

DIGITAL ENERGY GOVERNANCE AND SMALL-STATE ENERGY SECURITY: DIGITAL POLICY AND INSTITUTIONAL CAPACITY IN MOLDOVA'S ENERGY TRANSITION

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Abstract: *In recent years, driven by global energy transition and geopolitical competition, energy security has become a central issue in international political economy. The Russia–Ukraine conflict has profoundly reshaped Europe’s energy landscape, highlighting the structural vulnerabilities of small Eastern European states along geopolitical fault lines in terms of energy structure and governance capacity. Using Moldova as a case study, this paper explores how digital policies can be transformed into a novel form of institutional capacity for small states to address limited physical resources and asymmetric interdependence. The study finds that digitalization of energy systems, through virtual peak-shaving mechanisms, effectively compensates for deficiencies in physical storage and infrastructure, providing an institutional substitute for external energy dependence. Moreover, digital transformation reconstructs the state’s knowledge-power structure by reducing information asymmetry, enhancing governmental regulatory capacity and capital attractiveness. Digital platforms also act as technical interfaces connecting small states to regional multilateral rules, and through deep institutional alignment with the European Union, reinforce strategic energy security. The paper highlights the role of digitalization as a tool of sovereignty empowerment, offering new theoretical insights and empirical evidence for understanding how resource-constrained small states navigate energy security challenges in complex international environments.*

Key words: *Energy Transition; Energy Security; Digital Energy Governance; Renewable Energy; Moldova*

JEL: Q48, F52, P28.

Introduction

The global energy system is undergoing a structural transformation driven by the urgency of climate action, the fragility of energy security, and escalating geopolitical tensions, prompting states to reconfigure their energy governance models (Kuzemko et al., 2020). The 2022 Russia–Ukraine conflict not only represents a regional war but also signifies the collapse of Europe’s reliance on cheap external energy. As energy becomes increasingly weaponized, Eastern European states along geopolitical fault lines are compelled to redefine national security under heightened uncertainty, elevating energy transition from a carbon-neutral objective to a core instrument of strategic resilience. In this context of global power reconfiguration, small economies face disproportionate constraints: limited infrastructure, narrow domestic markets, and restricted fiscal capacity place them at a structural disadvantage within asymmetric interdependence, weakening their bargaining power and shock-absorption capacity. From a structural power perspective, as articulated by Susan Strange, this

subordinate position reflects deficiencies in key domains such as knowledge, finance, and security, rendering small states largely passive rule-takers in international energy governance.

Moldova constitutes a paradigmatic manifestation of this structural predicament. Historically reliant on a single external source for electricity and natural gas, the country's energy system has, in the wake of the 2022 Russia–Ukraine conflict, been exposed to acute uncertainty and heightened risks of supply disruption, exemplifying the vulnerability and sensitivity dimensions articulated in complex interdependence theory (Keohane & Nye, 1977). In response, the Moldovan government has advanced a set of comprehensive reforms aimed at mitigating external exposure through electricity market liberalization and infrastructure modernization. Within this framework, energy digitalization has transcended its technical function to emerge as a pivotal institutional lever, entailing not merely the deployment of smart grids and metering technologies but a reconfiguration of energy governance boundaries (Sioshansi, 2019). Under conditions of constrained physical resources and limited fiscal capacity, Moldova seeks to operationalize data as a strategic production factor to enhance allocative efficiency, improve market transparency, and facilitate regulatory convergence with the European Union, thereby enabling a form of institutionalized digital sovereignty.

However, existing scholarship has largely focused on macro-level transition pathways or the diversification of physical energy supplies, leaving the question of how energy digitalization can be transformed into a novel form of institutional capacity for small states underexplored. This paper posits that digitalization provides a critical institutional compensatory mechanism, enabling small states, despite limited traditional power, to enhance administrative effectiveness and policy agency in the energy sector through precise governance and rule integration (Xu et al., 2022). From this perspective, the study conducts an in-depth analysis of Moldova's transition practices, examining how digital policies reconstruct the energy security framework of a small state navigating the dual challenges of high dependency and resource scarcity. By qualitatively exploring the interaction between technology and institutions, the paper aims to illuminate the profound implications of digitalization as a tool of sovereign empowerment, demonstrating how small states can leverage technological upgrades to strengthen institutional capacity and secure higher-order protections within geopolitical fault lines.

