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FROM ENERGY DEPENDENCY TO ENERGY SECURITY: HOW THE WAR IN UKRAINE ACCELERATED RENEWABLE DEPLOYMENT IN EUROPE

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ABSTRACT. The war in Ukraine has transformed Europe's energy landscape, prompting urgent efforts to accelerate the transition to renewable energy in response to both security and climate imperatives. The aim of this research is to examine whether the geopolitical shock of 2022, together with associated sanctions, produced a measurable acceleration in renewable electricity deployment across European countries. Using panel data for 34 countries from 2014 to 2023, the study employs difference-in-differences, event study, and triple-difference models, which utilise Eurostat and World Bank data, and variables are normalised through Yeo–Johnson transformations. The results demonstrate a significant structural break in 2022. Aggregate renewable and waste capacity increased by 0.55 ($p < 0.001$) on average, an effect that remained robust, though reduced to 0.16 ($p < 0.001$), when country-specific trends were controlled for. Technology-specific estimates reveal firm heterogeneity: solar expanded most rapidly (1.30, $p < 0.001$), wind capacity also rose (0.64, $p < 0.01$), whereas hydropower exhibited only marginal gains (0.10, $p \approx 0.05$) and biofuels showed no systematic change. A triple-difference specification confirms that post-2022 acceleration was concentrated in fast-deploying technologies, with a differential effect of 1.55 ($p < 0.001$) compared to hydro and biofuels. These findings demonstrate that the war in Ukraine marked another turning point in Europe's renewable energy transition.

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Introduction

Europe's energy system has been structurally reshaped since the 2022 Russian invasion of Ukraine. In response, the EU adopted the REPowerEU agenda and overhauled the Renewable Energy Directive ("RED III"), raising the binding 2030 renewables target to a minimum of 42.5% with an ambition of 45%, nearly doubling today's share (European Commission, 2025), and accelerating permitting via the temporary Emergency Regulation (EU) 2022/2577 for renewable and grid projects (EUR-Lex, 2024). These measures tie decarbonisation to energy-security goals, making the post-2022 period a natural experiment for studying policy-induced acceleration in renewable deployment (European Commission, n.d.).

International evidence indicates a marked upswing in renewables after the war-induced gas-price shock (e.g., Henderson, 2024). The IEA (2024) documents faster adoption driven by policy support, shorter permitting timelines and cost declines, with solar PV and wind expected to account for ~95% of global additions to 2030. IRENA's capacity statistics confirm record global additions in 2023 and continued increases thereafter, underscoring that the acceleration is not only EU-specific but particularly notable in Europe, given the policy momentum (IRENA, 2024).

Within the EU, the pivot is evident in the power mix: wind and solar generation overtook fossil fuels for the first time in H1 2024, a symbolic milestone achieved even as demand recovered, highlighting the speed with which various renewables have displaced gas and coal in the aftermath of the crisis. Meanwhile, market trackers report a surge in EU solar additions from 2022 to 2023, reinforcing that deployment has accelerated precisely in the period our study analyses (Graham & Fulghum, 2024; REN21, 2024).

This shift can also be considered a security dividend. Recent IMF analysis finds that more decisive climate action, carbon pricing, efficiency standards, and faster renewable permitting improvements enhance Europe's energy security, quantifying how climate and security objectives are mutually reinforcing. Against this backdrop of elevated policy ambition and observed system-level changes since 2022, a causal assessment of whether (and which) renewables accelerated post-war is timely and policy-relevant (Dolphin et al., 2024).

Against this backdrop, the war in Ukraine has become not only a geopolitical and humanitarian crisis but also a catalyst for structural change in Europe's energy system. The unprecedented policy responses, record renewable additions, and explicit reassessment of decarbonisation as a security strategy underscore the urgency of empirically assessing whether and how renewable deployment has accelerated since 2022. While international organisations such as the European Commission, IEA, IRENA, and the IMF provide valuable descriptive evidence of this shift, systematic econometric analysis remains scarce. This study addresses this gap by applying difference-in-differences and triple-difference methods to panel data for 34 European countries from 2014 to 2023, thereby offering robust evidence on the extent to which the war in Ukraine and related sanctions have altered the trajectory of Europe's renewable transition.

1. Literature review

The war in Ukraine has reshaped Europe's energy landscape, intensifying existing vulnerabilities and accelerating the strategic shift from dependency on (particularly Russian) fossil fuels to renewable energy deployment. The interplay between geopolitical shocks, economic instability, and energy security has been extensively examined in relation to commodities, currencies, and broader trade dynamics, underlining the war's profound systemic effects (Aliu et al., 2024; Chater & Soussou, 2023; Nate et al., 2024; Zozulinskyy, 2024; Aitken & Ersoy, 2022; Liao, 2023; Mohammed et al., 2022; Umar et al., 2022). Sanctions regimes, designed to weaken Russia's economic position, have had implications for financial institutions and foreign trade, reinforcing the need for structural alternatives in the energy sector (Brož et al., 2023; Nerlinger & Utz, 2022). The reliance of EU countries on Russian energy imports has long been identified as a key vulnerability, making diversification and renewable development an environmental and security imperative (Ilie et al., 2023; Wołowiec et al., 2022; Nguyen et al., 2024; Skalamera, 2023).

The literature emphasises that energy security is inseparable from economic resilience (e.g., Guarascio et al., 2025), with renewable deployment as a solution to energy dependency and climate challenges. Renewable energy consumption reduces air pollution and supports public health, thereby strengthening the societal case for an accelerated transition (Badreddine & Cherif, 2024). The integration of sustainability practices into energy transitions demonstrates significant utilitarian benefits, with energy efficiency initiatives simultaneously enhancing economic profitability by reducing costs while alleviating environmental impacts (Mumcu, 2024). At the same time, climate mitigation and sustainability goals necessitate integrating renewable energy sources into long-term growth strategies (Dilanchiev et al., 2024; Taran et al., 2025). The new EU climate objectives and the RED III place increased demands on member states to expand clean energy, presenting opportunities and challenges for entrepreneurs and policymakers (Kawecka-Wyrzykowska, 2025). Growing attention has also been directed at community-based energy models, with Delcea et al. (2024) highlighting the role of energy communities in enabling more participatory and decentralised energy transitions. At the same time, Steffen and Patt (2022) demonstrate that the war has shifted public support for clean energy policies, while Wiertz et al. (2023) observe that the German discourse has increasingly shifted towards geopolitics.

