

Green Economy Transition in Ukraine: Decoupling, Structural Breaks, and Post-Socialist Constraints

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Abstract

This paper evaluates green economy implementation in Ukraine during 2005–2024 and benchmarks its performance against Poland and Romania as post-socialist EU comparators and Germany as an advanced EU benchmark. Using data from the State Statistics Service of Ukraine, the

World Bank, and Eurostat, the study applies the Tapio decoupling model and OLS regression with structural-break indicators. The results indicate that Ukraine achieved only weak decoupling between economic growth and CO₂ emissions. Improvements in energy efficiency and renewable energy deployment remained limited relative to the selected comparator countries. The analysis identifies statistically significant structural breaks coinciding with the 2014 and 2022 conflict periods, indicating changes in the relationship between economic activity and CO₂ emissions.

The findings indicate that the green transformation in Ukraine is not only limited by the technological disconnect, but also by institutional and structural legacies of the socialist legacy. The policy implications include the necessity to align reconstruction to the EU environmental standards, enhance the carbon pricing mechanism, and assist the industrial regions with the help of the well-developed just transition framework.

Keywords: green economy, decoupling, energy intensity, structural breaks, post-socialist, Ukraine.

JEL Classification: Q56; Q48; O44; P28; H23.

Introduction

The concept of the green economy has gained increasing importance as countries seek to reconcile economic growth with environmental sustainability. The policy challenge is no longer whether growth and environmental protection should be aligned, but how this alignment can be achieved under diverse structural conditions. This question is particularly relevant for post-socialist economies, where economic restructuring coincides with environmental modernization (Khan et al., 2025). Central planning historically prioritized output expansion in heavy industry, energy production, and extractive sectors, often with limited regard for environmental costs (Cetin, 2025). Such structural features still determine the trajectories of transition of various countries in the region. The case of Ukraine is exceptionally significant in this overall transformation. Being the largest post-Soviet state in Europe (Golod and Drobotiuk, 2025), it is a blend of a significant industrial production and the ongoing institutional reform process (Roudometof, 2026). It still has aspects of the Soviet division of labour in its economic organisation and institutional formation that makes the shift to a low-carbon model more difficult (Shchepetylnykova and Oleksiyenko, 2024).

Concurrently, the policy orientation of Ukraine has shifted towards a more European integration, thus bringing the environmental performance under the wider social and institutional framework (Kougias et al., 2021). This combination of inherited industrial institution, transformation of institutions and external alignment instability render Ukraine analytically significant in comprehending green transitions in post-socialist circumstances.

Although there is an increase in literature on sustainability transitions in Central and Eastern Europe, Ukraine continues to be under investigated in a coherent macroeconomic context. Current literature covers such aspects of the transition process as green entrepreneurship (Kašauskaitė, 2025), fiscal and environmental relationships (Khurshid et al., 2025), decoupling tendencies of regions (Ziemblińska et al., 2025), energy convergence (Borožan, 2024) or the barriers to the development of a circular economy in Ukraine (Zavadskykh et al., 2025). Although such contributions are valuable, they fail to combine the long-term decoupling analysis with structural break assessment and systematic benchmarking against two post-socialist EU comparators (Poland and Romania) and one advanced EU benchmark (Germany). Consequently, scanty empirical data exists regarding the comparison between the green transition in Ukraine and the green transitions in the other post-socialist economies that have experienced previous institutional consolidation.

This study addresses two interrelated research questions. Firstly, how much has Ukraine dissociated economic growth and environmental pressure between 2005 and 2024 and what has been the performance in comparison to the countries of two post-socialist EU comparators (Poland and Romania) and one advanced EU benchmark (Germany)? Secondly, what role do structural and institutional considerations like industrial structure and conflict-based spill overs play in explaining the difference in the green transition process in Ukraine?

The three hypotheses are used to guide the empirical analysis. H1 assumes that Ukraine will have a lower level of decoupling between the growth of its GDP and CO₂ emissions compared to the selected comparator economies. H2 indicates that a higher share of energy-intensive industry is associated with higher carbon intensity in Ukraine. H3: it is hypothesized that the conflicts of 2014 and 2022 created structural discontinuities that influenced the dynamics of emissions and led to the short-term change of decoupling patterns. The comparative analysis with Poland, Romania, and Germany is descriptive and is intended to provide contextual benchmarking rather than formal econometric inference.

The research has three contributions. To begin with, it offers the systematic quantitative analysis of the green transition of Ukraine during the last 18 years based on the same macroeconomic data. Second, it combines the decoupling analysis with structural break test to both capture long-term trends and discontinuities. Third, it puts the empirical results in a post-socialist institutional context to provide policy-relevant understanding of sustainable reconstruction and European integration.

Through emphasizing on comparative performance and institutional constraints, the paper aims at illuminating whether the perceived positive changes in the environment are manifestations of structural change or interim measures in a continuum carbon-intensive development model.

