

GEOPOLITICS AND ENERGY TRANSITION FROM DEPENDENCE TO AUTONOMY: THE COMPARATIVE CASE OF THE REPUBLIC OF MOLDOVA AND ROMANIA

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This study examines how the global transition from fossil fuels to renewable energy is reshaping geopolitical power dynamics, using Romania and the Republic of Moldova as comparative case studies. It explores whether the energy transition disperses power or reconfigures it spatially, economically, and institutionally through a qualitative framework integrating energy geography, energy economics, and geopolitics. Based on historical analysis and policy discourse interpretation, the research shows that while the decentralized nature of renewable energy weakens traditional geographic monopolies over fossil resources, new forms of dependence are emerging around critical raw materials, clean technologies, financial capital, and regulatory regimes. These dynamics form a “technology–capital–rules” network that intensifies competition over technological sovereignty and institutional access. As a result, geopolitical influence is shifting from the control of pipelines and fuel supply routes to instruments such as carbon tariffs, green standards, and regulatory frameworks, creating new patterns of “weaponized interdependence” within global green supply chains. The comparison of Romania and R. Moldova further demonstrates that, despite different institutional trajectories, both countries have relied on EU frameworks to manage energy crises and accelerate energy transition—R. Moldova converging toward EU norms and Romania strengthening its energy resilience and regional role—offering insights for both EU candidate states and member states navigating the evolving geopolitics of the energy transition.

Keywords:

Energy Transition, Energy Economy, Energy Geography, Geopolitical Restructuring, Weaponized Interdependence, Technological Sovereignty, Institutional Identity

JEL Classification: F5, Q4, R12

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1. Introduction

Amid the global green transition and rising geopolitical competition, the energy – politics nexus has become co-evolutionary, marked by mutual feedback between renewable energy decentralization and geopolitical restructuring. Technological advances in solar and wind, facilitated by global trade, have diluted the dominance of oil- and gas-rich regions, dispersing energy sovereignty across more states. This transformation undermines traditional centralized energy geopolitics and fosters a new global paradigm shaped not by resource control, but by institutional frameworks, technology standards, and supply chain governance - signaling a shift to toward a rules-based and innovation-driven international energy order.

In this context, the study adopts a qualitative approach to construct a three-dimensional analytical framework, integrating macro-level structural analysis with meso-level institutional comparison. Centered on Romania and the Republic of Moldova, it examines how energy transitions intersect with geopolitical restructuring and how national energy trajectories are influenced by geopolitical identity and institutional embeddedness. The findings reveal how the EU's "Open Strategic Autonomy" is interpreted -and partially internalized- in Moldova's case, offering strategic insights for other candidate states. Nonetheless, varying institutional trajectories among candidate countries constrain the broader applicability of these conclusions.

1.1. Background: Traditional energy geography and geopolitical situation

The heterogeneity of energy geographic distribution and transportation modalities has shaped the role differentiation in modern international energy supply chains, forming a tripartite structure centered on producer, transit, and consumer states (Wang & Qin, 2012). This geographical determinism not only defines nations' inherent energy endowments but also fosters multiple energy-geopolitical power centers through the "hydrocarbon economy" mechanism (Mitchell, 2009).

Under the traditional fossil energy system, the United States controls the energy supply chain through the "petrodollar" system (Yergin, 2011). Resource-rich regions such as the Middle East and Russia accumulate strategic capital and enhance their international discourse power through energy trade. Industrial economies such as Japan and South Korea are structurally vulnerable due to their dependence on energy imports (Yang et al., 2023). The competition for control of energy transportation corridors (such as the Strait of Hormuz and the Nord Stream Pipeline) further transforms geographical elements into geo-game tools, constituting a unique form of "pipeline politics" (Siddi, 2022; Divsallar, 2022).

Competition among major powers for control of energy and access routes affects the stability of energy trade, and even leads to regional conflicts and political heated debates, highlighting

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the profound impact of energy geography on the international political and economic landscape (IEA, 2024).

1.2. Research Question: Will the development of renewable energy break the traditional energy geo-power map?

Over the past decade, driven by the maturation of renewable energy generation technologies, the large-scale expansion of electricity grids, and the widespread adoption of electric vehicles, the global energy system has been undergoing a paradigm shift—from the “carbon-based geography” of fossil fuels to the “silicon-based network” of electrified infrastructure. (Blondeel et al., 2021). Although the distributed and localized characteristics of renewable energy power generation reduce the security problems of the traditional energy supply chain, it gives birth to a new dimension of competition centered on key minerals (lithium, cobalt, etc.) and technical standards (IREANA, 2023).

The energy transition leads to a triple paradox: First, the wide geographical distribution of renewable energy potentially weakens the concentration of traditional energy and leads to the “weaponized interdependence” of energy trade (Farrell & Newman, 2019; LaBelle, 2024). Secondly, supply chain concentration in PV panel manufacturing and energy storage battery technology (e.g., China accounts for 76% of global polysilicon production) is creating a new type of asymmetric dependence (Zabelin, 2024). Thirdly, in response to geopolitical conflicts, the European Commission evolved the “Geopolitical Committee” (Yan, 2021). Due to the impact of the novel coronavirus pandemic, liberalism and protectionism collided sharply, and trade policy shifted, it proposed an “open strategic autonomy” of the EU. On the contrary, trade framework and supply chain have become key tools to achieve geopolitical goals (Schmitz & Seidl, 2023; Christou & Damro 2024).

Since World War II, energy has frequently been “weaponized” to coerce other countries and distort markets. The Russia-Ukraine conflict has further weaponized energy, affecting European countries that depend on Russian energy (Goldthau & Sitter, 2022). In this context, the authors of the article formulate some research questions as follows:

- Does the Energy transition truly decentralize geopolitical power or does it merely reshape the spatial vehicle for power competition?
- Does the trade intensify competition in energy technologies and strengthen the tools of the geopolitical power?

1.3. A Case study: Differentiated energy transition paths in Romania and R.Moldova

Romania (EU member) and R.Moldova (EU candidate), located in the geo-sensitive region of Eastern Europe, are selected as a comparative case. Although the two countries share the Dacian cultural gene (Simionov, 2023), there are significant differences in the

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embeddedness of political institutions (Gohlke, 2018). Amid the energy crisis caused by the Russia–Ukraine conflict, Romania and R.Moldova responded differently. Romania, with domestic energy reserves, enhanced its supply chain resilience through EU support. R.Moldova, lacking resources, urgently sought international aid, joined the EU Energy Community’s emergency framework, aligned its energy laws and markets with EU standards, and deepened cooperation with Romania to address the crisis.

Specifically, Romania has built an energy corridor through the Danube River basin by deeply internalizing the EU Energy Charter and its union rules (Sirbu, 2023). Its energy autonomy is reflected in its adherence to the "Union cornerstone" rules within the framework of the "Brussels Consensus" (Schmitz & Seidl, 2023). In contrast, in the "stress test" of the Russia–Ukraine conflict, R.Moldova was forced to strike a balance between "institutional imitation" and "path breakthrough" (Hall, 2020), and its energy transition practice is essentially a process of geo-identity reconstruction (Loskot-Strachota, 2024; EEAS 2024). This process not only strengthens Dacian cultural identity and solidarity between Romania and R.Moldova but also supports the EU’s aim of advancing “European unity” through practical integration.

This study offers three key innovations. First, it constructs an interdisciplinary three-dimensional analytical framework—combining energy geography, economics, and geopolitics—to analyze power restructuring in renewable energy transitions, moving beyond resource-centric security paradigms. Second, it extends the theory of “weaponized interdependence” to green energy, revealing how dependencies on key technologies, standards, and materials have become tools of institutionalized geopolitical power. Third, using the Moldova–Romania cooperation case within the EU framework, it examines how candidate countries enhance energy autonomy through institutional alignment and regional collaboration. These contributions form both the core innovations and the analytical structure of the study.

2. Three-dimensional analysis framework and literature review

The strategic nature of energy continues to shape the international political and economic order. Based on the taxonomy of energy, this study constructs a three-dimensional analysis framework of energy geography, energy economy and geopolitics to systematically examine the restructuring mechanism of the geopolitical pattern caused by the green transformation of energy.