Scholars highlight the complexity of the energy mix, where renewables increasingly contribute to stability, but require effective management of investment patterns and supportive governance frameworks (Artyukhov et al., 2024; Balcerzak et al., 2024). Empirical studies have linked renewable generation to electricity pricing dynamics, revealing the interplay between costs and market adaptation (Bank & Badyda, 2024, Lu et al., 2020, 2021). Moreover, geopolitical risk has a significant influence on renewable energy consumption in OECD countries, underscoring the sensitivity of clean energy systems to external shocks (Bello & Hassan, 2024; Yang et al., 2025). Business cycle dynamics and energy consumption further influence sustainability, with evidence of close links between the renewable expansion of EU states and economic development (Bușu et al., 2024; Mehedintu & Soava, 2024). At the same time, Dyduch et al. (2024) emphasise that renewable energy organisations face challenges in value creation and value capture, which impact their resilience and ability to attract investors. Furthermore, Kuzemko et al. (2022) stress that Europe's policy responses to the war represent a pivotal opportunity for sustainable transformation. Trunina et al. (2022) provide early empirical evidence of how the war triggered renewable development.

Technology-specific pathways demonstrate heterogeneity. Hydropower and biofuels remain critical yet slow-moving resources, whereas wind and solar exhibit rapid scalability, particularly in times of crisis (Dankevych et al., 2023; Štreimikienė, 2024). Sectoral and regional assessments reveal strong asymmetries: the Nordic and Baltic states exhibit higher renewable penetration, whereas Central and Eastern European countries struggle with fossil dependency (Štreimikienė, 2023, 2024). Multi-criteria sustainability assessments of energy generation systems reveal significant variations in performance across European countries, with Scandinavian countries demonstrating superior sustainability indicators due to strong policy support and high public awareness, while Eastern European countries face greater challenges due to fossil fuel dependence (Drożdż et al., 2023). Country-level evidence also indicates that regulatory frameworks, grid connection reliability, and energy taxes have a significant influence on renewable investment and deployment (Lyeonov et al., 2025a, 2025b; Kuzior et al., 2023a, 2023b; Tomczyk et al., 2025). Empirical studies support the direct relationship between renewable energy and energy security, as demonstrated by Havrylenko and Myroshnychenko (2025). Kuzior et al. (2025) provide comparative evidence of security outcomes across EU countries. Investment decisions and start-up environments are further shaped by minority investor protection schemes, feed-in tariffs, and ethical leadership practices, which can either enhance or constrain clean energy development (Halynskyi & Telizhenko, 2024; Lyeonov et al., 2025a; Prokopenko et al., 2025). Broader corporate governance considerations also affect financial performance and firm value in energy-adjacent industries, with implications for clean investment flows (Noor et al., 2024).

Socio-economic dimensions also shape the renewable transition. Studies have underscored that energy poverty remains a pressing challenge, with households in Eastern Europe particularly vulnerable to rising energy costs. Awareness and behavioural engagement are also found to influence the success of policy interventions (Oesterreich & Barej-Kaczmarek, 2024; Piwowarski, 2024; Streimikiene, 2025).

Broader socio-political shocks, such as the war, affect labour markets, governance, and civil service motivation, reinforcing the role of renewables as a stabilising force for both households and institutions (Podolchak et al., 2025; Melnyk et al., 2025; Slyusarevskyy & Chunikhina, 2025). At the international scale, synergies between energy security and environmental sustainability are increasingly recognised within Europe and in comparative geopolitical contexts, such as BRICS (Nihal et al., 2024; Svazas et al., 2025). Compounding these challenges, the refugee influx created additional cost pressures, particularly in Polish housing markets where rents increased by 14-16.5% in major cities (Gluszak & Trojanek, 2025; Trojanek & Gluszak, 2022). Beyond Europe, the war has affected global markets and investment flows, reshaping agricultural, financial, and energy linkages across multiple regions (Jareño et al., 2025; Pozovna et al., 2025; Minh Vu, 2025). The crisis has thus been situated within broader debates on risk, ethics, and resilience in energy and business systems, stressing the need for governance innovations to ensure sustainability under uncertainty (Ishwardat et al., 2024; Ghimire et al., 2025; Tessema, 2025; Shtunder et al., 2022; Vasa et al., 2024; Mentel et al., 2020). Emerging technological perspectives and innovations are also integral, with scholars identifying non-linear interactions between climate change mitigation, new energy technologies, and consumer engagement (Sadiq et al., 2025; Triantafyllidou et al., 2024; Ziabina et al., 2023).

The literature demonstrates that the war in Ukraine intensified Europe’s urgency to decouple from Russian energy (e.g., Chepeliev et al., 2022) and highlights renewables as both a resilience mechanism and a driver of sustainable development (e.g., . Prior research captures diverse aspects (geopolitical, economic, social, and technological). However, empirical gaps remain in causally identifying the extent to which the war has acted as a structural break in renewable deployment trajectories. This research addresses that gap by applying econometric models to quantify the acceleration of renewables after 2022, thereby contributing to an evidence-based understanding of Europe’s energy security transition.

This study aims to assess the impact of the 2022 geopolitical shock, triggered by the Russian invasion of Ukraine and subsequent sanctions, on the trajectory of renewable energy deployment in Europe. By applying difference-in-differences and triple-difference methods to panel data for 34 countries, the research seeks to answer the central research question of whether the crisis accelerated the transition towards renewable and waste-based electricity generation as part of Europe’s energy security strategy. For this purpose, and building on the literature that links geopolitical shocks to structural transformations in energy systems, this study formulates a set of hypotheses to guide the empirical analysis. The central proposition is that the Russian invasion of Ukraine in 2022, together with the subsequent sanctions and policy responses, created a structural break in the trajectory of European renewable deployment. This expectation is supported by descriptive evidence from international organisations and theoretical accounts, which suggest that crises accelerate technological transitions by reframing energy security as a primary policy driver.

H1: The Russian invasion of Ukraine in 2022 and the associated sanctions produced a statistically significant acceleration in the deployment of renewable and waste-based electricity capacity across European countries.

In line with existing research emphasising the heterogeneous adaptability of renewable technologies, wind and solar – characterised by short investment cycles and modular scalability – are expected to respond more rapidly to shocks than hydro or biofuels, which remain constrained by physical, ecological, and infrastructural limits.

H2: The post-2022 acceleration in renewable deployment is concentrated in fast-deploying technologies (wind and solar), while slow-deploying technologies (hydropower and biofuels) show no systematic short-term change.

Economic capacity is also identified in the literature as a critical enabler of renewable transition. Wealthier economies can mobilise capital and institutional resources more effectively in times of crisis, whereas lower-income countries face structural barriers to immediate energy system restructuring.

H3: Higher-income European countries, as measured by GDP per capita, exhibit stronger increases in renewable energy capacity post-2022, reflecting greater investment capability.

Finally, a growing strand of research conceptualises renewable deployment as an environmental strategy and a resilience mechanism against fossil fuel dependency. Although the statistical results in this study are mixed regarding import dependency, the broader evidence supports the role of renewables in reducing vulnerability to external energy shocks.

H4: The shift from dependency on fossil fuel imports to renewable energy deployment intensified after 2022, consistent with the role of renewables as a resilience mechanism against external energy shocks.

