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KYIV SCHOOL OF ECONOMICS
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MASTER’S THESIS

“Impact of Russia’s 2022 Energy Weaponization on Poland’s Renewable Energy Transition”

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Abstract. The main analysis of this thesis is to research how and whether Russia's 2022 energy weaponization acted as a driver for accelerating Poland's renewable energy transition. Recent literature suggests that energy crises can stimulate decarbonization, but there is limited empirical research quantifying this effect. The central analytical question is: to what extent did Russia's 2022 energy weaponization accelerate Poland's transition from Russian fossil fuels toward renewable energy, as measured by the change in the electricity sector share of renewable energy sources (RES)? To find out this, the study employs an exploratory research design and utilizes two regression models: a panel model and a change model, based on data from 30 European countries for the period 2021–2023. The findings indicate a significant relationship: countries that reduced their reliance on Russian fossil fuel energy indicated a measurable increase in their renewable electricity %. Poland was an outlier according to the change regression model expectations, reflecting a proactive political and institutional reaction to the energy crisis. Thus, the conclusion is that geopolitical threats can accelerate renewable transitions, but outcomes depend on national capacities and strategies. However, limitations such as potential endogeneity (spurious correlations) and the short time horizon suggest the need for quasi-experimental research in future studies. This work contributes new empirical evidence to the theories of energy security and energy transition, highlighting the potential of crises to drive structural decarbonization under good governance and strategic institutional decision-making.

Key words: energy transition, energy security, energy weaponization, renewable energy sources, decarbonization.

Number of words: 8046.

1. INTRODUCTION

In recent years, scholars in energy security, economics, and sustainability studies have increasingly explored how external shocks shape energy transitions, particularly in states with high fossil fuel dependency. The concept of energy weaponization, where states strategically manipulate energy flows to exert geopolitical leverage (Grigas, 2017; Blank & Kim, 2016), has resurfaced in academic debates following Russia's full-scale invasion of Ukraine in 2022. Concurrently, the literature on crisis-induced transitions (Overland, 2019) and energy sovereignty (Kuzemko et al., 2022) suggests that security threats can accelerate the shift to renewable energy, particularly when it is framed as a systemic risk. The theoretical understanding of the energy transition has been expanded by these new developments from a purely economic or technological challenge to one that is also shaped by security imperatives, institutional capacity, and political agency. Within this evolving academic landscape, empirical research on energy security and decarbonization connections has become a primary subject.

Despite extensive policy attention, academic debates, and a surge in energy-related legislation. There is a lack of empirical research that quantifies the impact of Russia's 2022 energy weaponization on national energy systems, particularly in terms of accelerating the adoption of renewable energy in Europe. The analytical problem this thesis addresses is the empirical gap in understanding whether and how the 2022 geopolitical shock of Russian energy weaponization translated into measurable increases in renewable energy shares, with a focus on electricity generation. Existing literature often assumes that crises lead to structural energy transitions, but rarely tests this hypothesis with comparative data across countries. Poland presents a compelling case: historically reliant on Russian fossil fuels, it has demonstrated unusually rapid growth in renewable energy deployment since 2022. However, it remains unclear whether this reflects a broader pattern or a national exception.

This leads to the central analytical question of this thesis: To what extent did Russia's 2022 energy weaponization accelerate Poland's transition from Russian fossil fuels toward renewable energy, as measured by changes in the share of renewables in its electricity sector?

Other sub-questions include: how did Poland's reliance on Russian energy imports change between 2021 and 2023? What was the corresponding change in the share of renewables in its electricity mix? How does Poland's trajectory compare with other European countries based on the same indicators?

To address these questions, this study employs an exploratory research design. This approach is appropriate given the limited existing empirical work in this area and the need to investigate emerging patterns rather than test a fixed theoretical model. The exploratory design enables the analysis of a short time horizon (2021-2023). Poland, as a case study for this thesis, does not align with the renewable energy transitions of other European countries, according to the change regression model. This divergence shows the strength of this thesis, it gives identification of new empirical relationships and proposes hypotheses for future researchers. Speaking of limitations, here could be identified the difficulty of establishing definitive causality.

Future researchers could leverage further expanding comparative regression models, including adding broader time series to them.

The structure of the thesis: Chapter 2 reviews the academic literature on energy weaponization, energy security, the relationship between economic development and renewable energy transition, and different decarbonization paths in Europe. Chapter 3 outlines the analytical framework, including conceptual definitions and theoretical assumptions guiding the research. Chapter 4 describes the methodology, including data sources analysis, operationalization of variables, and the rationale for model selection. In Chapter 5, there are the empirical results of the panel and change regression models, and Chapter 6 discusses the implications of the findings, including their alignment with theoretical expectations, key limitations, contributions to the field, and future research directions. Finally, Chapter 7 offers policy recommendations for policymakers.

2. LITERATURE REVIEW

2.1 Energy weaponization and energy transition acceleration

Scholars such as Grigas (2017) and Blank and Kim (2016) argue that Russia has systematically used energy exports, particularly natural gas, as instruments of geopolitical coercion to exert leverage over dependent states. While Grigas (2017) highlights the long-standing strategic nature of Russia's energy policies, Blank and Kim (2016) emphasize that energy weaponization is not an occasional tactic but a sustained and integrated element of Russia's broader national security strategy. Their analysis illustrates how Moscow's manipulation of energy markets has aimed to fracture European cohesion and reinforce Russian political influence. Russia attempted to create vulnerabilities, but European countries have responded with increased efforts toward greater energy diversification and resilience. These trends underscore the importance of researching how Russian energy weaponization and European counries reliance on Russian fossil fuels affect energy transitions at the national level.

Other scholars posit that energy weaponization can act as a catalyst for rapid decarbonization. Overland (2019) asserts that crises often trigger strategic shifts toward renewables as states seek to reduce vulnerabilities and achieve greater energy autonomy. Harmsen et al. (2024) project that Europe's accelerated shift to renewables following the 2022 crisis could lower CO_2 emissions by 1% to 5% by 2050. This study suggests a measurable and lasting impact on the European countries energy transitions. These insights align with other authors focusing on crisis-driven transitions, where external shocks disrupt existing energy systems. This development could also open political space and social acceptance for accelerated technological change in deploying renewable energy sources. In the European context, the urgency to reduce dependency on Russian fossil fuel energy has merged with the need to achieve climate goals and become the first carbon-neutral continent by 2050, according to the European Green Deal objectives. The issue that appeared is to enforce both the level and speed of the energy transition while simultaneously diversifying suppliers and investing to build balanced energy systems among EU member states. These dynamic highlights the critical role of geopolitical factors in shaping the pace of structural decarbonization across national energy systems.