2.1. Energy classification

We compared the classification of energy provided in official documents of IEA, IRENA, and Eurostat. Due to their different characteristics, there are cross-relationships. Therefore, we created Figure 1 to further visualize and define them. This study focuses on the relationship

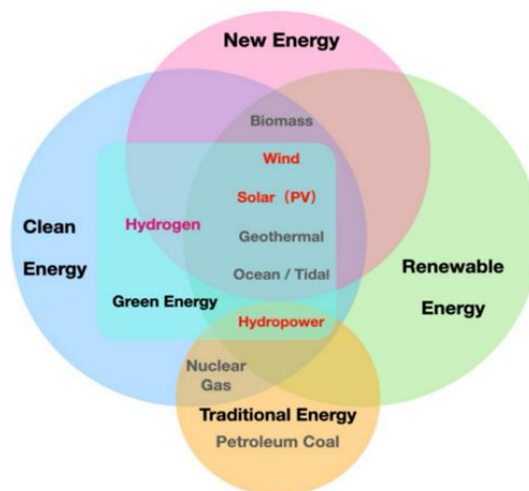
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between energy transition and geopolitics. It prioritizes low-carbon energy types—green, renewable, clean, and new energy—while incorporating geopolitical, technological, and trade dimensions. Solar, wind, and hydropower are selected as representative sources to illustrate the paradigm shift from traditional fossil fuels (oil, coal, and gas). Other energy forms are excluded based on three core considerations to ensure analytical clarity and thematic consistency.

- There is ambiguity in the classification of hydrogen energy due to differences in carbon emissions from production paths (IRENA, 2024);
- Nuclear energy has been commercialized since the 1960s, so it is considered a traditional energy source. Nuclear energy is still considered a clean energy source both in terms of its source and its use. (IRENA, 2024);
- Biomass, geothermal and tidal energy are limited by technological maturity and market penetration (IEA, 2024), and do not yet have a significant geographical impact.

Note: Cherp and Jewell (2011) argue that institutional identities shape national perceptions of energy security, influencing energy system design and dependency paths. Thus, meso-level analyses should consider institutional and cultural roles in energy geography. Yet, their variability limits their suitability as a macro-level analytical foundation.



Source: Authors' creation

Figure 1: Cross relationship of different energy categories and types

2.2. Literature Review from the prism of the Three-Dimensional Framework

Based on the three-dimensional interaction between energy geography, energy economy and geopolitics, this study constructs this analytical framework to reveal the dynamic mechanism of the interdependence between energy transformation and weaponization, the conceptualization of which is specially discussed further. The framework emphasizes the

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paradigm shift from "carbon-based hegemony" to "silicon-based network", and analyzes the complex role of spatial reconstruction of international energy power, green economic fission and political game.

Constructing the energy geography dimension

Michael Bradshaw (2010), in *Global Energy Dilemmas: A Geographical Perspective*, examines the spatial distribution and geopolitical dynamics of global fossil fuels, analyzing the complex interplay between energy security, climate change, and energy poverty. He introduces the concept of "energy dilemmas" to highlight the spatial inequalities and policy tensions embedded in the global energy system. Gavin Bridge, integrating political economy with geographical analysis, critically investigates the socio-spatial dimensions of energy extraction, distribution, and consumption. In *Global Production Networks and the Extractive Sector* (2008), Bridge applies the Global Production Networks (GPN) framework to explain how transnational mineral and energy supply chains are embedded within asymmetric global power relations. Additionally, he combines Material Flow Analysis with political ecology to expose the exploitative dynamics of resource extraction on labor and the environment. In 2013, Bridge and colleagues proposed the concept of "geographical sensitivity" in energy transitions, advocating for the integration of spatial analysis into energy planning to mitigate social and territorial conflicts (Bridge et al., 2013).

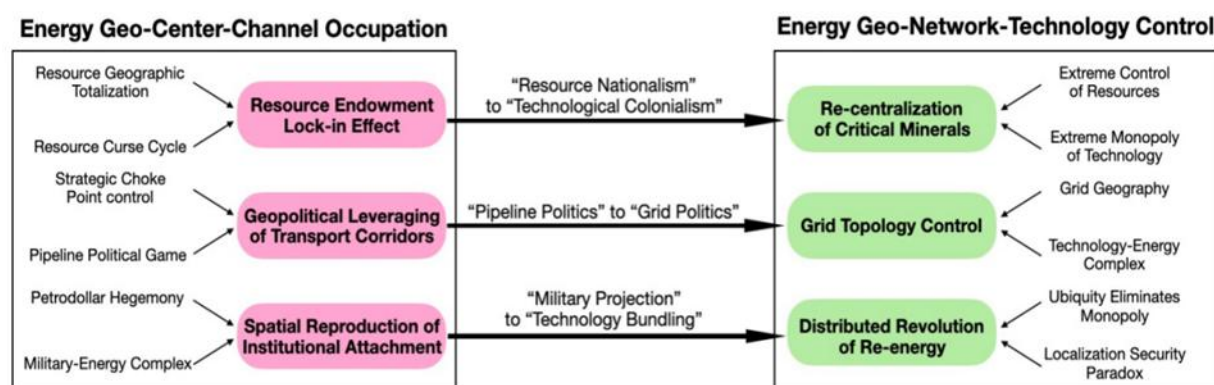
Based on the scholarly foundations of these researchers, this article reveals how traditional energy systems shape hegemonic patterns and how energy transition reconstructs geographical power logic through analyzing the spatial distribution of energy resources, infrastructure layout, and their interaction with power structures. Thus the authors formulate the theoretical framework that encompasses three core logics (Figure 2), The author's three major logical constructions are as follows:

- *Geopolitical Logic of Traditional Energy and Hegemony.* The immobility and spatial agglomeration of fossil fuels construct carbon-era hegemonic systems through three mechanisms: Resource Endowment Lock-in Effects (geographical totalitarianism, resource curse cycle); Geopolitical Leverage of Transportation Corridors (strategic chokepoint control, pipeline political gaming); Spatial Reproduction of Institutional Dependence (petrodollar hegemony, military-energy complex).
- *Geospatial Restructuring Characteristics of Energy Transition.* Re-concentration of Critical Minerals (Southern Hemisphere resource pole dominance, Northern Hemisphere technological pole monopoly); Distributed Revolution of Green Energy (ubiquitous generation dissolving monopolies, localization security paradox). This drives energy power transformation from "spatial monopoly" to "grid topology control" (geopoliticized power grids, techno-energy complex), creating a paradox combining decentralization and new dependencies.

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- *Power Transition Pathways in Geographical Dimensions.* Energy transition propels hegemonic logic evolution: from "resource nationalism"¹ to "techno-colonialism"²; from "pipeline politics"³ to "grid politics"⁴; from "military projection"⁵ to "technological entrapment"⁶. Ultimately achieving the shift from "geopolitical hub-corridor dominance" to "geospatial network-technological control".



Source: Elaborated by the first author

Figure 2: Constructing Energy Geographic Dimension**Constructing the energy economic dimension**

The "Smile Curve" (Kaplinsky, 2013) reveals the inherent connection between international division of labor and value distribution. The high value-added parts such as R&D, technology, and brands at both ends of the curve are mostly controlled by developed countries, while developing countries mainly undertake the low value-added processing and manufacturing links in the middle. Rafael Kaplinsky pointed out that the deepening of international division of labor has made global value distribution increasingly unequal. Developing countries have long been trapped in the low value-added field and have difficulty in industrial upgrading.

¹ Resource Nationalism: The assertion of control by people and governments, for strategic and economic reasons, over natural resources located on their territory

² Techno-colonialism: how digital innovation, data and AI practices entrench power asymmetries and engender new forms of violence and new inequities

³ Pipeline Politics: the geopolitical game surrounding the construction, operation and control of transnational energy pipelines

⁴ Grid Politics: International power grid interconnections can offer political benefits to the countries participating in power trading.

⁵ Power Projection: in international relations is the capacity of a state to deploy and sustain forces outside its territory.

⁶ Technical Entrapment: a situation where a society becomes overly reliant on a particular technology or system, hindering the adoption of more sustainable alternatives.