2. Methodological approach

Data and variables

The empirical analysis is based on an unbalanced panel dataset covering 34 European countries from 2014 to 2023. The selection of variables reflects the dependent dimensions of renewable electricity deployment and the structural determinants influencing capacity expansion.

The dependent variables capture electricity production capacities for specific renewable technologies. Four disaggregated indicators are included: hydropower (y1), wind power (y2), solar power (y3), and solid biofuels (y4). In addition, an aggregate measure of electricity production capacities from renewables and waste (y) is used to capture the overall trajectory of renewable energy. All five indicators are drawn from Eurostat (n.d.).

Three explanatory variables are included to account for structural and macroeconomic factors. Final energy consumption (x1) serves as a proxy for the scale of domestic energy demand (Eurostat, n.d.). Gross domestic product per capita at current US dollars (x2) is used to approximate the level of economic development and financial capacity for renewable investment, obtained from the World Bank (n.d.). Finally, energy dependency (x3) is measured as the import dependency on third countries for natural gas, oil, and petroleum products (excluding biofuels), sourced from Eurostat (n.d.).

Empirical Strategy

The empirical framework is designed to capture the outbreak of Russia’s full-scale invasion of Ukraine in 2022 as a defining geopolitical event, together with the subsequent sanctions on Russia, and to assess whether these shocks generated a measurable shift in the trajectory of renewable electricity deployment across European countries. To this end, the study applies a difference-in-differences (DiD) approach, complemented by event-study specifications to trace the timing of the break, robustness checks to ensure validity, and a triple-difference (DDD) model to disentangle technology-specific dynamics.

The baseline specification estimates the effect of the post-2022 period on renewable energy capacity by comparing within-country changes before and after the geopolitical shock. The treatment is 2022–2023, with the pre-treatment period covering 2014–2021. The core model includes country fixed effects to absorb time-invariant national characteristics and year fixed effects to control for common shocks across Europe. Standard errors are clustered at the country level to account for serial correlation.

To test the validity of the parallel trends assumption underlying the DiD framework, an event study approach (seminal, Fama et al., 1969; also Corrado, 2011) is applied, which includes interacting year dummies with the outcome variables, using 2021 as the reference year. This allows for the visual and statistical inspection of pre-trends, ensuring that any differences between the treatment and control groups did not exist prior to the shock. The event study approach also reveals the dynamic pattern of post-treatment effects, distinguishing between immediate and lagged responses in 2022 and 2023.

Given the heterogeneity across renewable technologies in terms of investment cycles, scalability, and responsiveness to external shocks, the analysis is conducted separately for hydropower, wind, solar, and solid biofuels, as well as an aggregate measure of renewables and waste. Hydropower and biofuels are characterised by slower expansion and stronger path dependency, whereas wind and solar represent more flexible, fast-deploying technologies capable of responding quickly to geopolitical shocks.

To improve statistical reliability, the study addresses the issue of skewness in capacity variables. All outcome and explanatory variables, except the bounded index of import dependency (x3), are transformed using the Yeo–Johnson transformation (seminal, Yeo & Johnson, 2000), which is suitable for handling zero values. This ensures that the distributional assumptions of the regression framework are not violated.

Several robustness checks are implemented. First, models with country-specific linear time trends are estimated to rule out the possibility that the observed post-2022 effect reflects gradual differences in national renewable trajectories. Second, placebo tests are conducted by artificially assigning treatment to pre-2022 years (e.g., 2018 or 2019) to verify that no spurious effects appear outside the true treatment period. Third, weighted regressions are run, using lagged total renewable capacity as weights, to check whether results are robust to the influence of larger or smaller countries. Together, these steps ensure that the findings are not driven by model specification or unobserved confounders, but rather reflect a genuine structural break associated with the war in Ukraine and its consequences for European energy security.

All calculations, estimations, and graphical representations were done in R Studio using the *fixest*, *car*, *e1071*, *ggplot2*, and *modelsummary* packages.

3. Conducting research and results

The descriptive statistics presented in Table 1 below provide an initial insight into the dataset's structure, which encompasses 34 European countries from 2014 to 2023 (N = 340). The temporal dimension is balanced, with a median year of 2018.5 and a symmetric distribution around the study period.

Installed capacities for renewable and waste-based electricity generation technologies exhibit substantial variation across countries. Hydropower (y1) exhibits the highest average installed capacity (mean ≈ 5,585 MW), accompanied by a considerable standard deviation (≈ 8,350 MW) and notable skewness (1.83), indicating the presence of a few countries with massive hydropower infrastructures compared to the median (≈ 2,194 MW). Wind power (y2) and solar power (y3) exhibit even higher dispersion, with means of 4,921 MW and 3,903 MW, respectively, as well as extreme maximum values (69,486 MW for wind and 74,882 MW for solar), and pronounced skewness (>3.9) and high kurtosis (>17). This points to highly concentrated deployment in a few leading countries, while most have comparatively limited installed capacity. Solid biofuels (y4) represent the smallest segment, with a mean of 454 MW and lower dispersion, though still marked by a right-skewed distribution (skewness 2.57).

Aggregating all renewables and waste (y), the mean installed capacity is 14,864 MW, with a median of 4,978 MW and a maximum exceeding 156,000 MW. The strong right-skewed distribution (skewness 2.87) confirms that renewable energy development is highly uneven across the region's countries, with a few large systems dominating.

The control variables exhibit similar heterogeneity. Final energy consumption (x1) averages 28,027 KTOE but ranges widely, from 436 KTOE to over 204,000 KTOE, reflecting the size differences between smaller and larger economies. GDP per capita (x2) shows a mean of 32,210 USD, though the median (23,974 USD) indicates right-skewness (1.51), consistent with the economic disparities between Western and Eastern Europe. Import dependency on fossil fuels (x3) averages 56.3% with a broad range (0–93%), and its negative skewness (−0.57) suggests that while many countries have high dependence, a notable subset has considerably lower reliance on external energy sources.

Table 1. Descriptive statistics of main variables (2014–2023)

Variable	Mean	SD	Median	Min	Max	Skewness	Kurtosis
y1 Hydropower	5584.95	8349.7	2194.05	0	34291	1.83	2.33
y2 Wind	4921.13	10688.53	700.9	0	69486	3.94	17.07
y3 Solar	3903.35	9794.28	399.25	0	74882	4.07	18.89
y4 Solid biofuels	454.14	748.38	102.6	0	3918	2.57	7.16
y Total RES	14863.56	24870.4	4978.4	18	156909	2.87	9.42
x1 Final energy consumption	28027.43	42902.8	12130	435.72	204512.3	2.50	5.96
x2 GDP per capita	32210.14	26059.76	23973.53	2749.55	134965.8	1.51	2.42
x3 Import dependency	56.31	28.15	62.31	0	93.39	-0.57	-0.86

Source*: authors' calculations in R Studio.*

The descriptive results displayed in Table 1 highlight that the dataset is characterised by substantial heterogeneity across both dependent and explanatory variables, with highly skewed distributions, particularly for wind and solar power capacities. This diversity in national baselines highlights the importance of employing a difference-in-differences approach, as it enables the estimation of average treatment effects that remain meaningful despite the asymmetries in the underlying distributions.