1. Literature Review

The literature on green economy transitions has progressively moved from descriptive accounts toward analytical frameworks that explain the determinants of sustainable structural change. For the purposes of this study, three strands are most relevant: the theory and measurement of decoupling, the institutional political economy of post-socialist environmental reform, and empirical assessments of Ukraine's environmental performance. Rather than reviewing these contributions separately, the discussion below synthesizes their insights in order to clarify the analytical foundations of the present research.

The main conceptual instrument of assessing the possibility of economic growth taking place without corresponding rise in environmental pressure is the decoupling analysis. Tapio (2005) formalized a framework of elasticity based, which differentiates weak, strong, and expansive decoupling states. This method shifted the discussion out of ratio of emission or energy intensity towards the direct connection of environmental change and economic processes. The framework has since been developed by other applications to groups of countries and environmental indicators to prove that the decoupling results are also contingent on structural composition, technological upgrading and institutional quality and the adoption of green technologies (Fedirets et al., 2025). Environmental assessments of resource-intensive industries further demonstrate the importance of integrating economic development with environmental protection. There is some evidence based on Central and Eastern Europe that integration into European regulatory systems and the depth of institutional reform are strongly linked with better decoupling performance (Kilinc-Ata et al., 2026). Comparative studies also

imply that more sustained decoupling is more likely to occur in higher-income economies, which can be achieved either by structural change towards services or by energy efficiency, or by policy-induced innovation. Nevertheless, these results are also indicators of heterogeneity in the region, especially between the EU member states and the post-Soviet economies.

The second literature on the topic focuses on institutional legacies and path dependence during post-socialist transitions. Anastasiou and Zaroutieri (2023) demonstrated that the convergence in the power of energy among the members of the Central European EU was observed, and some post-Soviet countries were not included in the process of convergence. Eitan et al. (2023) explained this divergence by the concept of path dependency, which states that the sequence of early reforms and institutional consolidation have long-lasting impacts on the environmental performance. These analyses indicate that it is impossible to isolate the outcomes of green transition and put it in the broader institutional paths.

This divergence was further strengthened by the European Union (EU) accession processes. The European countries of the centre embraced environmental acquis, took part in the EU Emissions Trading System and made use of the structural funds in the environmental upgrading. Such institutional tools led to quantifiable output in terms of energy efficiency and reduction of emissions. By comparison, there were more fragmented reform processes in a number of post-Soviet states. The regulative uncertainty, incompatible financial access, and ineffective enforcement were cited as regulatory barriers to green entrepreneurship (Kropelnytska et al., 2025). It is therefore proposed in the literature that institutional consolidation and regulatory credibility mediate the relationship between policy intent and environmental results.

The third strand targets Ukraine in particular. The current studies cover fiscal tools, limitations of the circular economy, and the performance of energy policies, but generally separately. Nazarkevych and Sych (2023) investigated that the environmental taxes are not adequate to internalize environmental externalities. Shpak et al. (2024) correlated the barriers to the circular economy with the institutional weaknesses and lack of investments, while Pimenow et al. (2026a) highlighted the role of circular economy policies in supporting sustainable resource use and green transition. Pavlov et al. (2025) pointed out the continued high-energy intensity and untapped efficiency. While these studies identify important sectoral challenges, they do not systematically evaluate whether Ukraine has achieved macro-level decoupling over time or how its performance compares with regional peers.

Research on renewable energy potential and conflict-related environmental impacts provides additional but partial perspectives. IEA. (2025) discovered that they have a lot of technical potential. Petlenko (2024) determined that the energy structure and investment efforts are behind the peers due to inconsistency in policies and regulatory barriers to deploying renewables. Ukraine's long-term green transition also presents opportunities for hydrogen integration with European energy markets (Terekhov et al., 2024). A thorough evaluation of the opportunities of green transformation, which is the result of the Stockholm Environment Institute, (SEI., 2025) highlighted the necessity to implement reconstruction in accordance with climate goals.

The conflict aspect provides an additional complexity which is not available in the general transition literature. Filho et al. (2024) reported the environmental nature of conflict, such as destruction of industrial facilities and energy facilities in Ukraine. Allam et al. (2022) examined the energy system of Ukraine under conditions of the war, pointing out that the capacity to generate energy was destroyed, and it became difficult to even sustain supplies under fire. These contributions emphasize exogenous shocks and structural weaknesses, but seldom assimilate discontinuities occurring as a result of conflicts into formal econometric means of determining decoupling.

The literature can be observed to exhibit three gaps. To start with, there is minimal decoupling analysis/structural break testing co-testing over a steady long-term time series (Niță et al., 2025). Second, the comparative benchmarking of Ukraine and Central European economies has not been developed yet. Third, models of interaction between inherited industrial structures and shocks related to conflicts have not been quantified in a single macroeconomic model (Kaczmarek, 2022). Moreover, the performance alignment in Ukraine to the comparative metrics with counterparts in the two post-socialist EU comparators (Poland and Romania) and one advanced EU benchmark (Germany) is not highly developed limiting the opportunities of drawing lessons on the basis of more advanced transitions. The literature also lacks a direct quantification of an interaction of legacies of the post socialist industrial structure in combination with conflict disruption to establish the impact on the environment. These deficiencies are the direct impetus of the current study. The paper links theoretical hypothesis to empiricism by building a consistent dataset between 2005-2024, using Tapio decoupling measures, and structural break analysis, and compares Ukraine to a selected set of Central European states. The hypotheses are based on the main arguments of the literature: the weaker institutional consolidation predicts the weaker decoupling; the industrial legacies are predictive of the greater carbon intensity; and the exogenous shocks can interfere in the alignment of the old trends of the environment. In such a manner, the review goes beyond being concept-driven and ends with a well-defined research agenda that is attempted to be filled with the following empirical analysis.