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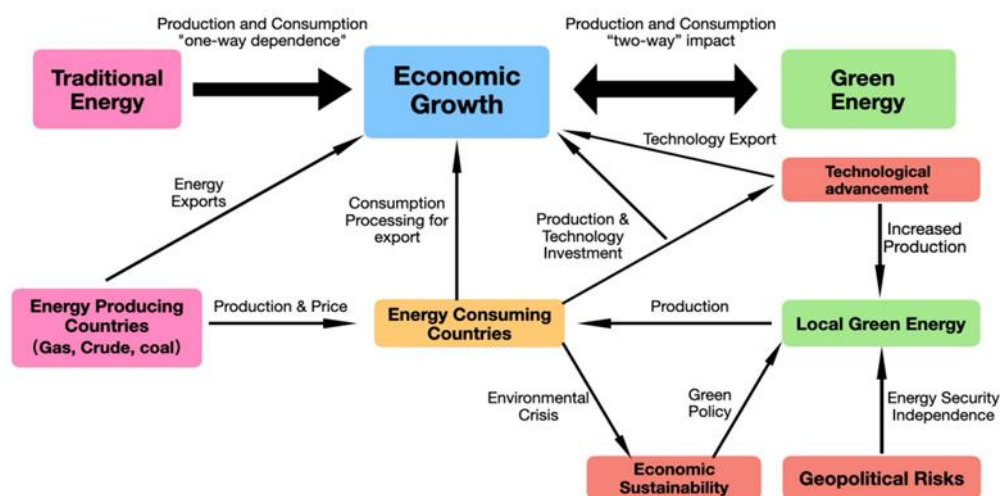
The "core-semi-marginal - marginal" model proposed by Emanuel Wallerstein (1976) considers the international division of labor as the foundation of global value distribution. Core countries engage in high value-added activities by means of technological monopoly and financial control, while peripheral countries can only participate in them by means of cheap labor and resources. This kind of structural unequal exchange leads to the continuous flow of value from the periphery to the core countries. The researcher emphasizes that the international division of labor is not only economic activities, but also a manifestation of political power relations.

On the basis of the theory of international division of labor and value distribution, Vaclav Smil (2017) in his masterpiece "Energy and Civilization" discusses the energy transition and reconstruction of international division of labor, the dependence of the green value chain on the supply chain of key minerals, and the concentration of the manufacturing links of renewable energy technologies (photovoltaic, wind turbines) in a few countries. Resulting in a new type of dependence and centralization of the green value chain, "The New Map" is an extension of Daniel Yergin (2020) research on traditional energy economy to the field of new energy. He points out that energy transformation will trigger green geo-economy.

This paper further argues that the paradigm transfer of energy economy is embodied in the evolution from the traditional "unidirectional dependence on resource control" to the "technology - capital - rules compound bidirectional shaping" (OIES, 2025; IPCC 2022). This deduction emphasizes the economic interaction and the new structural vulnerability arising from the restructuring of the value chain in the process of transformation. Authors breaks this analytical dimension down into the following two logics and creates Figure 3:

- *Unidirectional dependence*: based on the linear relationship between resource endowments and market demand (resource curse and institutional capture, unipolar monopoly of pricing power), a "producer-consumer" hierarchical dependency network is formed.
- *Two-way shaping*: the closed-loop of technology-capital-system (green technology monopoly, patent gradient exploitation) and the embedment of institutional power (rule restructuring of carbon tariff, green certificate financing) promote the economic dependence relationship from one-way control to two-way interlock (dominance-recessive interlock, technology-resource bundling).

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Source: Elaborated by the first author

Figure 3: "One-way dependence" and "two-way shaping" of the energy-economy relationship

The conclusion derived here is that structural vulnerability is interconnected: instead of reducing systemic risk, the increase in economic interoperability has led to more complex vulnerabilities due to single point failures of key nodes (supply chain bottlenecks, technology lockup risk), fragmentation of the rule system (technical standards fragmentation, climate club exclusivity), and reverse siphoning of capital flows (green premium arbitrage, debt-environment trap).

Constructing the energy geography dimension

Robert Keohane and Joseph Nye (1977) published "Power and Interdependence", based on classical economic theories such as comparative advantage and factor endowments, and proposed two dimensions of interdependence: sensitivity and vulnerability. Interdependence is not symmetric, and asymmetric interdependence is the norm. Therefore, vulnerability and sensitivity in asymmetric interdependence become power resources – the less dependent actors gain power advantages and influence other actors. Henry Farrell and Abraham L. Newman (2019) proposed the concept of "Weaponizing interdependence", which argues that interdependent economic networks (such as financial networks or high-tech industrial networks) create persistent power imbalances among states. The misalignment of network structures is called "weaponized interdependence", and some countries at the hub of the network can use interdependence to coerce other countries.

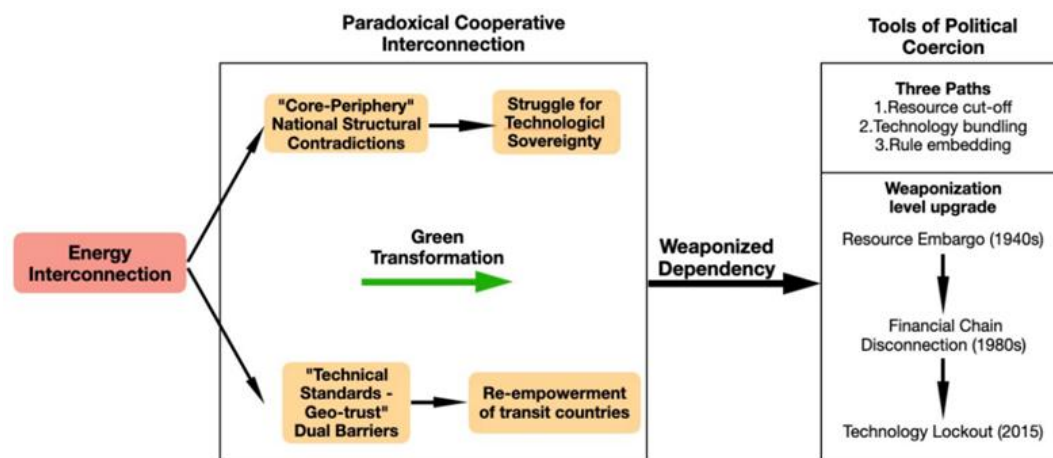
Instead of dispelling traditional geopolitical competition, the interconnection of energy systems is creating "pipeline politics". Through the complex game of technical standards and institutional tools, the "weaponized interdependence" in the field of energy is spawned, that

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is, the "energy weapon" proposed by Meghan L. O'Sullivan (2013), which has been further expanded to the field of renewable energy (O'Sullivan et al., 2017). Based on the above theories, this paper constructs the geopolitical analysis dimension as the core logical component of its theoretical framework to reveal how energy transition reconstructs the spatial carrier and action mechanism of power game (Figure 4). The key ideas of this logic are as follows:

- *The dual geo-effects of energy connectivity.* The physical connectivity and technological empowerment of energy networks not only promote win-win cooperation, but also intensify strategic competition. However, contradictory cooperative interconnection has been formed in the geopolitical dimension (structural contradiction of "core-periphery" countries and dual barriers of "technical standards-geo-trust"). With the construction of transnational power grids, competitive contradictions have been further manifested (competition for technological sovereignty, re-empowerment of transit countries etc.).
- *Weaponized interdependence under energy transformation.* Green supply chains facilitate the weaponization of energy through three pathways (resource cut off, technology bundling, embedded rules), to use further sanctions (from resource embargo to financial chain break, and then to technology lock up), and to achieve deep interlocking and institutional tool innovation and construction. Thus, the interdependence from economic ties to political coercion tools, eventually strong geopolitical power controls weak geopolitical power, weak power further relies on strong power for green technology.



Source: Elaborated by the first author

Figure 4: Constructing Geopolitical Dimension

2.3. Integration of three-dimensional interaction mechanisms

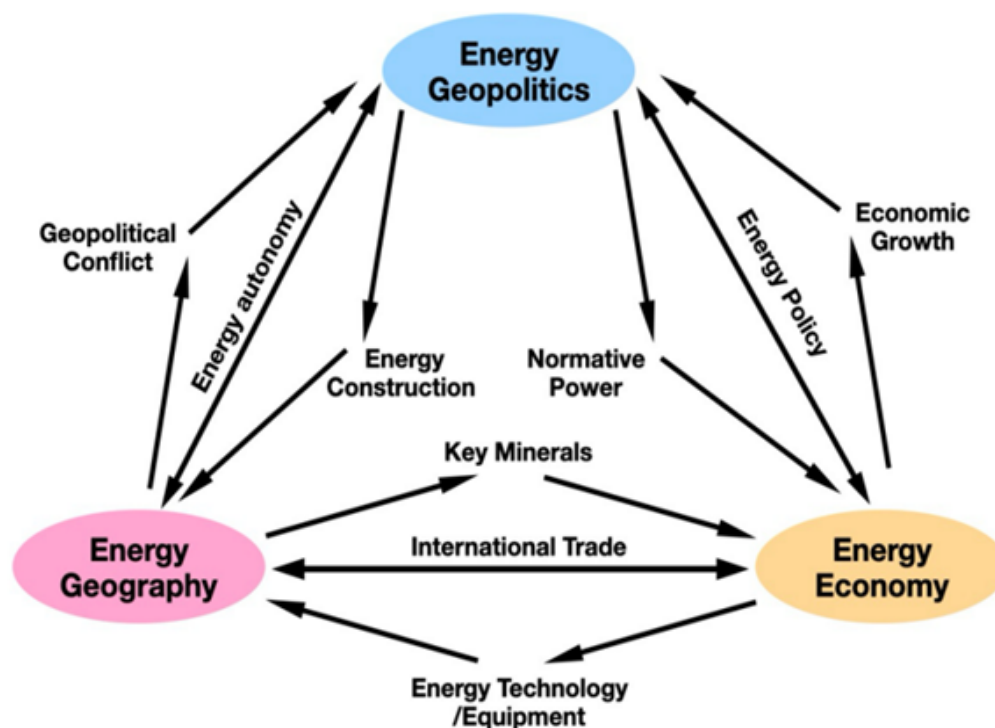
Having analyzed the interaction between the components of the three-dimensional framework, the following mechanisms are revealed:

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- *Energy geography* - energy economy coupling mechanism: the distributed characteristics of renewable energy weaken the traditional geographical monopoly of energy, but the recentralization of key minerals reshapes the economic dependence network through the "mineral-technology/equipment-trade" chain.
- *Energy economy* - geopolitical resonance mechanism: green technological advantages are transformed into global normative power (such as the EU CBAM), and economic instruments are endowed with geopolitical functions.
- Geopolitical energy - geographical feedback mechanism: geopolitical conflicts (such as the Russia-Ukraine war) trigger the "De-Russification" of energy infrastructure and accelerate the formation of new geographical patterns such as the independent construction of green energy.

The three form an interactive mechanism. Finally, an analysis of the dependence relationship under the energy transition is constructed (Figure 5).



Source: Elaborated by the first author

Figure 5: Framework for 3D analysis of energy transformation

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3. Methodology: Qualitative and Comparative Approaches

This study adopts a qualitative and comparative research design to analyze the geopolitical restructuring mechanisms embedded in the global energy transition. It employs a three-dimensional analytical framework—energy economics, energy geography, and geopolitics—to explore how institutions, resources, and power interact in shaping energy politics. Particular focus is placed on how the EU promotes green transition and institutional diffusion toward neighboring countries, namely Romania and the R.Moldova.

3.1. Qualitative Approach and Framework Development

Given the complex interdependence of policy, technology, resource distribution, and geopolitical security in energy transitions, qualitative research enables a deeper understanding of institutional logic and power restructuring (Cherp & Jewell, 2011). This study uses an exploratory strategy combining text analysis, spatial analysis, and policy discourse interpretation to examine key EU, Romanian, and Moldovan documents on green energy policy.

The study develops an interactive framework—"Institutional Embeddedness—Resource Dependency - Geopolitical Power"—to analyze how renewable energy gains geopolitical relevance under specific institutional conditions. Three types of materials support this framework: (1) EU and national policy texts (e.g., European Green Deal); (2) structural data from IEA, IRENA, and Eurostat; and (3) visual resources like critical mineral maps and transmission network charts.

3.2. Comparative Case Method and Country Selection

To enhance contextual interpretation, the study compares Romania and R. Moldova. While geographically and culturally proximate, they differ in institutional embeddedness, energy security, and responses to EU mechanisms. This "proximate divergence" enables meaningful comparison across four dimensions: energy autonomy paths, shifts in Russian energy dependence, adaptability to EU mechanisms (e.g., CBAM), and norm absorption patterns. By comparing institutional responses during the Russia–Ukraine crisis, the study examines how the EU extends its Open Strategic Autonomy through institutional and normative diffusion at its eastern periphery.

3.3. Methodological Contribution

- This research contributes by integrating theory-building and institutional interpretation through qualitative and comparative approaches. Key innovations include:

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- Cross-scalar integration connecting supranational strategies with national institutional layers;
- Triadic modeling that links institutions, resources, and power in a coherent analytical structure;
- Exploratory projection of institutional adaptability, offering a theoretical basis for further cross-regional comparisons.

3.4. Methodological Limitations

Despite its strengths, the approach has limitations. The high level of abstraction and reliance on discourse weaken causal inference and limit generalizability. The use of secondary data and absence of original modeling reduce empirical rigor. Additionally, the shared historical and linguistic traits of Romania and R.Moldova may diminish response independence, while overreliance on official documents restricts insights into informal mechanisms. Future research should expand to multi-case designs and integrate quantitative tools for greater robustness.

4. Three-dimensional framework analysis and discussion

4.1. Energy Geography Dimension: chain reconstruction and power transfer

Reflecting on energy geography theory (Solomon & Pasqualetti, 2004), the “resource endowment locking effect” of fossil fuels is being eroded by the distributed nature of renewables. The widespread availability of solar and wind disrupts the dominance of traditional “oil heartlands” and shifts energy production closer to consumption sites (Baka & Vaishnava, 2020). This spatial reconfiguration drives two key changes: first, the decentralization of energy infrastructure weakens the strategic centrality of conventional energy hubs; second, energy power is being redistributed along new geographic lines, fostering a “democratization of energy production” with more actors gaining control over energy generation.

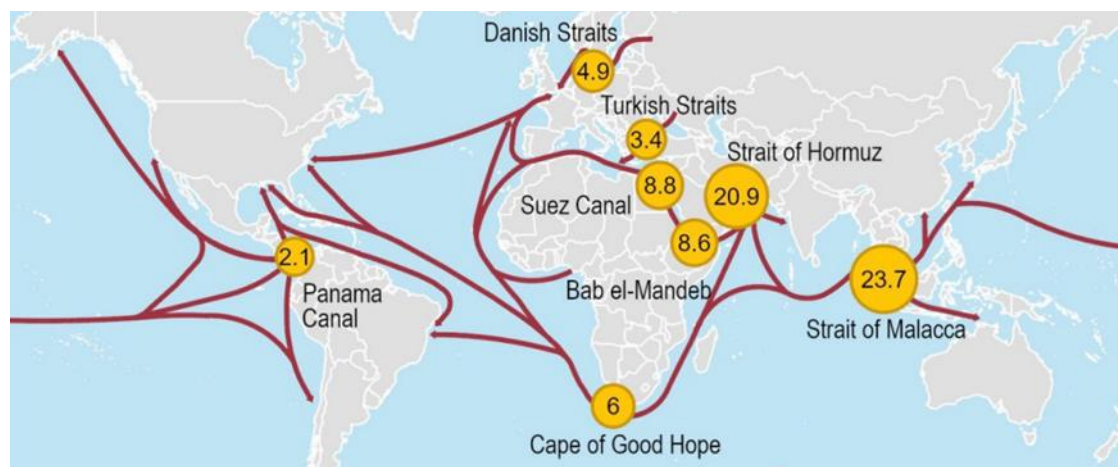
Carbon-based energy and hegemonic iteration

The hydrocarbon economy framework examines the global hydrocarbon industry and its intricate interactions with international markets. Building on this, Mitchell has dissected the deep-seated linkages between traditional energy economies and political institutions at the national level. By tracing the production and circulation of oil—the “lifeblood of empire”—the scholar has exposed how the geographic concentration of energy resources historically enabled states to exert disproportionate influence over global political-economic structures (Mitchell, 2009). The Middle East, with its unparalleled oil wealth, exemplifies this dynamic: while hydrocarbon revenues have fueled regional prosperity, the region has simultaneously grappled with the paradox of the “resource curse,” underscoring oil’s pivotal role in shaping

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geopolitical realities (Mazaheri, 2022). Conventional energy has brought prosperity to production regions but also instability due to consumer competition—especially in the Middle East, Red Sea, and South China Sea, now key geopolitical hotspots (Figure 6). A state's control over energy resources strongly shapes its global status (Toprani, 2021).



Source: EIA (2024)

Figure 6: Daily transit volumes through world maritime oil chokepoints, million barrels per day, 2023

The energy evolution process is accompanied by technological progress, which brings about the reconstruction of geopolitical power (Yang et al., 2023). Britain once achieved global dominance through abundant coal resources, enabling a “coal–navy–institution” co-evolution (Watson, 2018), but its power declined as energy structures changed. The United States, by contrast, established the “petrodollar–aircraft carrier” system to control oil supply chains, thereby reinforcing its global hegemony (ibid.; Wagdi et al., 2023). Thus, hegemonic powers have long shaped the world political economy through control over energy geography. Today, emerging renewable technologies are gradually reshaping this geopolitical and economic landscape.