While the geopolitical and economic consequences of the invasion have been widely analyzed, there is limited empirical work quantifying how energy weaponization affected the pace and scale of national energy transitions, specifically percentage of renewable energy sources (RES) in electricity generation. For instance, scholar Schreurs (2023) argues that Russia's energy weaponization was the main factor that influenced the EU to speed up its climate efforts, accelerating "green" energy deployment. Kuzemko et al. (2022) further underline that the EU's response to the Russo-Ukrainian war shows return to more centralized management of energy policy in the process of decarbonization. One of the key initiatives in this shift was the European Commission's launch of the REPowerEU plan, which aimed to rapidly reduce reliance on Russian fossil fuels (fully eliminating dependence on Russian energy sources by 2027) (European Commission 2024b), while advancing renewable deployment and infrastructure investment. This legislative response is referenced throughout recent literature as a pivotal moment in aligning energy security with decarbonization (Schreus, 2023; Kuzemko et al., 2022). Although Koilo (2024) does not reference specific legislation or EU initiatives, their time-series analysis (2000-2023) supports the broader conclusion that structural changes in energy policy were triggered by the Russo-Ukrainian war, higher energy prices, and led to shifts in investment patterns and energy mix structure across the EU member states in 2022-2023 period.

The EU's sanctions on Russian energy were substantial, targeting key revenue streams such as seaborne crude oil and refined petroleum products. Banning 90% of Russian oil imports and prohibiting coal imports, which accounted for approximately one-quarter of Russia's global coal exports, resulted in significant economic losses for Russia, estimated at €8 billion annually from coal alone (European Commission, 2024a). The idea of these measures was to decrease Russian economic capabilities and profits of its energy companies, decrease dependence, make it harder to finance the war in Ukraine, and incentivize Member states to diversify their supply.

In tandem with these sanctions, the REPowerEU initiative catalyzed a rapid acceleration in renewable energy deployment. Since 2022, the EU installed a record 96 GW of new solar energy capacity and added 33 GW of wind capacity, contributing to renewables accounting for 46% of the EU's average electricity generation (European Commission, 2024b). Furthermore, the revised Renewable Energy Directive in November 2023 set a binding target leveling up the percentage of renewables in the EU's overall energy consumption to at least 42.5% by 2030, with the ambition to reach 45% (European Commission, 2024b).

Between 2021 and 2023, the volume of EU energy imports from Russia dropped by approximately 84%, falling from about 26% to just 4% of the EU's primary energy consumption (Bruegel, 2024). To be more specific, the imports of natural gas dropped by 83%, crude oil imports from Russia declined by 90%, and coal imports stopped entirely. The EU demonstrated resilience, maintaining energy security through internal solidarity and market adaptability, considering a serious reconfiguration of energy supply. For instance, such an instrument as AggreagateEU is used to implement demand aggregation and to support coordinated purchasing of natural gas at the European level. Additionally, Ukraine fully stopped the transit of Russian gas via its gas infrastructure at the beginning of 2025. However, the question arose of how to effectively balance the energy system mix, minimize high energy prices, and maintain competitiveness for the industry and the EU economy overall (Bruegel, 2024).

Collectively, these policy measures and their outcomes underscore the EU's commitment to reducing dependence on Russian fossil fuels and advancing its energy transition. The intersection of energy security and decarbonization strategies is quite new phenomenon that has not only been reshaping the EU's energy landscape but also providing a promising framework for empirical analysis of the impacts of 2022 Russian energy weaponization on energy policy but also on the scale of progress in the scope of RES in the energy mixes across the EU and other European states.

On the other hand, skepticism remains. Palle (2021) emphasizes that geopolitical and institutional power dynamics can limit energy transitions, with existing resource control and political interests resisting change to a new national energy structure. Similarly, Kivimaa and

Sivonen (2024) highlight that while geopolitical shocks such as the Russia–Ukraine war create pressures for transition, the outcomes depend heavily on domestic interpretations and policy responses. These perspectives suggest that external crises alone do not automatically drive structural decarbonization. Instead, they must be matched by intentional political agency and leadership to achieve institutional adaptation.

2.2. Economic development and energy transition

Economic development and renewable energy transitions are shaped by a country's capacity to invest, innovate, and adapt its energy infrastructure. A growing body of research examines how economic development levels impact the feasibility, pace, and effectiveness of the energy transition. High-income countries are generally better equipped to invest in infrastructure, deploy advanced technologies, and implement supportive policy frameworks, giving them a structural advantage in the clean energy transition (Li & Han, 2023; Demiral & Demiral, 2021). The latter also benefit from stronger institutions, higher human capital, and more resilient financial systems that can better manage the complexities of decarbonization in the long term (Alfalih, 2024). However, energy transitions also reveal intra-European disparities: Šikić (2020) finds that in developed EU economies, the adoption of renewable energy can dampen short-term growth, and in post-transition countries, it tends to stimulate economic expansion. This suggests structural readiness and legacy energy systems strongly condition the growth impact of renewables.

Further EU-focused studies support this view. Jóźwik et al. (2024) show that while renewables contribute positively to economic growth in the EU, their effect remains more fragile than that of non-renewables, but in the long term, in countries with high levels of non-renewable energy consumption, rising non-renewable consumption leads to a decrease in economic activity. Other scholars like Brodny et al. (2021) and Relich (2024), also underline differences in developing RES among EU member states. For instance, they mention Sweden and Finland as leaders in this process because of institutional, financial, and location advantages. While Prokopenko et al. (2024) further caution that the European energy transition, although environmentally necessary, may entail economic and ecological trade-offs, particularly for countries with carbon-intensive starting points.

In contrast, low-income countries outside the EU face even more fundamental constraints. These include limited access to capital, weak governance, and underdeveloped technical capacity, which hinder large-scale renewable adoption (Wandera et al., 2021; Ben Cheikh & Ben Zaied, 2024). Gozgor and Paramati (2022) show that while energy diversification benefits high-income countries over the long run, it may dampen economic activity in developing economies due to short-term volatility and institutional barriers. Adom (2024) further warns that unless "big push" investments are directed toward improving energy access and efficiency in lower-income states, the sustainability gap between the global North and South will deepen, exacerbating global energy inequities. Similarly, Vezzoni (2023) critiques the notion of "green growth," warning that the rapid expansion of renewables under REPowerEU may reproduce extractive dependencies, especially in critical raw materials, while reinforcing unsustainable economic models based on extraction or import resources needed for energy transition from developing countries where there is no strict legal basis to protect environment during these activities.

Considering the existence of such distinct opinions, there is a need to consider both the developmental opportunities and distributional consequences of energy transition policies, particularly in the context of crisis-driven shifts such as those prompted by Russia's 2022 energy weaponization in Europe. Thus, it is even more important to investigate more deeply how European states coped and reacted in the process of their renewable energy transition to the energy crisis provoked by Russia, considering their pre-2022 high dependence levels on Russian fossil fuels for a big chunk of them.