2. Research Methodology

This study uses annual time series data between 2005-2024 of Ukraine and three comparator countries, which are Poland, Romania, and Germany. The choice represents varying processes of green transitions in Europe. Poland and Romania were selected as post-socialist EU comparators because they have undergone comparable transition processes under EU environmental policies. Germany was included as an advanced EU benchmark representing a more mature low-carbon transition pathway.

Data are compiled from the State Statistics Service of Ukraine (SSSU)¹, supplemented by the World Bank's World Development Indicators (WDI)² for cross country comparability. Energy data come from the International Energy Agency (IEA)³ and Eurostat⁴, while emissions data are taken from the Emissions Database for Global Atmospheric Research⁵. Governance indicators are drawn from the Worldwide Governance Indicators (WGI) project⁶. Detailed

¹ <https://stat.gov.ua/en/explorer>

² <https://databank.worldbank.org/source/world-development-indicators>

³ <https://www.iiea.com/>

⁴ <https://ec.europa.eu/eurostat/data/database>

⁵ <https://edgar.jrc.ec.europa.eu/>

⁶ <https://www.worldbank.org/en/publication/worldwide-governance-indicators>

variable definitions, units, transformations, and treatment of missing values are reported in Appendix A, Table A1.

The empirical analysis employs two complementary quantitative methods as required. The main approach is the Tapio decoupling model, which quantifies the elasticity of environmental pressure with respect to economic growth. The robustness check consists of ordinary least squares regression with structural break indicators, testing the stability of relationships across different subperiods. The Tapio decoupling elasticity is calculated as (Tapio, 2005):

$$\varepsilon = \frac{\% \Delta \text{Environmental Pressure}}{\% \Delta \text{Economic Output}} \quad (1)$$

For energy intensity, elasticity is calculated by dividing the percentage change in energy intensity by the corresponding percentage change in GDP. Thus, declining energy intensity during GDP growth produces a negative elasticity. A different measurement of environmental pressure is in terms of CO₂ emission, energy intensity, and renewable energy share (to ensure directional consistency of interpretation). In line with Tapio (2005), the states of decoupling are categorized in the values of elasticity and the indications of change in the two variables. Strong decoupling is a situation whereby economic output grows and environmental pressure falls resulting in negative elasticity. Weak decoupling is a situation where the two increase, but with slower growth in environmental pressure with a range of 0 to 0.8 elasticity. Expansive coupling refers to proportional growth with an elasticity between 0.81 and 1.2 whereas expansive negative decoupling refers to an increase in environmental pressure that outpaces output (elasticity > 1.2). Other categories represent recessionary situations, such as recessive decoupling (output falls, pressure falls slower), recessive coupling (both fall in the same proportion). In recessionary periods, declining GDP accompanied by increasing environmental pressure is classified as strong negative decoupling under the Tapio framework. To further examine the sources of energy intensity change, a shift-share decomposition was applied for 2005–2021. The total change in energy intensity was decomposed into structural (sectoral shifts) and within-sector efficiency components (Ang, 2005): $\Delta EI = \Delta EIS + \Delta EIW$. In the regression case, the working specification is:

Model 1:

$$\ln CO_{2t} = \alpha + \beta_1 \ln GDPPC_t + \beta_2 HIS_t + \beta_3 GQ_t + \beta_4 EP_t + \beta_5 ET_t + \gamma_1 D2014_t + \gamma_2 D2022_t + \varepsilon_t \quad (2)$$

Model 2:

$$\ln EI_t = \alpha_0 + \beta_1 \ln GDPPC_t + \beta_2 HIS_t + \beta_3 GQ_t + \beta_4 EP_t + \beta_5 ET_t + \gamma_1 D2014_t + \gamma_2 D2022_t + \mu_t \quad (3)$$

Where in equation (2), for year t , the dependent variable Environmental Indicator is the natural logarithm of CO₂ emissions per capita and energy intensity. $\ln (GDPPC_t)$ is the natural logarithm of GDP per capita in constant 2015 USD. HIS_t is Heavy industry share that represents the share of metals, chemicals, and minerals in total industrial output. Governance Quality (GQ_t) is the average score from the Worldwide Governance Indicators. Energy Price (EP_t) is the industrial electricity price in constant USD per kWh. ET_t is environmental tax revenue as a percentage of GDP. $D2014_t$ and $D2022_t$ are binary dummy variables taking the value of 1 for the years 2014–2024 and 2022–2024 respectively, capturing structural breaks

associated with conflict. α is the constant term, β_1 through β_5 and γ_1 through γ_2 are coefficients to be estimated, and ε_t is the error term.