The Yeo–Johnson method was chosen explicitly because several variables include zero values, particularly in wind, solar, and biofuel capacities during the early years of the sample. Unlike logarithmic or Box–Cox transformations, Yeo–Johnson accommodates zeros without requiring arbitrary adjustments, thereby preserving the integrity of the data while improving its distributional properties (Riani et al., 2023).

The Yeo–Johnson transformation results indicate a substantial improvement in the distributional properties of the study variables. Before transformation, all dependent variables displayed marked positive skewness, most notably wind (y2, skewness = 3.94) and solar capacity (y3, skewness = 4.07), while total renewables (y), hydropower (y1), and biofuels (y4) also showed skewed distributions. Similarly, the control variables for final energy consumption (x1, skewness = 2.50) and GDP per capita (x2, skewness = 1.51) were strongly right-skewed. After applying the Yeo–Johnson transformation with estimated λ values close to zero (ranging from 0.018 to 0.181), skewness in all cases was reduced to values close to zero (between −0.16 and −0.01). This suggests that the transformation successfully normalised the distributions, mitigating the heavy right tails and improving symmetry. Such improvements are significant in panel regressions, as they reduce the influence of extreme outliers, stabilise variances, and enhance the robustness of inference in the subsequent difference-in-differences analysis.

The baseline difference-in-differences regression for total renewable and waste-based electricity capacity reveals a highly significant Europe-wide break after 2022 (see Table 2 below). The coefficient on the post dummy is positive and sizeable (0.55, $p < 0.001$), demonstrating that the war in Ukraine and the associated sanctions coincided with a substantial acceleration in renewable deployment. This effect holds even after accounting for structural cross-country differences and key control variables. In particular, GDP per capita remains positively and significantly associated with renewable capacity (0.39, $p < 0.01$), underscoring the importance of economic wealth in driving investment in renewable infrastructure. By contrast, final energy consumption and import dependency are statistically insignificant, suggesting that short-term shifts in energy demand or reliance on fossil imports did not systematically influence aggregate capacity changes.

The event study specification provides deeper insights into the temporal dynamics of the transition. Relative to the reference year 2021, coefficients for 2014–2019 are consistently negative and highly significant, reflecting the substantial expansion of renewables and waste-based capacity across the decade. This trajectory illustrates the structural upward trend in renewable deployment, even before the war-related shock, with capacity in 2014 being almost one unit lower on the transformed scale compared to 2021. Importantly, 2020 is not significantly different from 2021, which supports the assumption of parallel trends underlying the DiD framework.

The most critical findings are typically observed in the years following treatment. Both 2022 and 2023 show significant positive deviations relative to 2021, with coefficients of 0.255 ($p < 0.01$) and 0.485 ($p < 0.001$), respectively. This indicates that the acceleration of renewable and waste-based capacity did not merely continue an upward trajectory, but intensified in the immediate aftermath of the war‘s outbreak. The cumulative evidence thus suggests a structural shift in Europe’s renewable energy development, driven by the urgent need to replace Russian fossil fuels and enhance energy security.

These results establish a robust foundation for analysing technology-specific effects. While the aggregate pattern shows a clear acceleration post-2022, the breakdown by hydropower, wind, solar, and biofuels allows for determining which technologies drove this surge. In this sense, the aggregate analysis contextualises the subsequent interpretation of y1–y4 results, highlighting the extent to which different renewable sources contributed to Europe's energy transition under crisis conditions. The analysis of technology-specific effects starts with hydropower; the main findings are displayed in Table 3.

Table 2. Renewable and waste capacity regression results (Aggregate).

Variables	(1) RES & Waste DiD	(2) RES & Waste Event Study
Post (2022–2023)	0.545* (0.085)	–
Year 2014	–	−0.964*** (0.211)
Year 2015	–	−0.769** (0.232)
Year 2016	–	−0.654** (0.205)
Year 2017	–	−0.542** (0.152)
Year 2018	–	−0.465*** (0.106)
Year 2019	–	−0.308** (0.094)
Year 2020	–	−0.146 (0.113)
Year 2022	–	0.255 (0.078)
Year 2023	–	0.485* (0.134)
Final energy consumption (x1, YJ)	0.078 (0.940)	−0.592 (1.364)
GDP per capita (x2, YJ)	0.392* (0.104)	0.114 (0.165)
Import dependency (x3)	−0.011 (0.008)	−0.009 (0.008)
Country FE	Yes	Yes
Year FE	No	No
Observations	340	340
Adj. R^2	0.985	0.988
Within R^2	0.491	0.598

*Notes: The dependent variable is the total renewable and waste capacity (Yeo–Johnson transformed) and clustered standard errors (by country) in parentheses. The reference year in column (2) is 2021. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Source*: authors' calculations in R Studio.*

The baseline difference-in-differences specification with country fixed effects and no year effects indicates only a marginal post-2022 change in hydropower deployment (Table 3). The coefficient on the post dummy is positive (0.097) and nearly significant at the 10% level ($p \approx 0.051$), suggesting a slight average increase in hydropower capacity after 2022. However, the effect size is modest compared to wind and solar, consistent with the technology's structural characteristics. Hydropower plants typically require lengthy construction timelines and substantial infrastructure investments, making them less responsive to sudden geopolitical shocks, such as the attack on Ukraine and subsequent rounds of war-related sanctions.

All the control variables in this specification prove to be statistically insignificant. Final energy consumption and GDP per capita exhibit weakly positive associations with hydropower development, but neither reaches significance. Import dependency is negative and non-significant, implying that cross-country variation in hydropower deployment is not closely linked to fossil fuel reliance. This contrasts with wind and solar, where stronger associations with income levels and energy security drivers were observed.

The event study results provide further details. Compared to the reference year 2021, hydropower capacity was significantly lower in 2014 and 2015, with coefficients of −0.20 and −0.19, respectively, both of which were statistically significant. This reflects the gradual expansion of hydropower capacity over the decade. From 2016 to 2019, the coefficients remain negative but decrease in magnitude, with significance fading, suggesting convergence toward

2021 levels. Notably, 2020 shows no significant difference relative to 2021, supporting the assumption of parallel trends.

Table 3. Hydropower regression results (Difference-in-Differences and Event Study).