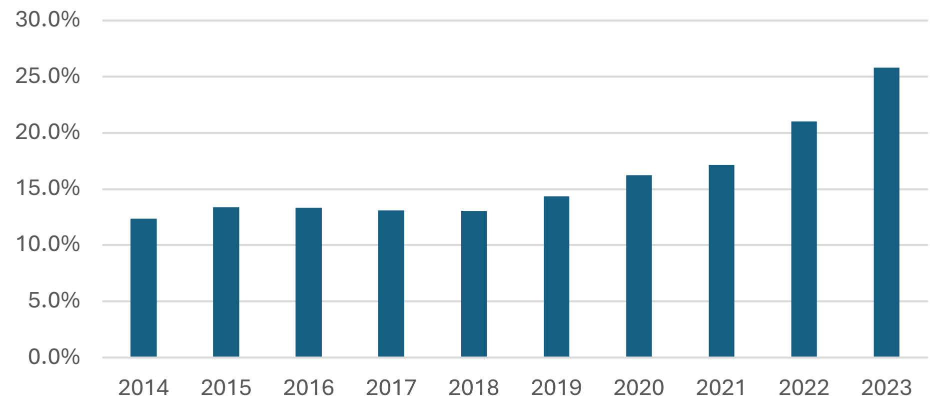
2.3 Multi-speed energy transition in Europe

Mata Pérez, Scholten, and Smith Stegen (2019) describe the "multi-speed energy transition" in Europe, where renewable energy deployment varies considerably across countries. They identify two clusters: the "green cluster" (e.g., Germany, Denmark, Netherlands), which perceives renewables as an economic and security opportunity, and the "blue cluster" (e.g., Poland, Czechia, Hungary), which views renewables as costly and unreliable, prioritizing fossil fuels and gas interconnectors for energy security.

Poland has traditionally belonged to the blue cluster due to its high reliance on coal and cautious approach toward EU climate initiatives. However, evidence suggests a post-2022 divergence from this pattern. Poland reduced its coal consumption, increased solar PV deployment, and invested in infrastructure diversification through projects like the Baltic Pipe (BGK, 2024; Hillebrand, 2023). Considering these insights, Poland could be viewed as an interesting case to research further.

The article also emphasizes the geopolitical and policy consequences of this East–West divide, noting that countries like Poland have historically resisted ambitious EU RES targets to domestic political, infrastructural, and employment concerns (Mata Pérez et al., 2019). However, Poland's recent actions—such as reducing coal production, expanding solar PV, and engaging in infrastructure diversification (e.g., Baltic Pipe)—suggest a shift from the typical blue-cluster profile, possibly indicating a unique response to energy weaponization, which you can see below in Figures 1 and 2.

Figure 1. Created by using Excel. Shows RES share in eletricity sector in Poland in the period of 2014-2023



Note: Source: Eurostat (2025).

2.4. Social significance

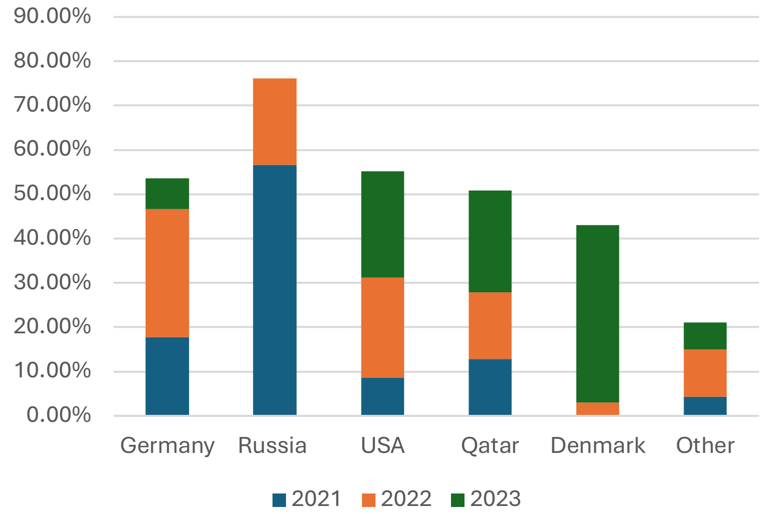
Multifaceted ramifications of Russia's full-scale invasion of Ukraine in 2022 and the energy crisis provoked by Russia in Europe have significantly influenced the energy market in Europe. EU member states made unprecedented changes in energy policy and legislation in response to Russia's weaponization of energy exports in 2022, aiming to replace Russian fossil fuels with domestic or diversified alternatives. This disruption activated not only a geopolitical recalibration but also a reevaluation of the relationship between energy security, sustainability, and social stability — the core of the EU energy trilemma (OSW, 2025).

For the Polish case, the significance of this transformation cannot be overstated. Ten years ago, Poland relied on Russia for around 84% of its fossil energy imports (Zaniewicz; Savytskyi, 2025), while its electricity mix remained among the most coal-intensive in the EU. Within two years, Poland eliminated imports of Russian oil, gas, and coal and increased its RES share in electricity from 17.2% in 2021 to 25.8% in 2023 (Figures 1,2,3,4). Among the seven largest electricity producers in the EU, only Poland was able in 2022 to reduce coal-based electricity production, limit gas consumption, and simultaneously develop renewables (Hillebrand, 2023). This marks a dramatic pivot — from energy conservatism to regional leadership in transition.

The social stakes of this shift are profound. Rising energy prices, aging infrastructure, and the costs of transition pose risks to economic competitiveness, energy affordability, and social cohesion. Poland in H1 2024 had among the highest electricity and gas prices in the EU (Figures 5,6), affecting sectors like steel and chemicals and exacerbating regional inequalities (OSW, 2025). As a result, managing a just transition — especially in coal-dependent regions — has become central to maintaining public support for decarbonization.

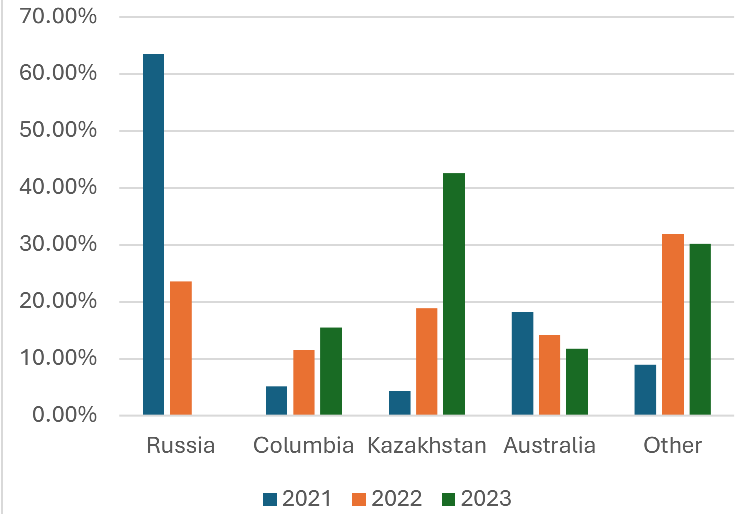
More broadly, this research is socially significant because it offers an empirical basis for evaluating the effectiveness of policy responses to energy weaponization. While countries like Hungary and Slovakia continue to depend on Russian gas, oil, and nuclear fuel, Poland's accelerated diversification (Figures 2, 3) and renewable deployment (Figure 1) suggest that political will and infrastructure investment can drive rapid energy transformation, even under crisis conditions. This aligns with an increasing number of arguments by scholars that clean energy transitions are no longer just environmental imperatives but have become essential instruments for enhancing state sovereignty and democratic resilience, particularly in response to Russia's weaponization of energy in 2022 (Goldthau & Sitter, 2022; Kuzemko et al., 2022). Goldthau and Sitter (2022) note the change in the perception of RES towards the securitization, which elevated them to the level of national interest, activating state-led measures to accelerate decarbonization and restructure energy markets. Similarly, Kuzemko et al. (2022) frame clean energy policy as central to Europe's geopolitical and democratic response, while also highlighting new strategic dependencies such as critical raw materials (CRMs), which are crucial to renewable technologies. In the EU as a supranational organization energy transition goals will likely require a shift from the EU's liberalized energy governance model toward more centralized, state-coordinated approaches. Taking these insights into account underscores the increasing integration of climate, security, and industrial strategy in European energy policymaking.