The inclusion of structural break dummies for 2014 and 2022 tests whether conflict related disruptions altered the underlying relationships between economic activity and environmental outcomes. Heavy industry share captures the post socialist industrial structure legacy. Governance quality tests the institutional channel through which post socialist transformation affects environmental performance.

Model diagnostics include tests for autocorrelation named Breusch Godfrey Lagrange multiplier test presented by Breusch (1978) and test for heteroskedasticity named Breusch Pagan test formulated by Breusch and Pagan (1979). The analysis prioritises parsimony to avoid overfitting while retaining theoretically motivated variables. Variance inflation factors are examined to assess multicollinearity.

Robustness checks employ three alternative specifications. The model is initially estimated with one-year lags of the independent variables to overcome the possibility of simultaneous and reverse causality. Second, the sample is estimated without the years of crisis 2008-2009 and 2014-2015 to test whether the results are caused by the recessionary years than structural relations. Third, the institutional quality proxies are replaced by the corruption perceptions index and rule of law indicators individually to determine the sensitivity to the measurement options. Fourth, it is estimated using Newey–West standard errors (Newey and West, 1987) to take care of any autocorrelation. The main findings remained qualitatively unchanged across these alternative specifications.

Chow tests that are introduced by Chow (1960) are used to determine that structural breaks differ significantly across the pre-2014, 2014-2021, and post 2022 periods. This offers further evidence on whether conflict related disruptions essentially changed the relationship between economic activity and environmental outcomes beyond those changes that are captured by the dummy variables. All statistical computations are done in R with *dynLM*, *lmtest*, *sandwich*, and *strata* change with decoupling measures calculated in base R with some elasticity classification functions.

3. Empirical Results

3.1. Decoupling Analysis

Table 1 presents Ukraine's Tapio elasticities for the 2005–2021 aggregate period and four subperiods covering 2005–2024. According to Tapio (2005), elasticity is a percentage change in the environmental pressure divided by the percentage change in the GDP. Measurements of CO₂ emissions are in terms of metric tons per capita, energy intensity as the unit of primary energy supply in relation to unit of GDP, and in relation to renewable share as a percentage of gross final energy consumption. The entire sample size will be 20 annual observations (2005-2024). Different lengths of subperiods change accordingly.

During 2005–2021, Ukraine recorded a CO₂ elasticity of 0.42, meaning that emissions grew at 42% of the GDP growth rate. Energy intensity decreased by 18.3%, corresponding to an elasticity of –0.40, while renewable energy share increased by 5.8%.

Table 1: Tapio Decoupling Elasticities for Ukraine by Period, 2005–2024

Period	GDP Growth Rate (%)	CO ₂ Emissions Growth Rate (%)	CO ₂ Decoupling Elasticity	Energy Intensity Change (%)	Energy Intensity Elasticity	Renewable Share Change (pp)	Decoupling State (CO ₂)
2005-2021	45.7	19.2	0.42	-18.3	-0.40	+5.8	Weak decoupling
2005-2008	27.8	18.6	0.67	-8.2	-0.29	+1.2	Weak decoupling
2009-2013	9.6	3.6	0.38	-5.4	-0.56	+2.1	Weak decoupling
2014-2021	8.3	4.2	0.51	-4.1	-0.49	+2.8	Weak decoupling
2022-2024	-32.5	40.2	-1.24	+12.7	-0.39	-0.3	Strong negative decoupling

Note: Elasticities are calculated as $\% \Delta \text{ indicator} / \% \Delta \text{ GDP}$. Negative values indicate declining energy intensity relative to GDP growth.

Source: Authors' calculations based on State Statistics Service of Ukraine, World Bank WDI, EDGAR, IEA, and Eurostat data.

The 2022–2024 period records a CO₂ elasticity of -1.24 , reflecting declining GDP alongside rising CO₂ emissions. Under the Tapio taxonomy, this pattern represents strong negative decoupling, because GDP declined while CO₂ emissions increased. It therefore indicates environmental deterioration rather than successful green decoupling. The intensity of energy rose by 12.7% during this period. The negative elasticity is not a success of green transition but the economic collapse after the wholesale invasion with subsequent changes in the structure of the surviving economic activity to military products and necessities (Bernykov et al., 2025). Table 2 compares cumulative performance for Ukraine, Poland, Romania, and Germany over 2005–2021 to avoid wartime distortions. All indicators are measured consistently across countries using the same definitions as in Table 1.