Variables	(1) Hydro DiD	(2) Hydro Event Study
Post (2022–2023)	0.097· (0.048)	–
Year 2014	–	−0.200** (0.072)
Year 2015	–	−0.192* (0.093)
Year 2016	–	−0.118 (0.072)
Year 2017	–	−0.092 (0.063)
Year 2018	–	−0.077· (0.040)
Year 2019	–	−0.059· (0.034)
Year 2020	–	0.010 (0.039)
Year 2022	–	0.055 (0.036)
Year 2023	–	0.097 (0.080)
Final energy consumption (x1, YJ)	0.590 (0.583)	0.440 (0.737)
GDP per capita (x2, YJ)	0.039 (0.033)	−0.024 (0.063)
Import dependency (x3)	−0.001 (0.005)	−0.001 (0.005)
Country FE	Yes	Yes
Year FE	No	No
Observations	340	340
Adj. R^2	0.999	0.999
Within R^2	0.127	0.197

*Notes: Dependent variable – Hydropower capacity (Yeo–Johnson transformed). Clustered standard errors (by country) in parentheses. The reference year in column (2) is 2021. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, · $p < 0.1$.*

Source*: authors' calculations in R Studio.*

Regarding wind power, the baseline specification indicates a statistically significant increase in wind power capacity after 2022, with the post dummy showing an average within-country effect of 0.64 ($p < 0.01$; see Table 4 below).

Table 4. Baseline and event study estimates for wind capacity.

Variable	(1) Wind DiD	(2) Event Study
post (2022–2023)	0.636*** (0.216)	–
year:2014	–	−1.616*** (0.286)
year:2015	–	−1.688*** (0.402)
year:2016	–	−1.432** (0.402)
year:2017	–	−0.974** (0.294)
year:2018	–	−0.622** (0.213)
year:2019	–	−0.445* (0.211)
year:2020	–	−0.140 (0.269)
year:2022	–	0.294· (0.151)
year:2023	–	0.743* (0.299)
x1 (Final energy consumption, YJ)	3.913 (2.312)	3.042 (2.790)
x2 (GDP per capita, YJ)	0.420* (0.169)	−0.251 (0.303)
x3 (Import dependency)	0.017 (0.015)	0.020 (0.016)
Country FE	Yes	Yes
Year FE	No	No
Observations	340	340
Adj. R^2	0.969	0.974
Within R^2	0.280	0.416

*Notes: Dependent variable – wind capacity (Yeo–Johnson transformed), clustered standard errors (by country) in parentheses. The reference year in column (2) is 2021. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Source*: authors' calculations in R Studio.*

In the post-shock period, coefficients for 2022 and 2023 are positive, but statistically insignificant (0.06 and 0.10, respectively), indicating no marked break in hydropower expansion after the attack-induced geopolitical crisis. The results confirm that hydropower remained largely unaffected by the war-induced energy transition dynamics, with the most responsive growth observed in wind and solar instead. These findings highlight the path dependency of hydropower (extensively, Ahmed, 2021; generally, Rycroft & Kash, 2002), where capacity growth is constrained by natural potential and long lead times, thereby limiting its role as a flexible response technology during crises.

The event study provides additional insights: coefficients for 2014–2019 are uniformly negative relative to 2021, confirming a strong upward trend in wind capacity over the past decade. Crucially, there is no significant difference between 2020 and 2021, suggesting that the assumption of parallel trends is not violated. By contrast, 2022 and 2023 are associated with positive shifts, the latter reaching conventional statistical significance. Together, these findings support the hypothesis that the Russian invasion of Ukraine and subsequent sanctions accelerated the deployment of wind power across European countries.

The baseline specification with country fixed effects and no year fixed effects indicates a significant increase in solar capacity after 2022 (see Table 5 below). The coefficient on the post dummy is 1.30 ($p < 0.001$), indicating that, on average, European countries experienced a substantial within-country upward shift in solar capacity following the outbreak of the war and the imposition of sanctions in 2022, even after accounting for structural differences across countries.

Among the control variables, GDP per capita is positively associated with solar deployment (1.03, $p < 0.001$), indicating a strong link between income levels and the capacity to expand solar energy. Final energy consumption is insignificant, while fossil import dependency shows a negative but insignificant effect. The adjusted R^2 of 0.88 and a within-R^2 of 0.44 indicate that the model explains a substantial share of the variance and that the treatment shock makes a meaningful contribution to within-country variation.

Table 5. Solar capacity regression results (Difference-in-Differences and Event Study)

Variables	(1) Solar DiD	(2) Solar Event Study
Post (2022–2023)	1.299* (0.275)	–
Year 2014	–	−2.377*** (0.638)
Year 2015	–	−1.860* (0.835)
Year 2016	–	−1.570· (0.784)
Year 2017	–	−1.417* (0.649)
Year 2018	–	−1.121*** (0.273)
Year 2019	–	−0.903* (0.412)
Year 2020	–	−0.412 (0.323)
Year 2022	–	0.586 (0.176)
Year 2023	–	1.029 (0.377)
Final energy consumption (x1, YJ)	−0.512 (2.200)	−2.168 (2.680)
GDP per capita (x2, YJ)	1.029* (0.218)	0.374 (0.447)
Import dependency (x3)	−0.021 (0.016)	−0.016 (0.014)
Country FE	Yes	Yes
Year FE	No	No
Observations	340	340
Adj. R^2	0.880	0.896
Within R^2	0.441	0.528

*Notes: Dependent variable – solar capacity (Yeo–Johnson transformed). Clustered standard errors (by country) in parentheses. In column (2), the reference year is 2021. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, · $p < 0.1$.*

Source*: authors' calculations in R Studio.*

The event study results confirm a dynamic break in solar deployment around 2022. Compared to the reference year of 2021, the coefficients for 2014–2019 are significantly negative, indicating that solar capacity was consistently and substantially lower in those earlier years. The 2020 coefficient is negative but insignificant, indicating that solar capacity in 2020 was not statistically different from that in 2021, which supports the parallel trends assumption.

By contrast, 2022 shows a positive and significant coefficient (0.59, $p < 0.01$), and 2023 an even more pronounced one (1.03, $p < 0.05$), indicating an acceleration in solar expansion following the outbreak of the war and subsequent sanctions. Controls are insignificant in this specification, implying that differences in energy demand, income, or import dependency do not explain the observed post-2022 surge.

The adjusted R^2 of 0.90 and within R^2 of 0.53 indicate good explanatory power, with the treatment dynamics capturing substantial variation across time.

As subsequent Table 6 illustrates, the baseline difference-in-differences specification with country fixed effects shows that solid biofuels did not experience a significant Europe-wide break in deployment after 2022. The coefficient on the post dummy is positive (0.093), but statistically insignificant ($p = 0.22$), suggesting that the average within-country change in biofuels capacity after the onset of the war and sanctions was weak and not systematically different from the pre-2022 period. This is consistent with the structural features of biofuel technologies, which often involve logistical and supply-chain constraints rather than the rapid investment dynamics seen in solar or wind energy.