Figure 2. Created by using Excel. Shows *change in Poland's natural gas import structure (2021–2023)*



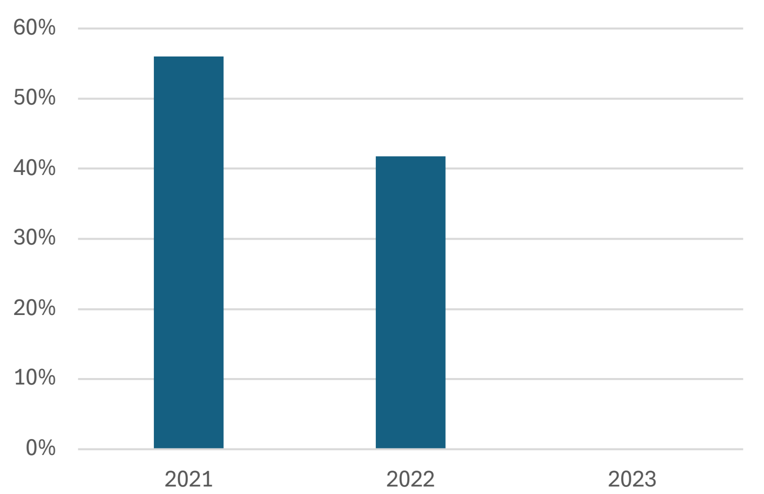
Note: Source: BGK (2024).

Figure 3. Created by using Excel. Shows *Coal import dependency in Poland*



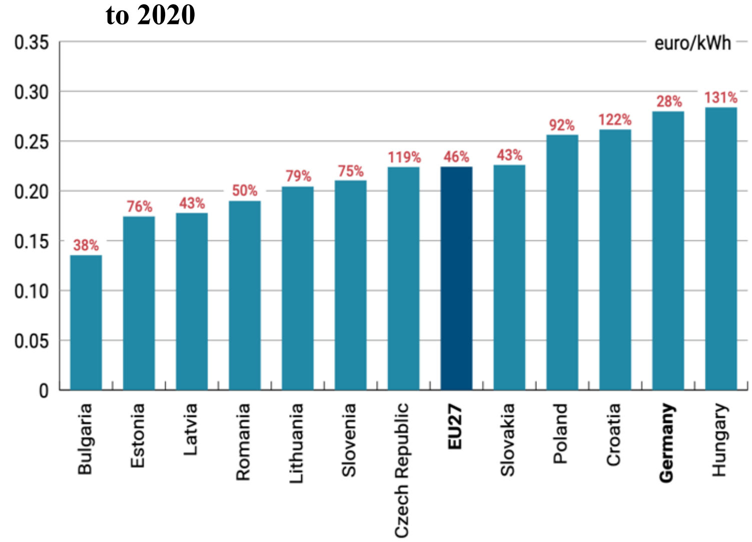
Note: Source: BGK (2024).

Figure 4. Created by using Excel. Share of oil imports from Russia in Poland



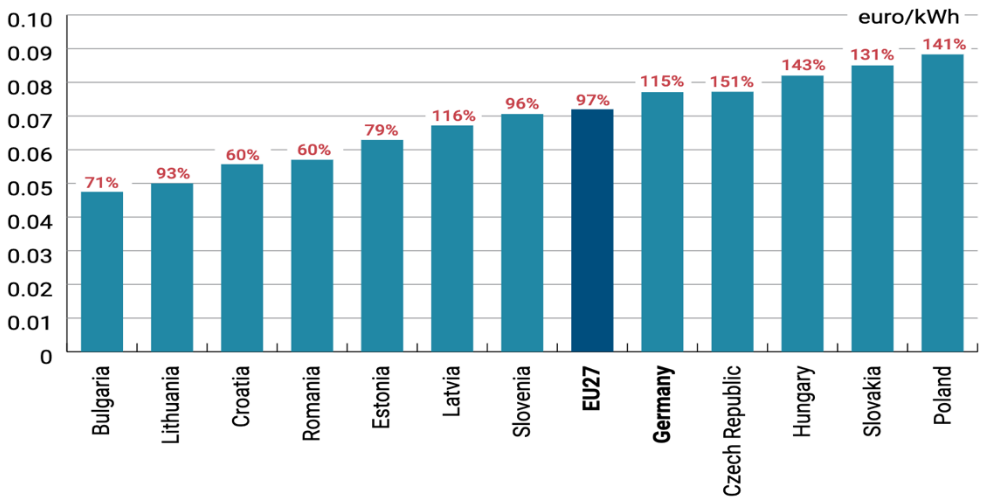
Note: Source: BGK (2024), Eurostat (2024).

Figure 5. Electricity prices for medium-sized enterprises* in H1 2024 and change compared to 2020



Note: *consumption for consumers using between 500 MWh and 1,999 MWh (band IC). This is significant, as different consumer groups in various countries are subject to different tariffs and, in some cases, benefit from exemptions or compensation schemes. For example, in Germany, the largest industrial energy consumers pay significantly less (excluding VAT). Source: OSW (2025)

Figure 6. Natural gas prices for medium-sized enterprises in H1 2024



Note: for consumption between 10,000 GJ and 99,999 GJ (band I3). Source: OSW (2025).

Recent policy studies similarly underscore that achieving both decarbonization and resilience will require systemic reforms in EU energy coordination and infrastructure planning. As EU member states navigate rising energy costs, cross-border integration challenges, and the need to reform energy governance, the Forum Energii and Bruegel report (2025) emphasizes that aligning energy security with sustainability requires coordinated EU action, investment in clean technologies, and a shift toward more collective infrastructure planning.

In the ongoing debates, a critical gap in empirical research persists. Most existing studies rely on scenario modeling, policy declarations, or macroeconomic analysis. However, there is a need for empirical research that directly measures how the national renewable energy structure changed between 2021 and 2023 in response to Russia's 2022 energy weaponization. The causal relationship between decreasing reliance on Russian fossil fuels and renewable energy deployment in the electricity sector across European countries remains underexplored and insufficiently quantified in the existing literature.

2.4 Analytical problem and analytical question

In summary, although theoretical and policy-oriented works highlight the possible acceleration of energy transitions due to geopolitical crises, empirical validation is sparse. Limited studies have measured how much the renewable energy share shifted in Europe, specifically in Poland, due to Russia's energy weaponization during 2021–2023.

Analytical question: to what extent did Russia's 2022 energy weaponization accelerate Poland's transition from Russian energy fossil fuels toward renewable energy deployment, as measured by changes in the share of renewables in its electricity sector? To answer this analytical question, I plan to use the analytical framework below.