Table 2: Comparative Decoupling Performance, Ukraine and Selected Countries, 2005-2021

Country	GDP Growth (%)	CO ₂ Emissions Growth (%)	CO ₂ Decoupling Elasticity	Energy Intensity Change (%)	Energy Intensity Elasticity	Renewable Share 2021 (%)	Renewable Share Change (pp)
Ukraine	45.7	19.2	0.42	-18.3	-0.40	9.3	+5.8
Poland	68.4	12.3	0.18	-31.2	-0.46	15.6	+12.4
Romania	52.9	4.8	0.09	-42.5	-0.80	24.5	+16.2
Germany	24.6	-5.7	-0.23	-19.8	-0.80	20.8	+14.7

Note: Data end in 2021 to avoid wartime distortions. Renewable share is measured as % of gross final energy consumption; energy intensity as primary energy supply per unit of GDP.

Table 2 shows that Ukraine's CO₂ elasticity (0.42) exceeds those of Poland (0.18), Romania (0.09), and Germany (-0.23). Energy intensity declined in all four countries, but Ukraine recorded a smaller reduction than Poland and Romania. Ukraine also had the lowest renewable energy share in 2021.

3.2. Regression Results

Table 3 reports ordinary least squares estimates for 2005–2024 ($n = 20$). Dependent variables are the natural logarithms of CO₂ emissions per capita and energy intensity. All continuous regressors are expressed in natural logarithms except governance quality and dummy variables. Table 3 explains that GDP per capita and heavy industry share have a positive relationship with both environmental indicators. In both models, the quality of governance is found to have negative coefficients. In both specifications, the 2022 dummy variable is significant in a positive manner.

Table 3: Regression Results

Dependent Variables CO ₂ Emissions and Energy Intensity		
Variable	Model 1: CO ₂ Emissions (ln)	Model 2: Energy Intensity (ln)
ln(GDP per capita)	0.48*** (0.09)	0.36** (0.11)
Heavy industry share	0.27** (0.08)	0.42*** (0.09)
Governance quality	-0.19* (0.07)	-0.24* (0.09)
Energy price	-0.11 (0.06)	-0.15* (0.06)
Environmental tax	-0.08 (0.05)	-0.12 (0.07)
D2014	0.14* (0.06)	0.09 (0.05)
D2022	0.31** (0.10)	0.23* (0.09)
Constant	2.84*** (0.42)	4.31*** (0.51)
Adjusted R ²	0.68	0.63

Note: Standard errors in parentheses. Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. All continuous variables except dummies are in natural logarithms.

Post-estimation diagnostics (Appendix B, Table B1) indicate no evidence of serial correlation, heteroskedasticity, or problematic multicollinearity. Chow tests for the reported breakpoints are presented in Table 4.

Table 4: Structural Break Test

Break Point	CO ₂ Emissions Model F-statistic	CO ₂ Emissions Model p-value	Energy Intensity Model F-statistic	Energy Intensity Model p-value
2014	4.82	0.008	3.96	0.021
2022	6.73	0.002	5.48	0.009
Unknown break (max)	7.21	0.001	5.93	0.005

Note: Chow tests compare models estimated separately for subperiods against the pooled model. Unknown break test uses the sup-Wald statistic from the strucchange package.

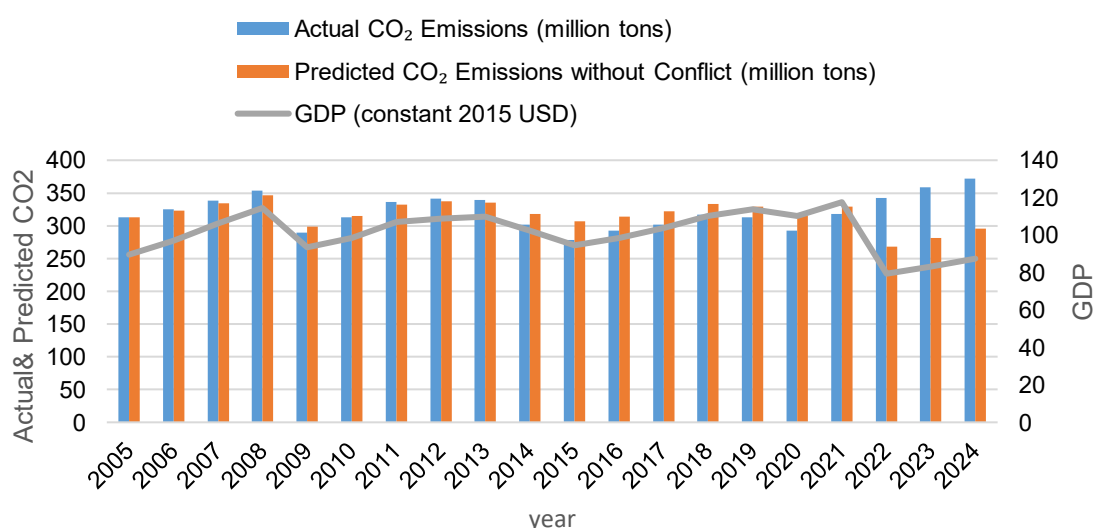
Table 4 presents Chow test results for structural breaks in 2014 and 2022. For the CO₂ emissions model, the 2014 break yields an F statistic of 4.82 with p value 0.008, rejecting coefficient stability. The 2022 break is larger, with F statistic 6.73 and p value 0.002. The unknown break test identifies 2022 as the most significant break point with F statistic 7.21. For the energy intensity model, both breaks are significant at conventional levels. These results identify statistically significant structural breaks coinciding with the 2014 and 2022 conflict periods, indicating changes in the relationship between economic activity and environmental outcomes.