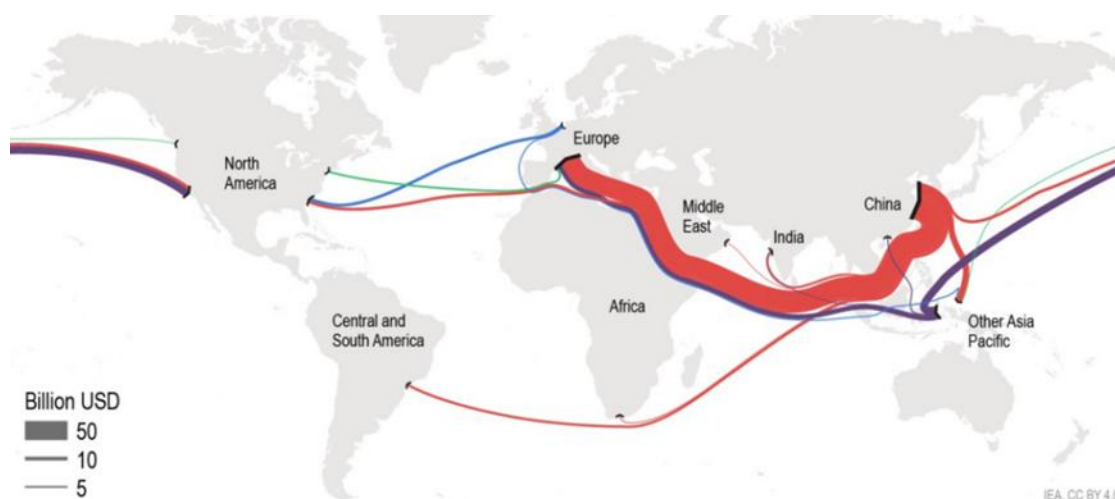
Silicon-based technologies build new geo-centers

The global energy system is shifting from a carbon-based to a silicon-based paradigm. Core green technologies like solar photovoltaics and wind are transforming production models and reshaping energy geopolitics through trade (Figure 7). In the fossil fuel era, power centered on the geographic concentration of oil and gas, forming “carbon hegemonies” such as the Middle East and Russia (Yergin, 2011). In contrast, the silicon era emphasizes technological capability and manufacturing. Its geography splits into “manufacturing poles” (e.g., China’s PV industry) and “resource poles” (e.g., Africa’s cobalt belt), connected through critical mineral supply chains (Fouquet & Pearson, 2012). This elevates the strategic value of “green

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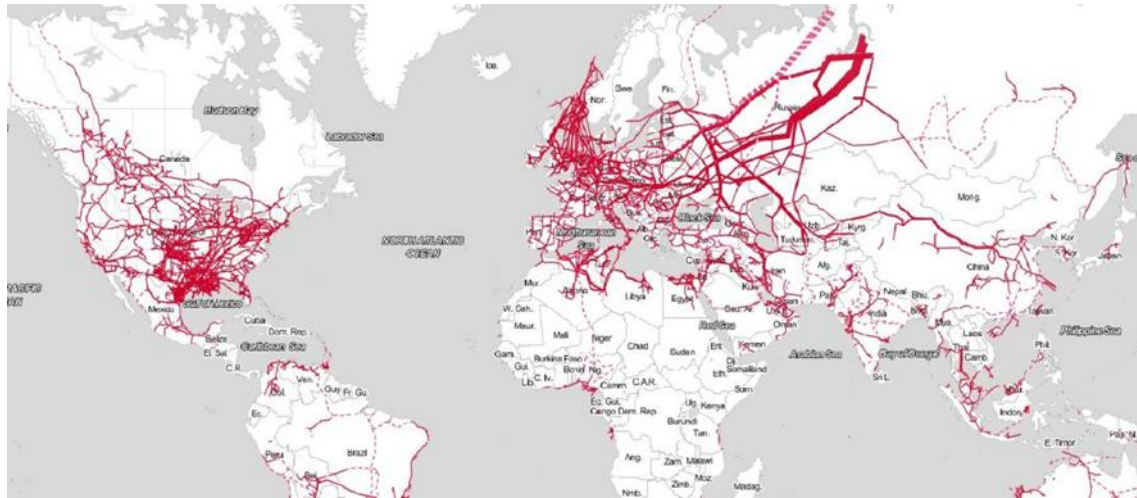
metals” like lithium, cobalt, and rare earths, now viewed as the “new oil” in geopolitical competition (Childs, 2023). As resource control gives way to supply chain and innovation control, energy dominance is increasingly defined by access to clean tech manufacturing and critical material flows.



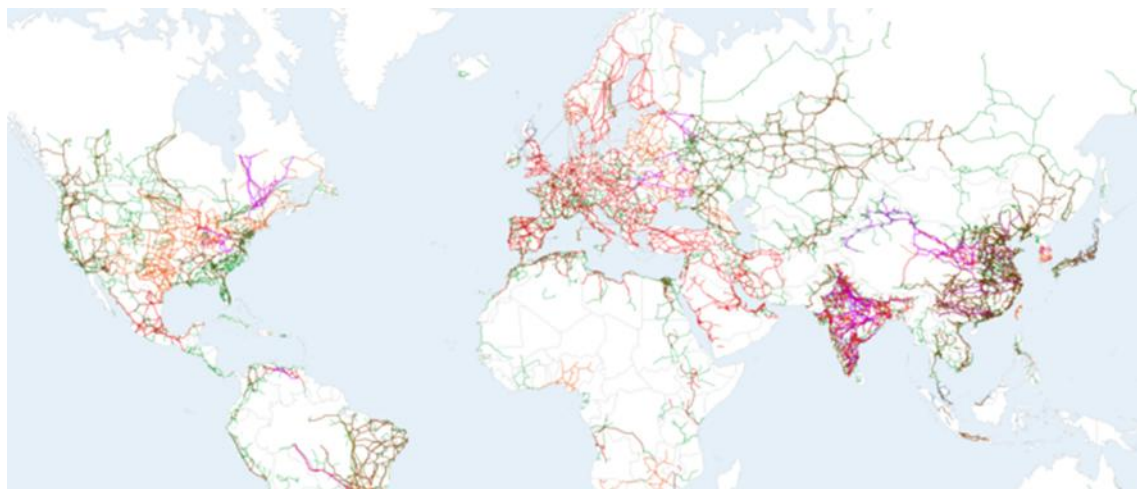
Source: EIA (2024)

Figure 7: Volume of global trade in clean energy technologies, 2023

The expansion of silicon-based energy networks is driving a new form of geo-economic interaction centered on electricity grids. Compared to natural gas pipeline maps, emerging power grid networks indicate that electricity infrastructure is becoming a new domain of “pipeline politics” (Figures 8 and 9). By 2035, global trade in green technologies is expected to reach USD 575 billion, with increased cross-border flows of photovoltaic panels, storage batteries, and smart grid equipment (IEA, 2024). This creates a triadic cycle of “technology export–resource development–market exchange,” shifting regional energy interconnection from pipeline-based to grid-based geopolitics (Jentleson, 2019; Westphal et al., 2022; Blondeel et al., 2021). The EU’s Mediterranean corridors and ASEAN’s smart grid projects compete over standard-setting, while China’s GEIDCO advances a continental UHV grid (GEIDCO, 2021). Energy security is thus redefined—from securing fossil fuel supply to ensuring the resilience of clean technology value chains and digital infrastructure sovereignty (Goldthau & Youngs, 2023).

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Source: Snam S.p.A

Figure 8: Global Natural Gas Pipeline Network, 2017

Source: Wikimedia Commons

Figure 9: Global Power Grid Network, 2023**4.2. Energy Economy Dimension: Technological hegemony and dependence transition**

Drawing on Hotelling's (1931) theory of non-renewable resource economics and Schumacher's (1973/2011) sustainable economy perspective, this study identifies a "double paradox" in the green energy transition. While new energy technologies lower marginal production costs, their technology-intensive nature creates a new form of "green technology

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hegemony." Supply chains for critical components—such as photovoltaic cells and rare earth magnets—reinforce asymmetric dependencies. Meanwhile, energy trade has shifted from bulk commodity flows to knowledge-based exchanges, including technology licensing and equipment exports. Rather than reducing global interdependence, this shift reorients it—away from resource control and toward technological innovation—resulting in “technology-locked interdependence” (OIES, 2025; IPCC, 2022).

Unilateral dependence on traditional energy

Economic growth is positively correlated with energy output or consumption (Yan & Chen, 2011). Traditional energy sources, as "economic donors," often create a unidirectional dependency model (Sachs & Warner, 2001). Both energy-producing and energy-consuming countries tend to exhibit strong economic performance (Figure 10), yet both are more vulnerable to fluctuations in energy prices. Energy-exporting countries are prone to the "resource curse," while developed regions rely on stable energy supplies for economic expansion. This model is typically singular and static, making it highly susceptible to foreign energy controls (Mitchell, 2009). Particularly in the context of geopolitical conflicts, such dependencies can become weaponized. Europe's reliance on Russian energy has exposed the fragility of such relationships (Krickovic, 2015; Stegen, 2011; Siddi, 2022).