3. ANALYTICAL FRAMEWORK

3.1 Conceptualization

Energy weaponization: the deliberate use of energy exports to achieve geopolitical objectives (Grigas, 2017). This study adopts Grigas' definition because it captures both the intentionality and the structural dependencies inherent in energy relations between Russia and Europe.

Energy transition: the shift to a more sustainable energy system entails switching from fossil fuels to low-carbon and renewable energy sources, improving energy efficiency in products, industry, and buildings, and creating a more sustainable energy system based on clean technologies (Widuto, 2023). The majority of sustainable energy is renewable energy. Thus, another term for energy transition is renewable energy transition. This concept is selected for its relevance to measurable energy metrics (e.g., RES share in electricity generation).

Energy security: this thesis adopts a multidimensional understanding of energy security that reflects both traditional concerns, such as stable supply and affordability, and increasing demands related to resilience, sustainability, and state autonomy. Initially, this term centered on fuel availability and economic price stability; energy security today increasingly encompasses system flexibility, infrastructure robustness, and reduced vulnerability to external shocks. While in the context of the sustainable energy transition, energy security is best understood as the capacity of energy systems to deliver reliable and affordable services while adapting to climate, technological, and geopolitical disruptions (Bruegel; Energy Forum, 2025).

The selected definitions reflect prevailing views in both energy geopolitics and energy transition research. They allow empirical operationalization through observable indicators such as changes in the share of renewables in the electricity and Russian fossil fuels import reliance rates in Europe.

Typology: for clarity, energy weaponization can be categorized into direct coercive threats (e.g., supply cuts) and indirect market manipulations (e.g., price volatility). Renewable energy transitions can be categorized by the primary technology (for instance, solar, wind, hydro, bioenergy) and by their contribution to national energy independence.

3.2 Theoretical framework

This study theorizes that external geopolitical shocks - specifically, Russia's energy weaponization - constitute a critical driver of renewable energy transitions under certain institutional frameworks in Europe.

This section expands the concept of energy security in line with recent academic and policy thinking and is grounded in the evolving field of energy security theory. In a nutshell, the classical approach to energy security meant conditions where a country had access to available, sufficient energy supplies at affordable prices without focusing on whether these energy sources were fossil fuels or RES. However, currently, an increasing number of energy experts and international organizations suggest a new enhanced description to analyze this concept. For instance, Watson and Page (2023) propose “a more comprehensive and coherent strategy is urgently needed that integrates energy security with the imperative to tackle climate change”. They propose that the concept focus on: reduction of energy demand, introduction of social tariffs to shield the most vulnerable, rapid deployment of non-fossil energy sources, strategy for a skills transition in the supply chain and risks associated with the legacy fossil fuel energy system, and emerging risks associated with critical materials, digitalisation and interconnection (Watson; Page, 2023). Nowadays, these developments provide a theoretical foundation for understanding how energy transitions are increasingly shaped not only by security imperatives but also by environmental and market-based considerations, where in the future it would be simply more economically costly to produce, supply, and consume fossil fuels.

Numerous definitions of energy security have been proposed, based on methods drawn from economics, political science, and engineering. The concept is widely recognized as context-dependent, with its meaning varying across countries and situations (Bruegel; Forum Energii, 2025.

Table 1. Definitions of energy security

Author	Definition
IEA	“uninterrupted availability of energy sources at an affordable price”. Note: Source: IEA, 2025.
OSCE	“having stable access to energy sources on a timely, sustainable and affordable basis” Note: OSCE, n.d.
United Nations	“access to affordable, reliable, sustainable, and modern energy for all” Note: Source: UN, 2017.
European Commission	“uninterrupted physical availability of energy products on the market at a price affordable for all consumers” Note: Source: European Commission, 2000.

Traditionally, it has been defined in two dimensions: physical (availability and reliability of supply) and economic (affordability and market stability) (Bruegel; Forum Energii, 2025). For example, Yergin (2006) summarized energy security as the "availability of sufficient supplies at affordable prices." The Asia Pacific Energy Research Centre (2007) proposed the “four As” framework: availability, accessibility, affordability, and acceptability, further emphasizing the complexity of energy security. More systemic approaches define it as a property of energy systems, focusing on their capacity to withstand various risks and adapt over time through stability, resilience, durability, and robustness. (Jones, O., & Dodds, P.,2017). In the context of clean energy transitions, energy security now encompasses the ability of energy systems to maintain continuous and sustainable services while managing challenges from climate change, digitalization, critical raw material (CRM) dependencies, and geopolitical disruptions. This includes both the protection of existing infrastructure and the strategic restructuring of supply chains. Thus, for the purpose of this study, energy security is defined as the capacity of an energy system to ensure uninterrupted, affordable, and sustainable energy access while adapting to climate constraints, managing technological dependencies, and withstanding geopolitical or market disruptions. (Bruegel; Forum Energii, 2025). This framework supports the thesis's investigation into how geopolitical shocks, particularly the 2022 Russian energy weaponization, affect national trajectories of renewable energy deployment.

The causal mechanism proposed here is that an external shock, which is perceived as a threat to national energy security, in this case, Russian energy weaponization in 2022, which is proposed to be reflected as European countries dependence on Russian fossil fuels (2021-2023), can influence strategic policy realignment and infrastructure investments, expand RES generation and as a result increase the share of RES in electricity generation in Europe.

Expected relationship:

- The greater the reduction in dependence on Russian energy, the greater the subsequent increase in the renewable energy share within a country's electricity mix.
- The strength of this relationship is conditioned by domestic institutional capacity, EU policy support mechanisms (e.g., REPowerEU), and pre-existing infrastructure readiness.

Underlying assumptions:

- Geopolitical shocks are necessary but not sufficient; institutional readiness and political will mediate the effect.
- Renewable energy infrastructure has a lead time; thus, observed changes in the RES share may lag slightly behind political decisions.
- External shocks can act as "critical junctures" that accelerate policy change beyond typical incremental pathways (Pierson, 2004).

3.3 Hypotheses

I argue that:

H1: higher reliance of European countries, specifically Poland, on Russian energy imports is associated with a lower share of renewables in their electricity mix, and this relationship may have changed after the 2022 invasion of Ukraine.

H0: there is no significant relationship between reliance on Russian energy imports and the share of renewables in the electricity mix of European countries, specifically Poland, and this relationship did not change after the 2022 Russian invasion of Ukraine.

Operationalization of variables for the panel model of 30 European countries for the period of 2021-2023:

- Independent variable (X): Russian energy reliance per year (%).
- Dependent variable (Y): renewable electricity share per country-year (2021–2023), (%).

- Dummy variable: I used the Russian post-invasion of Ukraine in 2022 as a dummy variable: 0 = 2021, 1 = 2022/2023.
- Interaction: I tested if the effect of reliance changed after 2022.

In the minimal panel model, the dependent variable is the renewable electricity share per country-year for 2021 to 2023. The key independent variable is the Russian energy reliance of these 30 European countries, along with a post-invasion dummy variable. An interaction term between these two variables was included to test whether the effect of Russian reliance on RES share changed after the 2022 invasion in 30 European countries.