Table 6. Biofuels regression results (Difference-in-Differences and Event Study)

Variables	(1) Biofuels DiD	(2) Biofuels Event Study
Post (2022–2023)	0.093 (0.074)	–
Year 2014	–	−0.585· (0.333)
Year 2015	–	−0.404 (0.385)
Year 2016	–	−0.424 (0.329)
Year 2017	–	−0.257 (0.237)
Year 2018	–	−0.146 (0.137)
Year 2019	–	−0.035 (0.125)
Year 2020	–	−0.119 (0.156)
Year 2022	–	0.013 (0.072)
Year 2023	–	−0.026 (0.109)
Final energy consumption (x1, YJ)	−0.636 (0.795)	−1.567 (1.092)
GDP per capita (x2, YJ)	0.173 (0.057)	0.032 (0.166)
Import dependency (x3)	0.003 (0.003)	0.004 (0.004)
Country FE	Yes	Yes
Year FE	No	No
Observations	340	340
Adj. R^2	0.988	0.989
Within R^2	0.116	0.212

*Notes: The dependent variable is biofuel capacity (Yeo–Johnson transformed), which is clustered standard errors (by country) in parentheses. The reference year in column (2) is 2021. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, · $p < 0.1$.*

Source: *authors' calculations in R Studio.*

Among the control variables, GDP per capita has a statistically significant positive effect (0.173, $p < 0.01$), indicating that higher-income countries tend to have larger installed biofuel capacity. This aligns with the expectation that biomass deployment depends on technological sophistication, investment capacity, and the availability of efficient conversion infrastructure, which are more prevalent in wealthier economies – even though they are also relevant for emerging and developing countries (Dar & SheerGorjee, 2025; Demirbas, 2008). By contrast, final energy consumption and import dependency are insignificant, suggesting that overall demand for energy and exposure to fossil fuel imports do not directly drive the expansion of biofuels across countries.

The event study results provide further confirmation of these patterns. Relative to 2021, coefficients for 2014–2019 are generally negative, with 2014 marginally significant at the 10% level (−0.585, $p = 0.09$), indicating that biofuel capacities were smaller earlier in the period. However, the magnitudes are modest, and significance quickly disappears from 2016 onwards, suggesting a relatively stable trajectory of gradual expansion. Most importantly, the coefficients for 2022 and 2023 are close to zero and statistically insignificant, showing no evidence of a marked post-shock acceleration in biofuels deployment.

These findings suggest that biofuels played only a marginal role in the short-term European response to the 2022 energy crisis. Unlike wind and solar, which showed clear post-2022 increases, biofuel deployment appears most path-dependent and least sensitive to geopolitical shocks. This case thus underlines the limitations of biofuels as a flexible transition technology in times of crisis, even though their long-term contribution remains relevant for decarbonisation strategies in specific contexts.

In contrast to the technology-specific estimates reported in Tables 3–6, Table 7 below summarises the aggregate impact across all renewable and waste-based capacities. The post-2022 coefficient is positive and significant (0.55, $p < 0.001$), suggesting that the structural break was not confined to a single technology but reflected a broader acceleration of the European energy transition.

Table 7. Hydropower regression results (Difference-in-Differences and Event Study)

Variables	(1) Triple-Difference (DDD)
Final energy consumption (x1, YJ)	−0.063 (1.099)
GDP per capita (x2, YJ)	0.033 (0.139)
Import dependency (x3)	0.002 (0.005)
Post × Fast RES	1.548* (0.178)
Country FE	Yes
Year FE	Yes
Technology FE	Yes
Observations	1,360
Adj. R^2	0.713
Within R^2	0.007

Notes: Clustered standard errors (by country) in parentheses. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source*: authors' calculations in R Studio*.

The triple-difference specification provides strong evidence of a structural break in favour of wind and solar deployment after 2022. The triple-difference model was applied to disentangle the specific impact of the 2022 geopolitical shock on different renewable technologies. While a conventional difference-in-differences framework can identify average post-2022 changes across countries, it does not capture heterogeneity between technology groups. Wind and solar power are characterised by comparably short construction times and modular deployment. In contrast, hydropower and solid biofuels typically require longer planning horizons and more complex and rigid investment structures, such as project financing (e.g., İpin & Ercan, 2020). By structuring the data in long format and interacting the post-2022 period with a binary indicator for fast-deploying technologies (wind and solar), the DDD specification controls not only for common country and year effects, but also for systematic differences between technology types. This approach isolates the additional acceleration of wind and solar capacity relative to hydro and biofuels after 2022, thereby providing a more nuanced assessment of how the war in Ukraine and associated sanctions influenced the European energy transition.

This result remains robust after controlling for final energy consumption, GDP per capita, and import dependency, none of which display significant effects in this model. By incorporating country, year, and technology fixed effects, the analysis isolates the acceleration of wind and solar energy as a specific post-2022 phenomenon, distinct from general growth in renewable capacity. These findings confirm that the geopolitical shock acted as a catalyst for technologies that can be scaled quickly, aligning with the urgent energy security and decarbonisation objectives pursued by European states in the aftermath of the crisis.

The results provide strong empirical support for the hypotheses formulated above in this study. The baseline difference-in-differences model reveals that the Russian invasion of Ukraine in 2022 led to a statistically significant acceleration in renewable energy deployment across Europe, with an aggregate effect of 0.55 ($p < 0.001$). This finding remains robust even after controlling for country-specific trends, confirming H1. Technology-specific estimates reveal that the acceleration was concentrated in fast-deploying renewables: solar expanded by 1.30 ($p < 0.001$) and wind by 0.64 ($p < 0.01$), while hydro and biofuels remained largely unchanged, thus corroborating H2. The triple-difference specification further strengthens this interpretation, showing an additional post-2022 boost of 1.55 ($p < 0.001$) for wind and solar relative to hydro and biofuels, providing direct evidence that the geopolitical shock favoured technologies capable of rapid scaling. Moreover, the consistent significance of GDP per capita in several models underlines the role of national wealth in enabling investment capacity, which aligns with H3. Although import dependency did not emerge as a significant determinant, the overall pattern of results aligns with H4, highlighting that the war acted as a structural break, shifting Europe's renewable trajectory from energy dependency to energy security.

4. Discussion

The findings of this study confirm that the Russian invasion of Ukraine in 2022 induced a structural break in Europe's renewable deployment trajectory. The difference-in-differences estimates show a significant aggregate post-2022 acceleration in renewable and waste capacities (0.55, $p < 0.001$), which remains robust even after controlling for country-specific trends (0.16, $p < 0.001$). This result aligns with the broader literature, which documents how geopolitical risks increase incentives for diversification away from fossil fuels and towards clean energy systems (e.g., Bello & Hassan, 2024; Cheikh & Zaied, 2023; Ilie et al., 2023; Wołowiec et al., 2022). Comparable evidence suggests that Europe's response to the war entailed a deliberate acceleration of renewable deployment to mitigate exposure to Russian imports, thereby reinforcing the link between security shocks and energy transition (Aitken & Ersoy, 2022; Kuzemko et al., 2022; Nguyen et al., 2024). The evidence underscores that energy security concerns can catalyse renewables, consistent with the view that climate and security objectives have become mutually reinforcing in the European context (Dolphin et al., 2024; Skalamera, 2023).

