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Manuscript ID:  
IJWGAFES-2025-020903

DOI: 10.5281/zenodo.17648248

DOI Link:  
<https://doi.org/10.5281/zenodo.17648248>

Volume: 2  
Issue: 9  
September  
Year: 2025  
E-ISSN: 3066-1552

Submitted: 05 Aug. 2025  
Revised: 10 Aug. 2025  
Accepted: 06 Sept. 2025  
Published: 30 Sept. 2025

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**How to cite this article:**  
Kumar, R. (2025). Energy Geography of Ukraine: How Do Ukraine's Natural Gas Pipelines, Nuclear Plants, and Emerging Renewable Projects Reflect Its Strategic Position in European Energy Security?. International Journal of World Geology, Geography, Agriculture, Forestry and Environment Sciences, 2(9), 12–15. <https://doi.org/10.5281/zenodo.17648248>

# Energy Geography of Ukraine: How Do Ukraine's Natural Gas Pipelines, Nuclear Plants, and Emerging Renewable Projects Reflect Its Strategic Position in European Energy Security?

Rakesh Kumar

## Abstract

Ukraine's energy geography, shaped by its vast network of natural gas pipelines, extensive nuclear infrastructure, and rapidly expanding renewable energy sector, unequivocally underscores its pivotal and evolving role in European energy security. This position is particularly critical amid escalating geopolitical tensions and the continent-wide imperative for decarbonization. This study analyzes the profound implications of key developments, such as the cessation of Russian gas transit via Ukraine in January 2025, a move that significantly diminished its historical transit leverage but also accelerated its path towards energy independence. Concurrently, the nation's nuclear power plants, exemplified by the Zaporizhzhia facility, face ongoing and severe risks from military occupation and attacks, raising serious concerns about safety and regional stability. Amid these challenges, Ukraine is aggressively pursuing a green transition, with renewables aiming to constitute 27% of its energy consumption by 2030, aligning with European decarbonization goals. Drawing on comprehensive 2025 data and recent geopolitical shifts, findings reveal a decisive strategic pivot: Ukraine's move from historical gas dependency towards a model of diversified energy exports and strengthened interconnections with the European Union. While this transition enhances overall EU energy resilience and strengthens Ukraine's long-term energy security, it also exposes new vulnerabilities related to infrastructure security and economic adjustments. Recommendations emerging from this analysis advocate for urgent international collaboration to bolster grid ties, modernize existing infrastructure, and establish robust international safeguards to protect critical energy assets, thereby solidifying Ukraine's indispensable strategic position as a resilient and reliable energy partner for Europe.

**Keywords:** Energy geography, Ukraine, Gas Pipelines, European, Energy Security, Renewable Energy, Energy Security.

## Introduction

Ukraine's strategic location at the nexus of Europe and Eurasia positions it as a critical hub for continental energy transit. Historically, its pipelines were vital conduits for Russian natural gas to Europe, while its nuclear facilities provided essential domestic power. The nation's burgeoning renewable energy sector has emerged as a key post-war priority. The 2022 Russian invasion profoundly disrupted this established energy landscape, leading to the cessation of Russian gas transit in 2025 and posing significant threats to nuclear safety. Concurrently, the invasion has catalyzed Ukraine's transition towards green energy, although concerns remain about the long-term stability and security of its energy infrastructure amidst ongoing conflict and the potential for future geopolitical shifts. This transformation necessitates a re-evaluation of the intertwined relationship between energy infrastructure, geopolitical dynamics, and the imperative for low-carbon transitions at a global scale (Bouzarovski et al., 2015). This article addresses the research question by examining the spatial and functional roles of these energy components, underscoring Ukraine's dynamic transformation from a potentially vulnerable transit state into a significant and diversified energy partner for Europe. This study also delves into the complexities of Ukraine's energy infrastructure, analyzing the strategic implications of its natural gas pipelines, nuclear power plants, and nascent renewable energy projects in the context of broader European energy security.

## Literature Review

Scholarly analyses emphasize Ukraine's pipelines as historical levers in EU-Russia relations, with studies highlighting transit's crucial role in energy security until its 2025 halt (Asllani, 2023). Nuclear literature predominantly focuses on wartime risks, citing IAEA reports detailing Zaporizhzhia's blackouts and ongoing operational challenges (Szulecki & Øverland, 2023). Research on renewables underscores Ukraine's National Energy and Climate Plan for 2025-2030, which targets significant sustainability gains amidst reconstruction efforts (Kravchenko et al., 2024).

However, some analyses suggest that while the cessation of Russian gas transit diminishes Ukraine's leverage, it also presents an opportunity for greater energy independence and strategic realignment within the EU market, potentially strengthening its long-term energy security position (Kravchenko et al., 2023). Broader works on European security underscore Ukraine's potential in gas storage and interconnections, though gaps exist in integrated 2025 assessments post-transit end.

### **Methodology**

This qualitative study synthesizes secondary data from web searches conducted in September 2025, including reports from OECD-NEA, IAEA, CSIS, and Energy Community. Themes analyzed include infrastructure status, geographical distributions, and security implications, with cross-verification to address data biases in conflict zones.