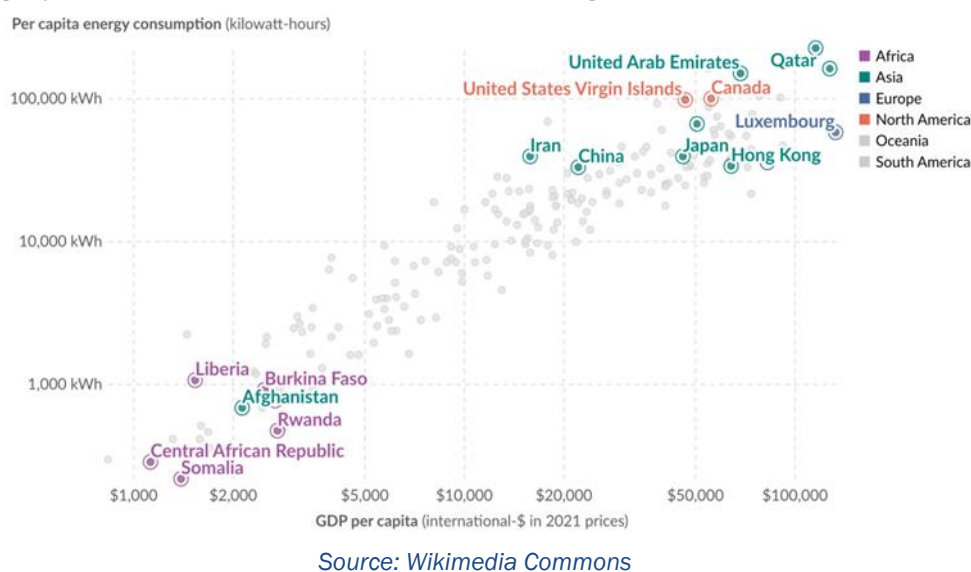


Figure 10: Energy use per capita versus GDP per capita, 2023

Bidirectional shaping driven by multiple factors

Under the combined influence of geopolitical risks, technological innovation, and sustainable development goals, the energy economy is shifting from a unidirectional model—where growth depends on fossil energy—toward a bidirectional, co-evolutionary framework (Pao et al.,

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2014; Omri, 2014). In this model, green technologies both drive and benefit from economic expansion. Green energy serves not only as a new engine of growth but also as a transformative force in global trade, reshaping energy structures from dependence on commodities to a model centered on innovation-driven energy independence (Ilechukwu & Lahiri, 2022).

The structural fragility of bidirectional shaping

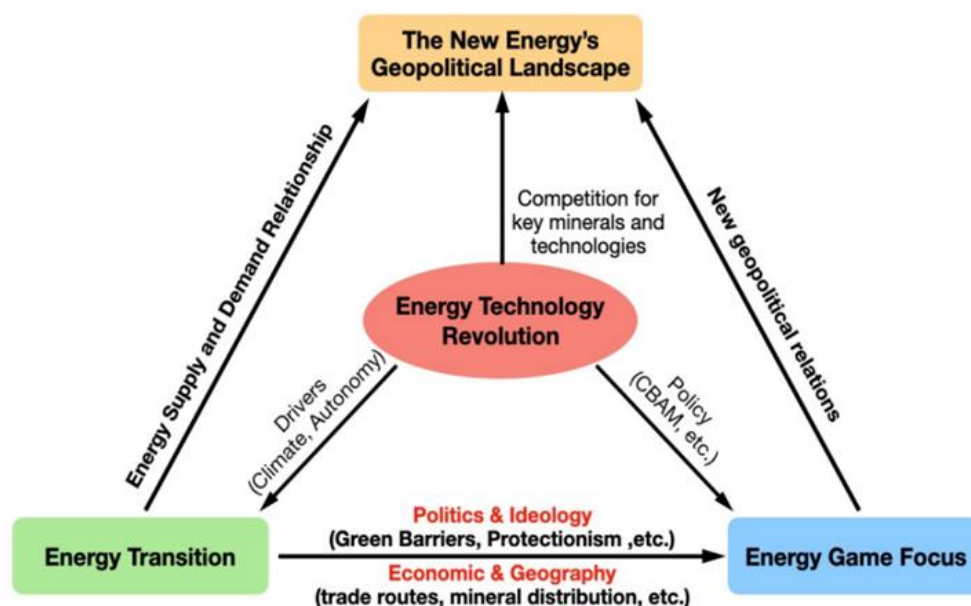
Comparative advantage theory and Geopolitical restructuring of the Energy Transition Comparative advantage theory illustrate how energy producers and consumers can use trade for mutual benefit while strengthening asymmetric dependencies (Lloyd & Klare, 2008). However, policy tools such as the "Green paradox" (Sinn, 2012) and the EU's Carbon Border Adjustment Mechanism (CBAM) are reshaping comparative advantage in the energy transition (Leonard et al., 2021). Complementary frameworks, including the theory of intermediate technologies (Schumacher, 2011) and the "stranded wealth" hypothesis (Van de Graaf & Bradshaw, 2018), describe the structural vulnerabilities of traditional energy systems in this transition.

While these theories argue that green economic growth and energy efficiency can be synergistically enhanced, such advances give rise to intense geo-technological competition. This competition, manifested in a scramble for control of key minerals, standardization of renewable technologies and dominance of intellectual property, has moved beyond traditional resource geopolitics and reconfigured the global energy hierarchy.

4.3. Geopolitical dimension: Technological game and institutional construction

The theory of land rights has been renewed in the context of energy transition (Mackinder, 1904/2004), and the focus of geopolitical game shifted from oil and gas pipeline control to technical standard formulation and industrial policy competition. The "Weaponized Interdependence" of green supply chains is manifested in the following aspects: first, the key mineral supply chain becomes a tool of strategic game; secondly, the new institutional weapons such as carbon border adjustment mechanism reshape international trade rules (Proedrou, 2025); thirdly, the new energy systems enabled by digital technologies exacerbate geo-risks in the cybersecurity dimension. This multidimensional game pushes the international energy order into a stage of competition for "technological commanding heights" (Su, 2021). The Green energy technology commanding heights are exposed in Figure 11.

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Source: Adapted by the authors based on (Cui, 2020)

Figure 11: Green energy technology commanding heights**Energy connectivity and competition conflict**

While promoting the global low-carbon transition (Rifkin 2011), the interconnected energy network restructures the geopolitical landscape and forms a triple contradiction system: first, the strategic energy dependence relationship, such as the Russia - EU gas game to promote the process of European energy independence (Halser & Paraschiv, 2022); secondly, the competition for technological dominance tends to be geo-politicized, with China and the United States competing on standards for UHV transmission and digital energy networks (Lewis, 2022). Moreover, the geopolitical risk is compounded (Sohag et al., 2022), which is reflected in the resource sovereignty dispute in the Eastern Mediterranean/South China Sea, the risk transmission in transit countries such as Ukraine/Pakistan, and the resource nationalism game in the cobalt mines in Africa and the lithium triangle in Latin America, resulting in increased supply chain risks (Roscoe et al., 2022) (Figure 12) .