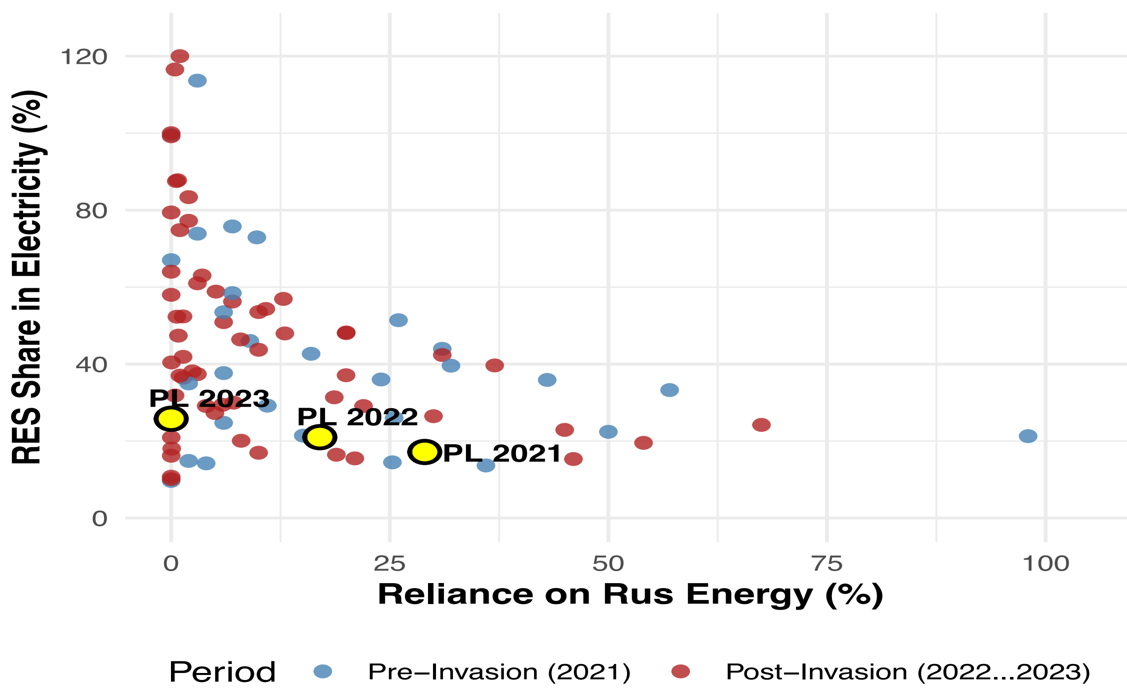
The analytical framework sets the theoretical and empirical foundation for testing the proposed hypotheses and evaluating Poland's renewable energy trajectory within the broader European context.

4. METHODOLOGY

This thesis applies an explanatory research design, using a quantitative comparative method supported by a case study, focusing on Poland. The design follows the institutional analytical framework, recognizing that external geopolitical pressures and domestic institutional arrangements shape renewable energy transition pathways. The aim is to evaluate whether and how Russia's energy weaponization in 2022 influenced the pace of renewable energy deployment in European countries, with a focus on national variation and institutional response.

The primary dependent variable is the share of renewable energy sources (RES) in electricity generation (*res_share),* a direct and observable metric of RES extracted from Eurostat (Eurostat, 2025). The main independent variable is Russian energy reliance (*rus_reliance*), measured as the percentage of total energy imports sourced from Russia extracted from the IEA for the years 2021-2022 and 2023 year results were calculated using data from Eurostat (IEA, 2023; Eurostat, 2023, 2025). A binary post-invasion indicator (*post_invasion*) was included to distinguish between pre- and post-2022 observations.

Figure 7. Created by using R. Shows the relationship between Russian energy reliance and the share of renewable energy in electricity generation across 30 European countries (2021–2023). Each point represents a country-year.



Note: colors differentiate pre-invasion (2021) and post-invasion (2022–2023) periods. The visualization complements the regression analysis by showing how Poland's (PL) renewable trajectory (yellow color) compares to other countries across the same period.

A second analytical approach involved constructing change variables, calculating:

- *delta_res*: change in RES share (2023 – 2021), and
- *delta_reliance*: change in Russian energy reliance (2021 – average of 2022–2023)

These variables allowed for a more focused test: whether countries that reduced their dependence on Russian energy also saw a corresponding increase in renewable electricity deployment.

I used the *dplyr* and *tidyr* packages to clean, organize, and merge data from different sources. *dplyr* helped me filter, rename, and summarize data, while *tidyr* helped me reshape it into a format suitable for analysis (e.g., converting wide tables into long format for regression). These steps were essential to prepare a clean and consistent dataset that I could use in my statistical models.

5. RESULTS

5.1 Regression model descriptions

Two linear regression models were applied. The first was a panel model (*model_min*) estimating the effect of Russian energy reliance (*rus_reliance*), the post-invasion dummy (*post_invasion*), and their interaction on *res_share*.

Model_min (*res_share ~ rus_reliance * post_invasion*)

This model tests whether higher Russian energy reliance correlates with lower renewable electricity share, and whether that changed after the 2022 invasion.

Key finding: Russian energy reliance is significantly negatively associated with RES share ($\beta = -0.437$, $p = 0.016$, robust standard errors used).

The post-invasion dummy and the interaction term are not significant, suggesting that while the relationship is strong, it didn't shift meaningfully post-invasion across all countries.

Poland stands out as a clear outlier in the panel regression model. While the model showed a significant negative association between Russian energy reliance and renewable electricity share ($\beta = -0.437$, $p = 0.016$), Poland appears closer to the model's expected trend, given its complete elimination of Russian reliance by 2023. However, its rapid RES growth, from 17.2% in 2021 to 25.8% in 2023, remains impressive and reflects strong national acceleration. The fact that Poland began from a lower-than-average baseline may explain the gap between actual and predicted values. The upward trend nonetheless indicates a strong post-invasion acceleration consistent with energy security motivations.

The second, a change model (*model_change*), tested the relationship:

Equation 1. Regression model testing whether reductions in Russian energy reliance (2021–2023) are associated with increased renewable electricity share. I used this equation to see if countries that reduced their dependence on Russian energy also increased their use of renewables. This simple equation helped me quantify that relationship across all 30 countries. It is easy to interpret and directly matches my hypothesis:

$\Delta RES_{2023-2021} = \beta_0 + \beta_1 \Delta Reliance_{2023-2021} + \varepsilon$, where $\Delta RES_{2023-2021}$ - is the change in renewable energy share between 2021 and 2023. It's the outcome I want to explain**;** β_0 (beta-zero) - the intercept — it shows the average change in RES when the change in Russian reliance is zero; β_1 (beta-one) - the slope — it tells us how much the RES share increases or decreases for each 1% change in Russian energy reliance. This is the most important number in the model; $\Delta Reliance_{2023-2021}$ - this is the change in how much energy a country imported from Russia between 2021 and 2023. It's the main variable I'm testing; **ε** (epsilon) - this is the "error term" — it represents the part of the change that can't be explained by this model (random or unknown factors).