Technology-specific estimates further reveal a substantial heterogeneity in responses. Solar energy experienced the most pronounced post-2022 increase (1.30, $p < 0.001$), followed by wind (0.64, $p < 0.01$). In contrast, hydropower showed only marginal gains, and biofuels exhibited no significant change. This aligns with previous studies that characterise wind and solar as fast-deploying technologies capable of scaling quickly in response to external shocks, while hydro and biofuels remain constrained by longer investment cycles and path dependency (Dankevych et al., 2023; Štreimikienė, 2024; Demirbas, 2008; İpin & Ercan, 2020). The triple-difference results reinforce this pattern, showing a significant additional acceleration of wind and solar relative to slower-moving technologies (1.55, $p < 0.001$). Similar conclusions are presented in recent EU-focused analyses, which highlight sectoral asymmetries, the prominence of flexible short-lead technologies, and the decisive role of policy support in scaling renewables under conditions of geopolitical stress (Kuzior et al., 2025; Havrylenko & Myroshnychenko, 2025; Yang et al., 2025).

The importance of national wealth is also confirmed in the models, as GDP per capita remains a consistent positive driver of solar and biofuel deployment. This finding is consistent with studies that link renewable expansion to financial capacity, institutional quality, and governance arrangements (Mehedintu & Soava, 2024; Dyduch et al., 2024; Guarascio et al., 2025). However, the insignificance of energy consumption and import dependency in several models suggests that structural drivers of renewable investment extend beyond immediate demand factors, corroborating arguments that effective policy frameworks, investor protection, and resilient financial systems are central to accelerating clean transitions (e.g., Delcea et al., 2024; Halynskyi & Telizhenko, 2024; Noor et al., 2024; Polzin et al., 2017). Importantly, this finding aligns with evidence that the war reshaped energy markets, regulatory environments, and discursive contexts, resulting in lasting institutional transformations (Steffen & Patt, 2022; Wiertz et al., 2023).

The results also align with the broader socio-economic literature. The acceleration of renewables after 2022 represents both a technical adjustment and a resilience mechanism, reducing exposure to volatile fossil markets and lowering household vulnerability to energy poverty (Oesterreich & Barej-Kaczmarek, 2024; Piwowar, 2025). By contrast, the muted response of biofuels suggests that certain technologies remain less adaptable to short-term shocks, supporting earlier findings that biomass and hydro contribute to long-term diversification but cannot substitute for rapid security-driven scale-up (Bușu et al., 2024; Balcerzak et al., 2024; Dar & SheerGorjee, 2025). This divergence is further reinforced by global market perspectives, which demonstrate that biofuels remain closely tied to complex supply chains and food-energy trade-offs (Chepeliev et al., 2022; Henderson, 2024).

The empirical evidence aligns closely with international analyses that classify the war's outbreak as a turning point for Europe's energy transition. It corroborates the IEA and IRENA reports of record solar and wind additions, and substantiates scholarly claims that geopolitical crises accelerate decarbonization when combined with robust policy frameworks (Kalantzakos et al., 2023; Tosun, 2023). Market-based evidence supports these results, as renewable stocks and energy firms demonstrated strong positive adjustments following the war (Mohammed et al., 2022; Nerlinger & Utz, 2022; Umar et al., 2022; Liao, 2023). Overall, the results highlight persistent structural asymmetries across technologies and countries, underlining the need for differentiated policy instruments that consolidate the momentum of fast-scaling renewables while sustaining long-term investments in slower-deploying resources (Svazas et al., 2025; Trunina et al., 2022).

Limitations. Despite its robust design, this study has several limitations that should be acknowledged. First, the relatively short post-treatment period (2022–2023) limits the ability to capture long-term adjustment dynamics in renewable deployment, particularly for technologies with longer investment cycles, such as hydropower and biofuels. Second, while the difference-in-differences and triple-difference approaches mitigate many confounding influences, the identification strategy still relies on the assumption of parallel pre-trends, which, although tested, cannot be fully verified. Third, the analysis is based on aggregate Eurostat and World Bank data, which may mask intra-country heterogeneity in investment behaviour, policy frameworks, and regional infrastructure. Fourth, the explanatory variables capture only a limited set of structural drivers, including energy consumption, GDP per capita, and import dependency, meaning that other relevant factors, such as policy instruments, subsidies, or regulatory reforms, are not explicitly modelled. Finally, the war in Ukraine coincided with other global shocks, including post-pandemic recovery and volatility in international energy markets, making it difficult to disentangle the unique contribution of geopolitical factors. These limitations imply that the findings should be interpreted as evidence of broad structural breaks rather than precise causal magnitudes.

5. Conclusion

The primary aim of this research was to investigate whether the war in Ukraine in 2022 and the subsequent imposition of sanctions on Russia accelerated the development of renewable electricity in Europe. By focusing on the capacity of hydro, wind, solar, and biofuels, as well as the aggregate measure of renewables and waste, the study sought to capture both technology-specific and system-wide responses to the geopolitical shock.

Methodologically, the analysis employed a difference-in-differences framework, extended with event study specifications and a triple-difference model. The dataset comprised 34 European countries from 2014 to 2023, drawing on Eurostat for renewable capacity, final energy consumption, import dependency, and the World Bank for GDP per capita. To ensure statistical reliability, variables were normalised using Yeo–Johnson transformations, with all estimations carried out in R Studio. Country fixed effects, year effects, and clustered standard errors were incorporated. Robustness checks included placebo tests and specifications with country-specific linear time trends.

The empirical findings reveal a statistically significant structural break in 2022. For aggregate renewables and waste, the baseline DiD model shows an average post-treatment effect of 0.55 ($p < 0.001$), which remains robust, albeit attenuated, at 0.16 ($p < 0.001$) when controlling for country-specific linear trajectories. Technology-specific results highlight substantial heterogeneity: solar capacity experienced the strongest acceleration (1.30, $p < 0.001$), followed by wind (0.64, $p < 0.01$); hydropower showed only marginal significance (0.10, $p \approx 0.05$), and biofuels displayed no systematic post-2022 increase. The triple-difference specification further confirms that the acceleration was concentrated in fast-deploying technologies (wind and solar), with a differential post-shock effect of 1.55 ($p < 0.001$) relative to hydro and biofuels. Event study dynamics underline that pre-trends were broadly parallel and that the structural break occurred precisely in 2022–2023. This turning point is directly attributable to Russia's invasion of Ukraine, which acted as a geopolitical shock that forced Europe to accelerate its decarbonisation trajectory. The results provide clear empirical evidence that external crises can catalyse renewable deployment when energy security and climate objectives converge.