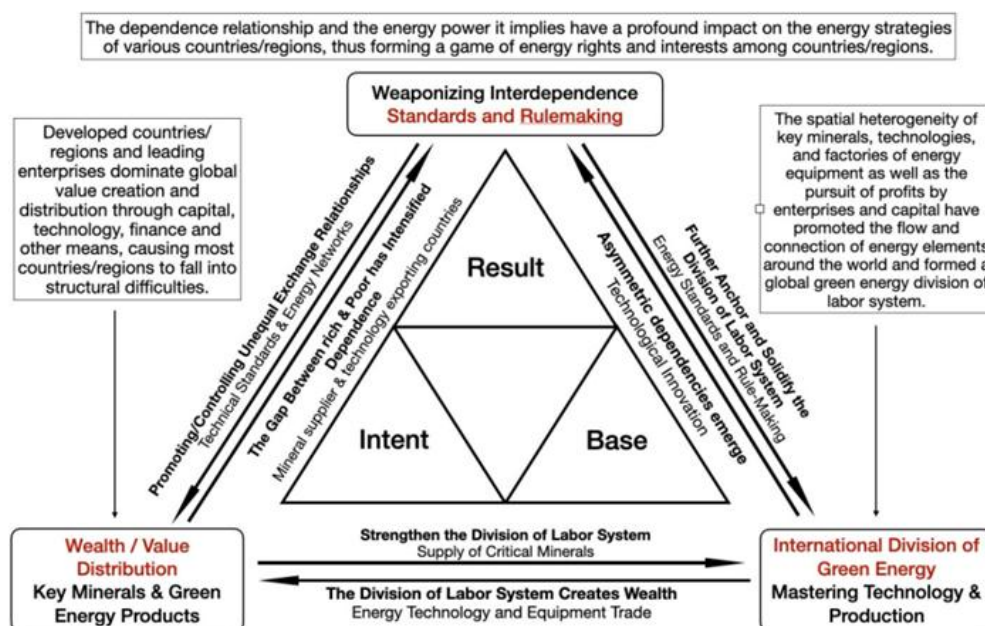
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Source: Adapted by the authors based on (Cui, 2020)

Figure 12: China's Global Power Interconnection Initiative**Weaponized interdependence under the Energy transition**

While green energy networks erode traditional oil and gas geopolitics, they also generate new contestations in regions rich in photovoltaic and wind resources. Incidents like the Ukrainian grid cyberattack and Mekong River ecological disputes reveal the security vulnerabilities of increasingly interconnected systems. This transformation reflects a restructured global division of labor and value, driven by control over green technologies (Li et al., 2022), access to key resources (Islam et al., 2022), and dominance in rule-setting mechanisms such as carbon tariffs and climate clubs (Skjærseth, 2021). These three axes underpin a new interdependence in green energy systems. As energy governance shifts toward regional blocs—such as the EU's integrated power grid and the proposed Asian Super Grid—global energy competition is becoming more multipolar, paving the way for a form of weaponized interdependence linking energy systems to technological rivalry (Westphal et al., 2021) (Figure 13).

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Source: Adapted by the authors based on (Zhang, 2024)

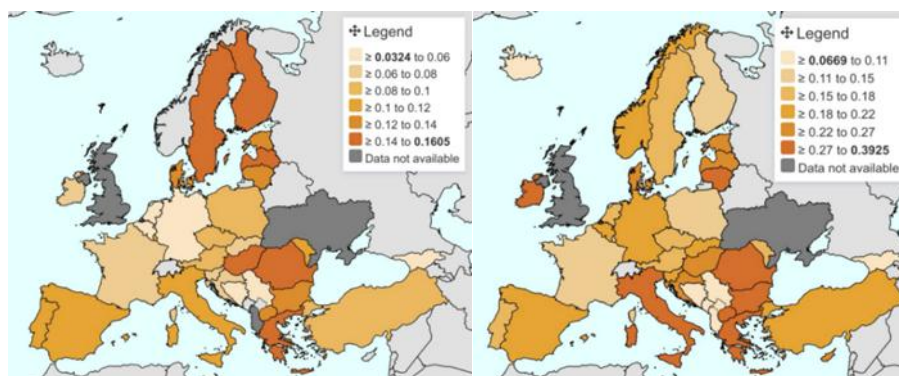
Figure 13: Equity game theory framework for global energy transition

5. Comparative Case Study: Energy interconnection between R.Moldova and Romania

5.1. The energy game in the "Heartland"

Mackinder identified East-Euro as the gateway to the Heartland—the strategic core of Eurasia. Historically, it has served as the collision zone between Asian land power and European sea power (Spykman, 2017). In modern geopolitics, from World War II to post-Cold War upheavals, East-Euro remains the front line of Euro-Asian tensions. Amid the Russia–Ukraine conflict, the region's geopolitical fragility has deepened. The “Weaponizing interdependence” through energy infrastructure—embodied in “pipeline politics”—has become central to this struggle (LaBelle, 2023). Central and East-Europe, reliant on gas and electricity flows, remains highly exposed to these dynamics (Figure 14).

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Source: Eurostat (2024)

Figure 14: Energy prices for non-household consumers in Europe (left: gas; right: electricity)

Eastern Europe, as an overlapping area of pluralistic geopolitical concepts such as "buffer zone", "crush zone" and "border triangle" (Figure 15), is an important gateway for Asian landlocked countries to enter Europe and control the Mediterranean (O'loughlin 1999). R.Moldova and Romania are at the heart of this region. Although the two countries share Dacian cultural genes, historical legacy as well as the differences in the embedment of political institutions, and the chain reaction caused by the Russia-Ukraine conflict have made this region a geopolitical sensitive area. In addition, the weaponization of energy caused by pipeline politics has further compounded the complexity of the situation in the region and the overall energy crisis of the EU (Iulian & Dinc, 2024).



Source: Anaz & OZKAN (2016)

Figure 15: The "Border Triangle" area

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5.2. Differences in energy transition paths

Romania maintains one of the highest energy self-sufficiency rates in the EU, leveraging a diversified resource base that includes oil, Black Sea gas, and coal to pursue a geo-strategically oriented energy transition. Traditional energy sources still account for 70% of its energy mix, while nuclear and renewables—mainly hydropower, wind, and solar—make up 21%, supporting a gradual low-carbon shift. The transition is strongly shaped by EU frameworks, notably the European Green Deal's 2030 target of 34% renewables, alongside funding mechanisms such as the National Recovery and Resilience Plan (NRRP) and the Modernization Fund (U.S. Department of Commerce, 2024). Institutionally, Romania's energy policy is embedded within EU regulatory structures, operationalized through instruments like the EU Emissions Trading System and renewable energy auctions. Geostrategically, Romania advances regional interconnection via the Three Seas Initiative, aiming to reduce dependency on Russian imports, enhance its position as a regional energy hub, and reconcile its energy security objectives with decarbonization goals (Tutak & Brodny, 2022).

The energy system of the Republic of Moldova is fragile, highly dependent on external sources and with institutional defects, and its transformation faces geopolitical and internal governance challenges. R.Moldova imports 90 percent of its natural gas from Russia and 70 percent of its electricity from Ukraine and Romania. It's deeply dependent on the energy systems of third countries. The 2030 Energy Strategy set a target of 30% renewable energy, but the lack of resources, capital and technology has slowed the development of photovoltaics. Institutionally, political fragmentation and oligopolies (e.g. "Moldovagaz") impede reform (CSD, 2024; Jamie et al., 2025). R.Moldova and the EU jointly drive reforms, promote grid integration through the "Energy community", etc. The Russia-Ukraine conflict forced R.Moldova to accelerate "autonomy", increasing electricity imports from Romania, and deepening cooperation with the EU (Sandu, 2022). The R.Moldova's situation reveals a dilemma between energy sovereignty and geopolitics, as well as the dilemma of path dependence of countries with weak institutions in the international game.

When synergistically enable these theories argue that green economic growth and energy efficiency can be hanced, such advances give rise to intense geo-technological competition. This competition, manifested in a scramble for control of key minerals, standardization of renewable technologies and dominance of intellectual property, has moved beyond traditional resource geopolitics and reconfigured the global energy hierarchy.

The divergent energy transition pathways of the two countries (Table 1) have led Romania to demonstrate a resolute ambition to become an "energy hub." Leveraging its Black Sea oil and gas resources and the Danube River's hydropower potential, Romania is actively strategizing to establish itself as Eastern Europe's energy nexus. Concurrently, it is strengthening its regional influence through participation in the "Energy Union." In contrast, R.Moldova faces acute energy security dependencies, with its energy supply partially constrained by Russia

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due to the unresolved Transnistria conflict. Consequently, Moldova’s energy transition process has become emblematic of broader geopolitical contestation.

Table 1: Differences in energy transition paths between R.Moldova and Romania

Criterion	Romania	R. Moldova
Institutional framework	EU legal constraints and strong policy coherence	Relying on external pressure for reform
Energy autonomy	Diversifying supply and gradually moving away from dependence on Russia	It is deeply dependent on Russian energy, and its transformation is impacted by geopolitical conflicts
Investment mechanism	Private capital + EU fund driven	EU aid is dominant, while domestic financing capacity is limited
Geopolitical role	Regional energy hub and strategic fulcrum on the EU's Eastern flank	The transformation of energy channel and security buffer zone is subject to the game of great powers

Source: Author's creation

5.3. EU-Mediated Energy Integration

During energy crisis, the European Union has played a pivotal mediating role. The EU has provided R.Moldova with substantial financial assistance and investments totaling approximately €940 million, encompassing funds and electricity capacity, while explicitly committing to sustained support for Moldova's energy transition and infrastructure development in the coming years (European Commission, 2025). This impetus has accelerated Moldova's integration into EU structures, marked by the formal commencement of accession negotiations (EEAS, 2024). Concurrently, the EU has actively bolstered Romania's energy sector through strategic collaboration with the Romanian Ministry of Energy (European Commission, 2024).