Table 5: Component Analysis of Energy Intensity Change, Ukraine 2005-2021

Component	Contribution to Energy Intensity Change (%)
Structural change (sectoral shifts)	-6.2
Within-sector efficiency improvements	-12.1
Total energy intensity change	-18.3
Memorandum: Heavy industry share change	-2.8%

Note: Shift-share decomposition separates total energy intensity change into structural and within-sector efficiency components. Negative values indicate reductions in energy intensity.

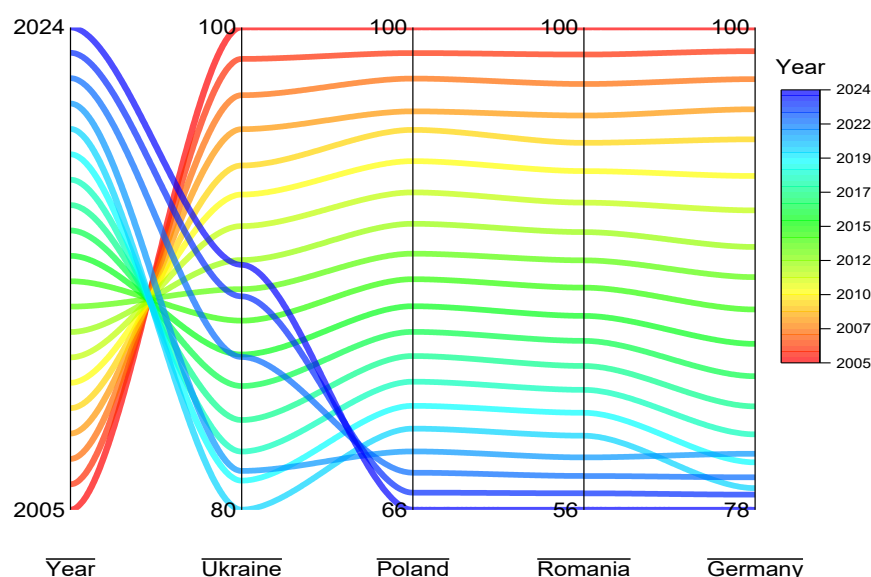
Table 5 indicates that within-sector efficiency gains are the main determinant of total energy intensity decrease, which is strictly two thirds of all the decrease. The contribution of structural change is about a third. The rather slow decrease in heavy industry share suggests slow, not fast structural change. The main conclusions remained qualitatively unchanged across all robustness checks (Appendix B, Table B2)

Figure 1: Ukraine CO₂ Emissions and GDP, Actual vs Predicted

Source: Author's calculations based on State Statistics Service of Ukraine, EDGAR, World Bank data.

The data tables for Figure 1 and Figure 2 provide the underlying values for the visual presentations. Figure 1 illustrates the divergence between actual CO₂ emissions and the emissions that would be predicted based on pre-conflict relationships, clearly showing the structural break effects after 2014 and especially after 2022. Figure 2 demonstrates Ukraine's persistent energy intensity gap relative to comparator countries and the reversal of progress during the wartime period, in stark contrast to the continued improvement in Poland, Romania, and Germany.

Figure 2: Energy Intensity Trends, Ukraine and Selected Countries (Index 2005 = 100)



Source: Author's calculations based on IEA, Eurostat, and State Statistics Service of Ukraine data.

4. Discussion

The empirical findings must be understood in terms of post socialist transformation. Compared with Poland and Romania as post-socialist EU comparators and Germany as an advanced EU benchmark, Ukraine exhibits a persistent gap in green transition performance. Poland recorded a CO₂ elasticity of 0.18 and a 31.2% reduction in energy intensity during 2005–2021. Romania recorded an elasticity of 0.09 and a 42.5% reduction. Ukraine recorded a CO₂ elasticity of 0.42 and an 18.3% reduction in energy intensity, indicating weaker improvement than Poland and Romania.

The persistence of the industrial structure that is energy-consuming comes out as one of the limitations. A 1% increase in heavy industry share is associated with an estimated 0.42% increase in energy intensity. Ukraine continues to have a larger heavy-industry base than the selected post-socialist comparators. This structural divergence has its origins in the specialisation of the Soviet era and remains as such due to the privatisation process which privileged the existing industrial classes rather than the structural reorientation.

There are a number of mechanisms through which the post-socialist constraints work. To start with, industrial electricity prices in Ukraine remain lower than those in the EU, which decreases efficiency investment incentives. Second, the effectiveness of environmental regulation is significantly lower in different regions, and the economic factor of the region is an important issue because in impoverished economic areas, facilities are not closely examined. Third, the reliance of the government on extractive and heavy industry revenues as a form of fiscal dependence results in government opposition to the issue of carbon taxation. Fourth, there is no much interest in green restructuring of the industrial sector by the banking sector. These mechanisms are interrelated and complete each other.