The change model returned a statistically significant result: for every one percentage point decrease in Russian energy reliance, countries experienced an average increase of approximately 0.12 percentage points in their renewable electricity share ($\beta = 0.119$, $p = 0.0014$). Even countries that did not reduce their reliance were expected to increase RES share by ~4.8 percentage points (*model intercept*).

Model_change (*delta_res ~ delta_reliance*)

This model assesses whether countries that reduced their dependence on Russian energy also experienced greater growth in RES share between 2021 and 2023.

Key finding: a statistically significant positive relationship ($\beta = 0.119$, $p = 0.0014$), with robustness checks performed.

Interpretation: every 1 percentage point drop in Russian energy reliance is associated with an average of around 0.12 percentage point increase in renewable electricity share.

Poland outperforms: after a 24.7 percentage point drop in Russian energy reliance, its 8.6 percentage point gain in RES share slightly exceeded the model-predicted 7.8%. This continues to highlight Poland's proactive transition.

Outlier & variability

Beyond Poland, several other European countries showed strong divergences from the model's predicted renewable energy trajectories, as measured by residuals in the change model.

Austria (+13.9% actual vs. 5.1% predicted), Spain (+10.9% vs. 4.4%), Sweden (+11.8% vs. 5.6%), Greece (+12.3% vs. 7.6%), and Finland (+12.8% vs. 8.5%) stand out as strong overperformers, exceeding model expectations by 4.3 to 8.8 percentage points. These cases likely reflect a combination of structural readiness, favorable renewable resource funds, and proactive 2022 post-invasion energy policies. Hungary, Slovenia, and Cyprus also moderately outperformed, each exceeding their predicted values by around 2 percentage points or more.

Poland, after reducing its reliance on Russian energy to zero by 2023, recorded an 8.6 percentage point increase in renewable electricity share, outperforming prediction of 7.8%. This suggests that Poland's green transition was strongly driven by institutional policy shifts and energy security imperatives, even if it did not appear as an extreme statistical outlier.

On the other hand, several countries underperformed relative to the model. Switzerland experienced a slight decline in RES share (–3.0 p.p.), despite a predicted gain of 3.2%, while Italy increased RES share by only 2.1% versus a predicted 4.4%. Malta, Iceland, and Latvia also fell short, though each started from very different energy baselines. Czechia and Estonia, for example, underperformed by roughly 2.3 and 2.6 percentage points, respectively. Slovakia showed a particularly sharp underperformance, with just a 1.8 percentage point gain in RES share compared to a predicted 6.0% — a gap of over 4 percentage points. This suggests that structural or institutional inertia limited its response despite moderate reductions in Russian reliance.

A number of Central and Eastern European countries showed wide variability. Lithuania, was the strongest overperformer in the entire dataset: a 15.2 percentage point RES share increase versus a predicted 3.3%, yielding a residual of nearly +12. This result signals decisive policy execution and infrastructural mobilization. Romania and Bulgaria also exceeded predictions by 2–3 percentage points, likely aided by EU funding and regional integration mechanisms.

Interestingly, countries previously assumed to have "limited movement"—such as Germany, Denmark, and Hungary—also outperformed model expectations. Germany increased its RES share by 8.35% versus a predicted 3.3%, Denmark by 6.47% vs. 3.8%, and Hungary by 5.88% vs. 2.7%. These findings challenge the assumption that high pre-existing RES shares leave limited room for improvement, and suggest that even mature systems were capable of scaling further in response to geopolitical disruption.

These divergences reinforce the concept of a "multi-speed energy transition" within Europe. While some countries closely followed the model's expectations, others exceeded or fell short depending on domestic institutional readiness, infrastructural capacity, and policies in response to Russia's energy weaponization.

All statistical analyses were conducted in R. Modeling was performed using *lm(),* visualizations with ggplot2, and tables exported using *stargazer* and *modelsummary.* I used *lm()* to run regression models. It helps analyze the relationship between variables — for example, how changes in Russian energy reliance are related to changes in renewable energy share. It is a basic but powerful command for running statistical models. Also, I used *ggplot2* to create clean, professional-looking graphs that make it easy to see patterns in the data, such as which countries increased their renewables the most, or how Poland compares to others. This helps turn numbers into visual stories. Additionally, *stargazer and modelsummary* packages make nicely formatted tables from regression models. Instead of copying results manually, I used these tools to export my model results (like coefficients and p-values) into tables so that I can paste them into my thesis (Table 2). They make my results easier to read and more professional.

Table 2. Created by using R. Shows the regression results: minimal and change models

	Dependent variable:	
	Share of renewable energy sources in electricity (%)	Change in renewable energy share (%) between 2021 and 2023 in electricity
	Minimal Model	Change Model
	(1)	(2)
Reliance on Russian energy (%)	-0.437*	
	(0.179)	
Post-Invasion Period (Dummy: 0 = 2021, 1 = 2022–2023)	2.670	
	(8.473)	
Interaction: Russian Energy Reliance × Post-Invasion Period	-0.232	
	(0.241)	
Reduction in Russian Energy Reliance (%) between 2021 and 2023		0.119***
		(0.033)
Intercept (baseline level of RES share when other variables are 0)	50.014***	4.825***
	(7.218)	(0.794)
Observations	90	30
R^2	0.144	0.311
Adjusted R^2	0.115	0.287
Residual Std. Error	24.46 (df = 86)	3.822 (df = 28)
F Statistic	4.835** (df = 3; 86)	12.66*** (df = 1; 28)
Note:		*p<0.1; **p<0.05; ***p<0.01

5.2. Regression diagnostics and robustness checks

To validate the regression models and ensure reliable interpretation of their estimates, tests for multicollinearity and heteroskedasticity were conducted.

Multicollinearity among predictors was assessed for the panel regression model (*res_share ~ rus_reliance * post_invasion*) using Variance Inflation Factors (VIFs), calculated with the *car* package in R. Given the interaction term, the VIFs were calculated using *type = 'predictor'*, which correctly accounts for interaction effects. The resulting VIF values were well below the threshold of 5, specifically:

- Russian reliance (*rus_reliance*) had a VIF of 2.07;
- Post-invasion indicator (*post_invasion*) had a VIF of 1.73;
- Interaction term (*rus_reliance:post_invasion*) had a VIF of 2.27.

These values indicate no problematic multicollinearity, supporting stable regression coefficient estimates.

Heteroskedasticity (non-constant variance of residuals) was assessed for both regression models using the Breusch-Pagan test from the *olsrr* package.

For the panel model (*model_min*)**,** the Breusch-Pagan test indicated significant heteroskedasticity (Chi-square = 11.33, p-value < 0.001). Consequently, to ensure robust statistical inference, heteroskedasticity-consistent (robust) standard errors were calculated using the *sandwich* and *lmtest* packages in R. With these robust standard errors, Russian reliance (*rus_reliance*) remained statistically significant ($\beta = -0.437$, robust SE = 0.179, $p = 0.016$), while the interaction and post-invasion (dummy) indicators were not significant.

For the change model (*model_change*) (*delta_res ~ delta_reliance*), the Breusch-Pagan test found no significant heteroskedasticity (Chi-square = 0.72, p-value = 0.397). Thus, standard regression estimates and their interpretation remained fully reliable for this model.

