate-neutrality objective.

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