The quality of governance is a key issue to environmental performance. One point increase in the quality of governance is linked to 19% reduction in emissions and 24% reduction in energy intensity. Ukraine's governance indicators remained below those of the selected comparator countries throughout the study period. This institutional void expresses

itself in practice: Renewable energy projects continue to face lengthy approval procedures in the country compared to the Central Europe, and enforcement in the courts of breaking the environment regulations is uneven. The same authors, Kropelnytska et al. (2025) have defined institutional weakness as the major obstacle to sustainable development in Ukraine.

The significant discontinuities of the conflict are structural and are peculiar to the experience of Ukraine. The 2022 conflict dummy is 31% higher than the expected values of emissions. This divergence can be attributed to a number of mechanisms. Physical destruction of energy infrastructure led to the need to use more emitting diesel generators. The natural gas supplies were disrupted and this in turn caused more coal and fuel oil to be burnt. The military activities alone produce a lot of emissions. Industrial composition was changed with the territorial occupation. The flux of populations changed the mode of transport and domestic energy consumption. IEA. (2025) reported the effects of the destruction of the energy system in Ukraine that raised the amount of emitted energy per unit of energy supplied.

Comparison with the literature in the past demonstrates some consistency and extensions. The elasticities of decoupling are consistent with those of (Szép et al., 2022) who discovered less decoupling in post-Soviet states compared to Central European EU members. The institutional results theorize Sokil (2024) by operationalizing the effects of governance in the Ukrainian context. The results of the renewable energy are consistent with Sala et al. (2023) regarding the limitation of the investment in the green energy sector in Ukraine.

A number of studies have contradictory results. Maniu et al. (2021) have highlighted the role of green entrepreneurship as an energy source of environmental change, and bottom-up innovation could be more important than the top-down institutional one. Although the outcomes of the regression do not test this directly, the small within-sector efficiency gains in shift-share analysis indicate that bottom-up innovation is not yet on the transformative scale. IEA. (2025) projected the renewable projections better than they have been realised, which is a sign of policy and investment barriers.

Several limitations apply. The time series length restricts econometric complexity. Data for 2022–2024 are provisional. Governance indicators are subject to measurement error. Regional heterogeneity is not captured in national aggregates. These considerations suggest caution in interpreting coefficient magnitudes. A few interpolated and extrapolated observations may introduce uncertainty for the affected years, particularly 2022.

To heal post war, the results are that the reconstruction process should not be as easy as replacing the pre-war infrastructures. The recovery in essence should restructure the industrial arrangement, improve institutional capacity in handling the environment and come up with war sensitive policies, which put into consideration the differing nature in war aftermath and economic makeup of the region. The issue of the political economy of industrial incumbency and institutional inefficiencies that allows regulatory capture ensures that green transition will not be achieved despite the amount of reconstruction investment.

Conclusion

This study has quantified Ukraine's green economy transition from 2005 to 2024. The analysis confirms weak decoupling between economic growth and environmental pressures, though Ukraine's performance consistently trails selected post-socialist comparators and an EU benchmark. The legacy of energy-intensive industrial structure and persistent institutional weaknesses explain much of this gap. The analysis identified statistically significant structural

breaks coinciding with the 2014 and 2022 conflict periods, indicating changes in the relationship between economic activity and environmental outcomes.

The analysis leads to four major conclusions. First, Ukraine exhibits weak decoupling between GDP and emissions, but the degree of decoupling remains substantially lower than in the selected comparator countries that completed deeper institutional reforms. Second, energy intensity improvements over the study period fall considerably short of reductions achieved by the selected comparator countries, reflecting the enduring legacy of Soviet-era industrial structure. Third, renewable energy deployment lags both EU averages and Ukraine's own targets, indicating persistent policy and investment barriers. Fourth, the 2014 and 2022 conflicts systematically worsened environmental outcomes beyond what economic contraction alone would predict, confirming that wartime disruptions carry significant environmental costs. These results have three level three implications in the reconstruction policy after the war. First, the reconstruction investments need to be in line with the European Green Deal principles and EU taxonomy to make sure that the rebuilding process does not entrap carbon-intensive infrastructure. Second, carbon pricing reform provides the means of avoiding stalling structural change, as long as transition periods consider the social and regional adjustment costs. Similar evidence from the EU indicates that targeted policy instruments can also support improvements in energy efficiency (Pimenow et al., 2026b). Third, the international financial support must incorporate green conditionality to strengthen domestic policy intentions and eliminate backsliding in the rebuilding effort.

The prospective studies should take three directions. Disaggregated regional analysis would shed more light on the subnational difference in transition paths. This macroeconomic perspective of energy efficiency can be complemented by firm-level analysis to establish factors (microeconomic) that drive energy efficiency. The studies of the political economy are expected to investigate how the interests of the incumbents influence the results of the reforms. The reconstruction process is in progress.