I conducted the above check tests to confirm the validity and results of the analysis of my panel and change regression models.

6. DISCUSSION AND CONCLUSION

This thesis explored the empirical relationship of data analysis in R between Russia's 2022 energy weaponization and Poland's renewable energy trajectory in the broader European context.

The first model, the panel model, which analyzed the association between annual Russian energy reliance and renewable electricity % from 2021 to 2023, revealed a statistically significant negative relationship ($\beta = -0.437$, $p = 0.016$). This suggests that countries more dependent on Russian energy had a lower renewable %. The interaction term with the post-invasion dummy was not significant, indicating that the strength of this relationship did not shift universally after 2022. Interestingly, while Poland's RES share remained lower than the model's predicted level in 2023, its post-2022 growth trajectory underscores its unique policy response to Russian energy weaponization in 2022.

The second model, the change model, examined how countries renewable shares evolved in relation to changes in Russian energy reliance and offered more decisive evidence. It showed that for every one percentage point reduction in Russian energy dependence (2021-2023), countries experienced a ~0.12 percentage point increase in their renewable electricity % ($\beta = 0.119$, $p = 0.0014$) between 2021 and 2023. The result shows a strong positive relationship between energy decoupling from Russia and renewable expansion. Poland's full decoupling from Russian energy (–24.7 p.p.) coincided with an 8.6 p.p. increase in renewable deployment, slightly exceeding the model's predicted value of 7.75 p.p., and demonstrating strong national policy alignment with energy security imperatives.

The results of this study strongly support the hypothesis that geopolitical shocks can catalyze renewable energy transitions, as theorized in recent energy security and crisis-response literature (Grigas, 2017; Overland, 2019; Kuzemko et al., 2022). However, the evidence also highlights that such effects are conditional: not all European states reacted equally. This supports the "multi-speed energy transition" framework (Mata Pérez et al., 2019), where national responses diverge based on prior dependency levels, policy capacities, and strategic orientation. Theoretical expectations were largely confirmed, especially the role of crisis as a driver of structural decarbonization, but only when matched by coherent national strategies. Poland's deviation from its prior "blue cluster" status (prioritizing fossil security over green ambition) adds new empirical depth to discussions on how external threats can realign domestic energy policy trajectories.

Several limitations should be acknowledged. First, the statistical models used are observational and subject to endogeneity, particularly the risk of spurious correlation. While the models demonstrate a statistically significant association, they cannot definitively establish causality. Future researchers could add to the regression models such variables as pre-existing infrastructure investment plans, political changes, or broader macroeconomic shifts. These could be influencing both the reduction in Russian energy reliance and the increase in renewable deployment.

An experimental design might offer a more robust test of causal mechanisms. However, in the field of energy security, randomized experiments are ethically and practically unfeasible, given that geopolitical shocks cannot and should not be induced for research purposes. Future researchers may address this challenge using quasi-experimental methods to better isolate the causal impact of energy weaponization on transition pathways. These techniques could help correct for endogeneity and allow more confident attribution of effects.

Although more longitudinal data (beyond 2023) would strengthen the conclusions, the data collected, covering 30 European countries and capturing pre- and post-invasion dynamics, is sufficient to answer the central research question. The inclusion of both a minimal panel model and a change model enhanced the robustness of the research. Nonetheless, the short time window limits generalizability and temporal extrapolation. Observed changes may partly reflect temporary responses rather than long-term structural shifts. While the conclusions are analytically sound, they should be interpreted as indicative, not universal.

This thesis could saturate the academic literature in several ways:

It provides empirical validation of crisis-driven energy transitions, a claim often made but rarely quantified in energy security literature.

It brings new evidence from a Central and Eastern European context, where such transitions are frequently understudied compared to Western Europe.

It challenges deterministic approaches that assume fossil-dependent countries cannot lead in renewables, showing instead how Poland’s structural dependency was overcome through rapid diversification of alternative suppliers and sometimes costly but feasible and public policy decisions that aligned with energy and economic security considerations.

In this research, theoretical assumptions of crisis-driven acceleration of deployment of renewable energy sources were confirmed, but also concurrently, this thesis is instrumental in reframing Poland as a potential leader in the EU energy decarbonization process in the future.

7. POLICY RECOMMENDATIONS

Based on the findings of this thesis, several policy recommendations are proposed:

1. Support countries that commit to structural decoupling from geopolitical risk. Poland's case shows that with political will, infrastructure investment, and policy clarity, rapid renewable deployment is possible, even for countries previously heavily dependent on Russian energy. Early movers could be nudged through enhanced access to transition funding and infrastructure investment tools, such as the Connecting Europe Facility (CEF) by the EU. Supporting national strategies that align energy security with decarbonization not only strengthens resilience but also contributes to geopolitical stability across the continent.

2. Strengthen EU-level mechanisms for just transition funding. Considering that coal-dependent and economically vulnerable regions face high-cost energy transition pressure, mechanisms like the Just Transition Fund (JTF) and REPowerEU could prioritize equitable support for affected communities. It is crucial in the process of decarbonization to mitigate political backlash or regional polarization. Financing trainings for the most vulnerable, supporting the most affected people in finding jobs in the rapidly developing sector of renewable energy, and creating temporary social benefits during the process of energy transition could not be underestimated. Implementation of these instruments can help maintain public trust and decrease social resistance to climate action.

3. Integrate geopolitical resilience into energy planning. The weaponization of energy must be treated as a strategic threat to democratic governance, not just market efficiency or market principles should be considered. National energy climate plans (NECPs) of the EU states and candidate countries should permanently include possibilities of geopolitical risks, prioritizing energy source diversification with like-minded states, domestic clean energy capacity, and grid interconnectivity expansion. This requires shifting from reactive to anticipatory planning, supported by scenario modeling, cross-border action plan frameworks, and coordinated EU responses.

4. Ensure that emergency-driven energy transitions become permanent. The surge in renewable energy deployment following Russia's invasion of Ukraine must not be allowed to fade once the Russo-Ukrainian war ends. National governments should embed renewable expansion in long-term regulatory frameworks, including binding capacity targets and streamlined permitting processes with strict monitoring of the sanctions regime against Russia. Institutionalizing these gains is essential to avoid regression into fossil fuel dependency under future market pressures or political cycles.

5. Encourage regional leadership and knowledge-sharing. Poland's rapid transition offers valuable lessons for other Central and Eastern European (CEE) countries still struggling with fossil dependency. EU platforms should incentivize peer learning through technical cooperation, joint investment projects, and policy mentoring. A stronger east–west integration in transition leadership would help bridge the "multi-speed" energy transition divide and foster more cohesive EU climate governance.

6. Support Ukraine’s long-term energy transition and EU integration. Ukraine’s integration with the ENTSO-E grid and its renewable energy potential (e.g., solar and bioenergy) provide a historic opportunity for green reconstruction. Drawing from Poland’s experience, the EU should facilitate Ukraine’s access to decarbonization tools, joint infrastructure investments, and energy market reforms aligned with EU standards. Clean energy recovery of Ukraine can reinforce both energy independence and political stability in the region, helping secure Europe’s eastern frontier, while also supporting sustainable and energy-efficient post-war reconstruction in Ukraine.

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