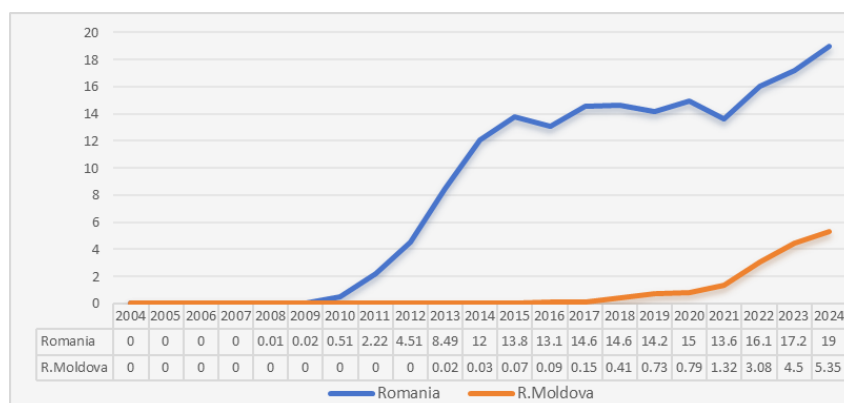
Within the framework of the EU Energy Strategy and Green Deal, supported by financial mechanisms from the European Bank for Reconstruction and Development (EBRD), R.Moldova and Romania have achieved significant progress in grid interconnection initiatives. This bilateral cooperation, formalized through a governmental memorandum (Government of the Republic of Moldova, 2024), demonstrates tangible advancements in regional energy integration (Figure 16).

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Source: Ministry of Energy of the Republic of Moldova (2024)

Figure 16: R.Moldova and EU energy interconnection

The crisis has rendered energy cooperation between R.Moldova and Romania critically urgent in the energy sector. This collaboration, strongly supported at the EU level, primarily aims to accelerate the development of indigenous green energy resources in both countries, thereby advancing their long-term strategic objective of achieving energy autonomy. Through resource integration and coordinated development, this synergy has yielded tangible results in their energy sectors. The proportion of indigenous green energy utilization has increased substantially (Figure 17), effectively alleviating critical energy bottlenecks. While this progress brings both nations closer to energy self-sufficiency and drives Moldova's geopolitical identity transformation, it simultaneously risks cultivating new dependencies on the EU.



Source: Ministry of Energy of the Republic of Moldova (2024)

Figure 17: Wind and solar trends in Romania and R.Moldova, 2004-2024, %

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6. Discussion and Recommendations

6.1. Case Discussion

The global energy transition is reshaping geopolitical relations along three interlinked dimensions: resources, technology, and institutions (Cherp & Jewell, 2011). For small states like Moldova, this transformation exposes structural vulnerabilities while also offering opportunities for strategic repositioning.

R.Moldova faces a threefold vulnerability in navigating the energy transition. Lacking domestic reserves of critical minerals and possessing limited renewable generation capacity, it risks becoming entrapped in new dependency structures as global competition over green inputs intensifies (European Commission, 2023). Technologically, its reliance on imported systems and inability to develop or enforce domestic standards compromise system interoperability and weaken strategic autonomy (ECFR, 2023). Institutionally, Moldova's membership in the Energy Community has not offset internal governance fragmentation, where administrative inefficiencies and political instability delay regulatory convergence with the EU. Paradoxically, The peripheral geographic position of R. Moldova offers leverage: situated between the EU and Eastern Europe, it functions as a geopolitical buffer and energy corridor. Participation in EU-funded projects and alignment with ENTSO-E strengthen its regional energy integration (CEPS, 2022).

This duality illustrates a broader dilemma for peripheral transit states: their significance lies not in material assets, but in the institutional alliances they build and the geopolitical utility of their infrastructure. Through flexible governance and strategic embedding, even structurally weak states can assert agency within an emerging global energy order shaped by interdependence and institutionalization.

6.2. Policy Recommendations (Condensed Version)

1. EU Level: Institutional Anchoring and Normative Expansion

To address structural dependencies among candidate countries, the EU should enhance the outward projection of its Green Deal and Open Strategic Autonomy agendas. A Green Institutional Pre-Accession Mechanism could provide regulatory incentives and financial instruments to help countries like R.Moldova internalize EU energy governance frameworks (Schmitz & Seidl, 2023). Additionally, the EU should lead in exporting green technology standards in photovoltaics, storage, and smart grids to institutionalize technological sovereignty. When synergistically enfile these theories argue that green economic growth and energy efficiency can be hanced, such advances give rise to intense geo-technological competition. This competition, manifested in a scramble for control of key minerals,

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standardization of renewable technologies and dominance of intellectual property, has moved beyond traditional resource geopolitics and reconfigured the global energy hierarchy.

2. Small State Level: Resilience through Institutional Coordination

R.Moldova's constrained energy sovereignty stems from its resource deficits and regulatory fragmentation. To overcome the dependent transition trap (Goldthau & Sitter, 2022), R.Moldova should prioritize distributed renewable pilot zones and diversify energy inputs. Institutional resilience can be improved by localizing EU-compatible legislation via the Energy Community and establishing a Green Governance Coordination Office to streamline multilevel regulation (Energy Community, 2024).

3. Regional Level: Green Connectivity and Joint Governance

Given its proximity and cultural ties to Romania, R.Moldova should be integrated into a Ro-MD Green Energy Coordination Council to align standards, co-manage cross-border projects, and enhance emergency response (Sandu, 2022). The EU could also support a Green Manufacturing Corridor in Eastern Europe, with R.Moldova contributing to photovoltaic assembly and storage maintenance—embedding it into a regional green value chain (Mazaheri, 2022).

7. CONCLUSION

Under the global wave of energy transition, the energy system is undergoing profound transformation from traditional fossil fuels to renewable energy, exerting far-reaching impacts on the geopolitical landscape. Through the analytical framework integrating energy geography, energy economy, and geopolitics, complemented by case studies of Romania and R.Moldova, this research reveals the complex relationship between energy transition and geopolitical power restructuring.

The three-dimensional qualitative analysis reveals that the global energy transition is reshaping geopolitical dynamics. Geographically, the distributed nature of renewables undermines fossil fuel monopolies by shifting production closer to consumption and decentralizing infrastructure. Yet, the re-concentration of critical minerals creates new dependency networks, transforming energy security into a triad of resources, technology, and institutions. First, a dual paradox emerges in the green economy: green tech hegemony reshapes global labor divisions, while energy trade shifts toward innovation competition, increasing interdependence and risks like fragmented standards. Second, geopolitical rivalry has shifted from pipeline control to competition over standards and industrial policy, generating “weaponized interdependence” in green supply chains. While interconnectivity supports decarbonization, it also increases geopolitical vulnerability. Altogether, this transformation signals the emergence of a Global Energy Order 2.0, defined by technological

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sovereignty, critical minerals, and resilient supply chains, which now serve as the pillars of power in the evolving energy landscape.

The divergent paths of Romania and R. Moldova validate the framework's explanatory power. As an EU member, Romania internalizes institutional consensus through EU funding and regulatory tools (e.g., ETS), constructing a diversified energy system (synergizing Black Sea hydrocarbons, nuclear, and renewables) to reduce Russian dependence while pursuing an Eastern European energy hub status. Conversely, R. Moldova's weak institutional embeddedness (political fragmentation and oligarchic monopolies) as well as geopolitical buffer attributes render its energy transition hostage to Russia-EU competition, oscillating between "institutional mimicry" and "path breaking." Building on its Dacian heritage, R. Moldova leverages EU external forces and Romanian cooperation to drive energy transition and geopolitical identity transformation. This comparison reveals that institutional identity and geopolitical positioning determine transition path resilience: strong-institution states enhance energy autonomy through EU institutional internalization and technological integration, while weak-institution states risk "dependent-type transition" traps through externally driven transformation.

Ultimately, energy transition reconstructs rather than decentralizes geopolitical power competition across spatial dimensions. Trade frameworks have become instrumental in energy technology competition, reinforcing geopolitical centers' strategic leverage. Moving forward, deepening energy transition necessitates international coordination in technological innovation, resource cooperation, and rule-making to address emerging geopolitical challenges while ensuring energy security and sustainable development. Due to the limitations of the three-dimensional framework and case selection, including the lack of quantitative analysis, future research could apply mathematical modeling and expand to more countries to enhance generalizability and address the current study's constraints.

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