This study gives the overview of the green economy transition in Ukraine with the explicit consideration of the constraints of post-socialist transformation and structure disruptions in the context of conflicts. The data confirms that the direction of Ukraine is rather different than the peers of two post-socialist EU comparators (Poland and Romania) and one advanced EU benchmark (Germany) due to the existing industrial legacies, the deficiency of institutions, and interruptions during the war. These problems can only be resolved by technical solutions but also the very structure of the institution in line with the European integration, and aided by the right policy of reconstruction.

CRediT Authorship Contribution Statement

Zhurba, O.: Conceptualization, Methodology, Formal analysis, Writing – review & editing. Hapieieva, O.: Data curation, Software, Visualization, Writing – review & editing. Yaremchuk, S.: Methodology, Formal analysis, Writing – original draft, Writing – review & editing. Petrukha, N.: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. Petrukha, S.: Software, Visualization, Formal analysis, Writing – review & editing.

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Data Availability Statement

The data supporting this study are derived from publicly available sources documented in Appendix A, Table A1. Source links and access information are provided in the methodology and reference list.

Ethical Approval Statement

This study relies exclusively on publicly available secondary and aggregate data and does not involve human participants, personal data, animal subjects, or experimental interventions. Therefore, ethical approval was not required.

Software Disclosure

All statistical analysis was conducted using R version 4.3.2. Key packages used include: *dynlm* for time series regression, *lmtest* for diagnostic tests, *sandwich* for heteroskedasticity-consistent standard errors, and *strucchange* for structural break testing. Decoupling calculations were implemented in base R with custom functions.

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Appendix A

Table A1: Data Inventory, Annual Frequency

Variable	Definition	Units	Source	Years	Transformations	Missing Data
GDP	Gross domestic product	Constant 2015 USD millions	WDI, SSSU	2005-2024	Natural logarithm	None
CO ₂ emissions	Carbon dioxide emissions from fuel combustion	Metric tons per capita	EDGAR, IEA	2005-2024	Natural logarithm	Interpolation for 2022
Energy intensity	Primary energy supply per GDP	MJ per constant 2015 USD	IEA, Eurostat	2005-2024	None	None
Renewable share	Renewable energy in gross final consumption	%	Eurostat, SSSU	2005-2024	None	None
Industrial share	Manufacturing value added	% of GDP	WDI	2005-2024	None	None
Heavy industry share	Metals, chemicals, minerals share	% of industrial output	SSSU	2005-2024	None	None
Trade openness	Exports plus imports	% of GDP	WDI	2005-2024	None	None
Energy price	Industrial electricity price	USD per kWh	IEA	2005-2024	Constant prices	Linear interpolation
Environmental tax	Environmental tax revenue	% of GDP	Eurostat, SSSU	2005-2024	None	None
Governance quality	World Governance Indicators average	Index (-2.5 to +2.5)	WGI	2005-2023	None	Extrapolated for 2024
Conflict dummy 2014	Indicator for post-2014 period	Binary (0/1)	Constructed	2014-2024	None	Not applicable
Conflict dummy 2022	Indicator for post-2022 period	Binary (0/1)	Constructed	2022-2024	None	Not applicable

Note: A small number of observations were interpolated or extrapolated where official data were unavailable.

Appendix B

Table B1: Diagnostic tests

Test	CO ₂ Model	Energy Intensity Model
Breusch–Godfrey LM (p value)	0.21	0.18
Breusch–Pagan (p value)	0.34	0.29
Maximum VIF	3.42	3.42
F-statistic	12.84***	10.37***

Note: Significance levels: * p < 0.05, ** p < 0.01, *** p < 0.001. VIF = Variance Inflation Factor

Table B2: Robustness specifications

Specification	GDP Coefficient	Heavy Industry Coefficient	Governance Coefficient	D2022 Coefficient	Adjusted R ²
Baseline	0.48*** (0.09)	0.27** (0.08)	-0.19* (0.07)	0.31** (0.10)	0.68
One-year lags	0.43*** (0.10)	0.24* (0.09)	-0.17* (0.08)	0.28** (0.09)	0.64
Excluding 2008-2009	0.51*** (0.11)	0.29** (0.09)	-0.21* (0.08)	0.33** (0.11)	0.66
Excluding 2014-2015	0.46*** (0.10)	0.25* (0.10)	-0.18 (0.09)	0.29* (0.11)	0.62
CPI instead of WGI	0.47*** (0.09)	0.26** (0.08)	-0.15 (0.08)	0.30** (0.10)	0.65
Rule of law instead	0.48*** (0.09)	0.27** (0.08)	-0.20* (0.08)	0.31** (0.10)	0.67
Newey-West SE	0.48*** (0.11)	0.27* (0.10)	-0.19 (0.10)	0.31* (0.13)	0.68

Note: Standard errors in parentheses. Significance levels: * p < 0.05, ** p < 0.01, *** p < 0.001. CPI = Corruption Perceptions Index. Newey-West row reports standard errors adjusted for autocorrelation and heteroskedasticity.