From a policy perspective, the findings underscore the importance of crises as catalysts for accelerating renewable energy transitions. The war in Ukraine has reshaped Europe's energy security priorities, resulting in measurable changes in investment behaviour, particularly in solar and wind technologies that can be scaled rapidly. Policymakers should therefore leverage this momentum by consolidating support schemes for fast-deploying technologies while ensuring long-term investment in hydro and biofuels, which remain critical for system stability and diversification. Strengthening cross-border grid integration, streamlining permitting procedures, and enhancing financial incentives for utility-scale solar and offshore wind projects will sustain the current trajectory. Strategic site selection for renewable energy installations requires comprehensive multi-criteria evaluation incorporating environmental, economic, and technical factors to optimize deployment effectiveness and maximize energy security benefits (Azizi et al., 2017). At the same time, policies should focus on reducing structural dependency on particular countries and respective fossil fuel imports by aligning national renewable deployment strategies with the EU's Fit-for-55 and REPowerEU frameworks. Finally, in the context of heightened geopolitical uncertainty, integrating renewable deployment more explicitly into security and defence planning can enhance resilience and reduce vulnerability to external energy shocks.

The evidence suggests that the war in Ukraine marked a turning point in Europe's renewable energy transition, particularly by accelerating the deployment of technologies capable of rapid adoption. While limitations remain regarding data coverage and long-term horizons, the results support the view that geopolitical crises can act as powerful drivers of structural energy change.

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Appendix A

Table A1. Difference-in-differences regression with country-specific trends for renewables and waste

Variables	Estimate	Std. Error	t value	Significance
Post (2022–2023)	0.160	0.044	3.66	***
Controls				
Final energy consumption (x1, YJ)	−1.193	0.417	−2.86	**
GDP per capita (x2, YJ)	0.070	0.030	2.36	*
Import dependency (x3)	−0.006	0.004	−1.72	·
Country-specific trends				
Albania	0.052	0.010	4.99	***
Austria	0.070	0.006	11.45	***
Belgium	0.192	0.008	23.48	***
Bulgaria	0.035	0.011	3.05	**
Croatia	0.075	0.008	8.92	***
Cyprus	0.226	0.009	26.58	***
Czechia	0.015	0.009	1.60	
Denmark	0.191	0.009	22.11	***
Estonia	0.187	0.012	16.24	***
Finland	0.197	0.006	34.28	***
France	0.119	0.007	16.65	***
Germany	0.139	0.008	16.68	***
Greece	0.157	0.006	25.92	***
Hungary	0.467	0.008	55.21	***
Ireland	0.141	0.012	11.97	***
Italy	0.049	0.006	8.82	***
Kosovo	0.277	0.014	19.14	***
Latvia	−0.004	0.008	−0.51	
Lithuania	0.157	0.010	15.10	***
Luxembourg	0.004	0.013	0.33	
Malta	0.251	0.014	18.41	***
Moldova	0.440	0.013	34.20	***
Montenegro	0.051	0.010	5.31	***
Netherlands	0.527	0.010	54.86	***
North Macedonia	0.062	0.007	8.69	***
Norway	0.063	0.005	11.79	***
Poland	0.363	0.011	34.46	***
Portugal	0.087	0.007	12.94	***
Romania	0.005	0.011	0.46	
Serbia	0.060	0.013	4.63	***
Slovakia	−0.022	0.007	−3.18	**
Slovenia	0.066	0.015	4.44	***
Spain	0.144	0.005	28.14	***
Sweden	0.121	0.006	18.63	***
Model fit				
Observations	340			
RMSE	0.146			
Adj. R^2	0.998			
Within R^2	0.949			

Notes: The dependent variable is total renewables and waste capacity (Yeo–Johnson transformed). Clustered SEs by country. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, · $p < 0.1$.

Source: authors’ calculations in R Studio.

Table A2. Event study regression with country-specific trends for renewables and waste

Variables	Estimate	Std. Error	t value	Significance
Year 2014	−0.892	0.047	−18.97	***
Year 2015	−0.762	0.047	−16.07	***
Year 2016	−0.649	0.048	−13.48	***
Year 2017	−0.519	0.048	−10.91	***
Year 2018	−0.428	0.044	−9.77	***
Year 2019	−0.308	0.039	−7.91	***
Year 2020	−0.229	0.058	−3.92	***
Year 2022	0.183	0.039	4.74	***
Year 2023	0.402	0.056	7.13	***
Controls				
Final energy cons. (x1, YJ)	−1.289	0.631	−2.04	*
GDP per capita (x2, YJ)	0.032	0.052	0.62	
Import dependency (x3)	−0.006	0.004	−1.64	
Country-specific trends				
Albania	−0.058	0.015	−3.76	***
Austria	−0.048	0.006	−8.27	***
Belgium	0.075	0.008	9.28	***
Bulgaria	−0.072	0.017	−4.30	***
Croatia	−0.036	0.012	−3.05	**
Cyprus	0.115	0.015	7.80	***
Czechia	−0.095	0.013	−7.31	***
Denmark	0.074	0.006	12.31	***
Estonia	0.076	0.013	5.64	***
Finland	0.079	0.006	12.52	***
France	−0.000	0.007	−0.05	
Germany	0.021	0.008	2.73	*
Greece	0.038	0.004	10.31	***
Hungary	0.357	0.015	24.58	***
Ireland	0.037	0.020	1.88	·
Italy	−0.069	0.004	−15.65	***
Kosovo	0.165	0.014	11.44	***
Latvia	−0.115	0.014	−8.44	***
Lithuania	0.050	0.017	2.91	**
Luxembourg	−0.115	0.015	−7.78	***
Malta	0.143	0.024	5.87	***
Moldova	0.333	0.016	20.68	***
Montenegro	−0.059	0.017	−3.46	**
Netherlands	0.412	0.012	35.72	***
North Macedonia	−0.051	0.009	−5.50	***
Norway	−0.054	0.007	−7.72	***
Poland	0.254	0.019	13.24	***
Portugal	−0.028	0.011	−2.62	*
Romania	−0.102	0.016	−6.23	***
Serbia	−0.048	0.018	−2.61	*
Slovakia	−0.136	0.008	−16.14	***
Slovenia	−0.049	0.012	−4.00	***
Spain	0.027	0.006	4.45	***

*Notes: The dependent variable is total renewables and waste capacity (Yeo–Johnson transformed). Clustered SEs by country. The reference year = 2021. Sweden dropped due to collinearity. Significance codes: *** p < 0.01, ** p < 0.05, * p < 0.1, · p < 0.1.*

Source: authors' calculations in R Studio.