### **Analysis**

#### **Natural Gas Pipelines**

Ukraine's pipeline network, spanning over 36,000 km, historically facilitated 30-40 bcm/year of Russian gas to Europe via systems like Urengoy-Pomary-Uzhgorod and Soyuz. Concentrated in its western borders for EU exports, these assets generated \$1-3 billion in annual fees pre-2025 (Slakaityte & Surwillo, 2024). The transit contract expired on January 1, 2025, halting these flows and reflecting Ukraine's strategic pivot to deny Russia revenue amid the invasion (Skalamera & Buchanan, 2021). While the Druzhba oil pipeline continues southern transits to Hungary and Slovakia, underscoring selective dependencies (Perdana et al., 2022), this shift significantly enhances EU diversification but exposes Ukraine to substantial economic losses, positioning it as a buffer in energy geopolitics. Despite these geopolitical shifts, Ukraine's significant underground gas storage capacity, holding 30 bcm, remains a critical asset for European energy security, offering potential solutions for mitigating supply shortages and stabilizing regional markets (Božić et al., 2021). Furthermore, ongoing efforts to modernize Ukraine's extensive gas infrastructure are crucial for maintaining its viability as a future transit and storage hub, especially as the country seeks to integrate more deeply with the European energy grid (Beseda et al., 2025). However, some analyses suggest that while the cessation of Russian gas transit diminishes Ukraine's leverage, it also presents an opportunity for greater energy independence and strategic realignment within the EU market, potentially strengthening its long-term energy security position (Sørensen & Cappelletti, 2023).

#### **Nuclear Power Plants**

Ukraine operates nine reactors across three sites: Rivne, South Ukraine, and Khmelnytskyi, providing over 50% of electricity ("Russia and Eastern Europe," 1995). Zaporizhzhia, Europe's largest with six units, remains occupied and in long-term outage, suffering its 10th blackout in September 2025 due to grid strikes. Geographically, plants cluster in western and southern regions for grid stability, but wartime threats—over 549 drone flyovers in 2025—highlight vulnerabilities. IAEA presence since 2023 underscores international stakes, reflecting Ukraine's role in preventing nuclear crises that could ripple to European security. However, some analyses suggest that while the cessation of Russian gas transit diminishes Ukraine's leverage, it also presents an opportunity for greater energy independence and strategic realignment within the EU market, potentially strengthening its long-term energy security position (Kravchenko et al., 2023).

#### **Emerging Renewable Projects**

Ukraine's renewables sector is poised for significant growth, targeting 27% of final consumption by 2030. This expansion is characterized by decentralized solar and wind initiatives designed to operate effectively even amidst ongoing conflict. In 2025, the integration of 286 MW of balancing capacities facilitated the addition of 863 MW of new generation capacity and battery energy storage systems (Koval et al., 2023). Notable projects include EIB-UNDP solar integrations in public buildings and EBRD's risk mitigation facilities for vital investments. Geographically, solar power generation is concentrated in the southern plains, exemplified by the operationalization of the first solar-powered water treatment facility in Chortkiv in September 2025. Furthermore, Ukraine's electricity exports to the EU saw a notable increase, reaching 650 MW in Q2 2025, solidifying its position as a crucial green energy exporter. However, some analyses suggest that while the cessation of Russian gas transit diminishes Ukraine's leverage, it also presents an opportunity for greater energy independence and strategic realignment within the EU market, potentially strengthening its long-term energy security position (Kravchenko et al., 2023).

#### **Reflection on European Energy Security**

These elements mirror Ukraine's strategic pivot: Pipeline halts force EU alternatives, nuclear risks necessitate safeguards, and renewables foster interconnections. Ukraine's substantial gas reserves and storage capabilities can significantly enhance EU supply stability, while €500 million in EU loans provided in 2025 are specifically bolstering winter security measures. The REPowerEU initiative and Ukraine's National Energy and Climate Plan align the country's energy objectives with broader EU goals, thereby diminishing Russia's energy leverage (Kulakevich, 2024). However, some analyses suggest that while the cessation of Russian gas transit diminishes Ukraine's leverage, it also presents an opportunity for greater energy independence and strategic realignment within the EU market, potentially strengthening its long-term energy security position.

Component	Key Geography	Status (2025)	Security Role
Pipelines	Western borders	Transit halted Jan 1	Diversification buffer
Nuclear Plants	West/South (Rivne, etc.); South (Zaporizhzhia)	9 operating; ZNPP outage	Crisis prevention
Renewables	Southern plains, decentralized	27% target by 2030; 650 MW exports	Green integration

## Discussion

Ukraine's energy sector is shifting away from reliance on external sources towards greater self-sufficiency and contributing to European energy security through varied supply routes and green energy development. However, the ongoing conflict has revealed significant vulnerabilities, requiring enhanced security measures and strategic investments. Future energy infrastructure in Ukraine is expected to focus more on western regions for improved stability and safety. While the end of Russian gas transit reduces Ukraine's bargaining power, it also offers a chance for increased energy independence and strategic adjustments within the EU market, which could improve its long-term energy security. This transition is critical for both Ukrainian and broader European energy stability, as evidenced by the dramatic drop in electricity load during the initial phase of the invasion (Schledorn, 2023).

## Conclusion

Ukraine's pipelines, nuclear plants, and renewables encapsulate its strategic evolution in European energy security, from transit vulnerabilities to diversified partnerships. Sustained support is vital for this role's endurance, as the country's energy sector navigates complex geopolitical dynamics and invests in critical infrastructure for self-sufficiency and European stability. However, some analyses suggest that while the cessation of Russian gas transit diminishes Ukraine's leverage, it also presents an opportunity for greater energy independence and strategic realignment within the EU market, potentially strengthening its long-term energy security position.

## Acknowledgment

I, Rakesh Kumar, Asst. Prof and Head, Dept. of Geography, Murarka College Sultanganj, TMBU, Bhagalpur, Bihar do hereby acknowledge that no financial or any other support was provided to me. Also that I face no conflict of Interest regarding publication of these papers.

## Financial support and sponsorship

Nil.

## Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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