Literature Review

In contemporary scholarship, "energy transition" has moved beyond a purely technical shift from fossil fuels to low-carbon systems, evolving into a central variable in geopolitical contestation and the reconfiguration of national security strategies (Cherp & Jewell, 2014). Existing studies suggest that energy security is determined not only by the physical continuity of supply but also by the degree of source diversification (Ang et al., 2015). However, for small states constrained by limited natural resources and fiscal capacity, the conventional pathway of achieving energy independence through large-scale physical infrastructure expansion is increasingly restricted by both institutional and economic barriers. Along the Eastern European geopolitical fault line, these constraints materialize as structural vulnerability. In responding to external energy shocks, the lack of physical buffering capacity often relegates such states to the margins of power within asymmetric interdependence (Goldthau & Sitter, 2015). This imbalance can be further interpreted through Susan Strange's theory of structural power: the subordinate position of small states in the international energy system ultimately stems from persistent deficiencies across the four key structures—finance, security, production, and knowledge—thereby limiting their agency in the formulation and implementation of energy governance rules (Strange, 2015).

With the rapid development of information and communication technologies, modern energy systems are undergoing a digital transformation from unidirectional physical networks to deeply integrated "cyber-physical" infrastructures (IEA, 2017). Digitalization extends beyond the physical deployment of intelligent hardware to represent a new data-driven logic of energy governance. Studies indicate that digital technologies can effectively mitigate physical bottlenecks, enhance system performance,

and provide technical buffering for the large-scale integration of intermittent renewable energy sources. More importantly, digital platforms reduce information asymmetries in energy markets, increase transaction transparency, and lower market entry barriers, thereby enabling small states with limited bargaining power to attract external capital and optimize resource allocation (Hafner & Tagliapietra, 2020). In this context, digitalization is conceived as an “institutional tool” that compensates for deficits in physical resources, offering small states a novel pathway to achieve governance effectiveness in the energy sector.

However, how small states can actively reshape their governance capacity within the international energy system remains an underexplored area. Although small states are often characterized as passive rule-takers (Thorhallsson, 2018), energy governance theory emphasizes that governance is fundamentally a dynamic process of institutional arrangements and multi-actor coordination (Florini & Sovacool, 2011). In the digital era, the center of governance is shifting toward “data-driven” approaches and “institutional agility.” For Moldova, balancing the vulnerabilities inherent in interdependence (Keohane & Nye, 1987) with the institutional opportunities presented by digital transformation has become a frontier of academic inquiry. Empirical studies on Eastern European small states remain scarce, particularly regarding how digitalization functions as an “institutional compensatory mechanism” to mitigate physical vulnerabilities. Accordingly, this study seeks to integrate insights from structural power, complex interdependence, and energy governance theories to examine how digital policies can reconstruct small states’ institutional capacities, thereby enabling higher-order sovereign security in unstable geopolitical environments.

This study conceptualizes energy digitalization as a “mechanism for generating institutional capacity.” As illustrated in Figure 1, digitalization operates through three interrelated pathways. First, the information transparency mechanism reduces market transaction costs by integrating real-time data and alleviating information asymmetries. Second, the regulation and optimization mechanism strengthens the state’s core coordination function in energy dispatch through data-driven forecasting capabilities. Third, the regulatory alignment mechanism achieves institutional isomorphism with regional (EU) energy markets via data standards and technical interfaces. Together, these three mechanisms synergistically drive the evolution of institutional capacity, enabling small states to achieve substantive improvements in energy security through governance optimization, even under the rigid constraints of limited physical resources (Ha, 2022).

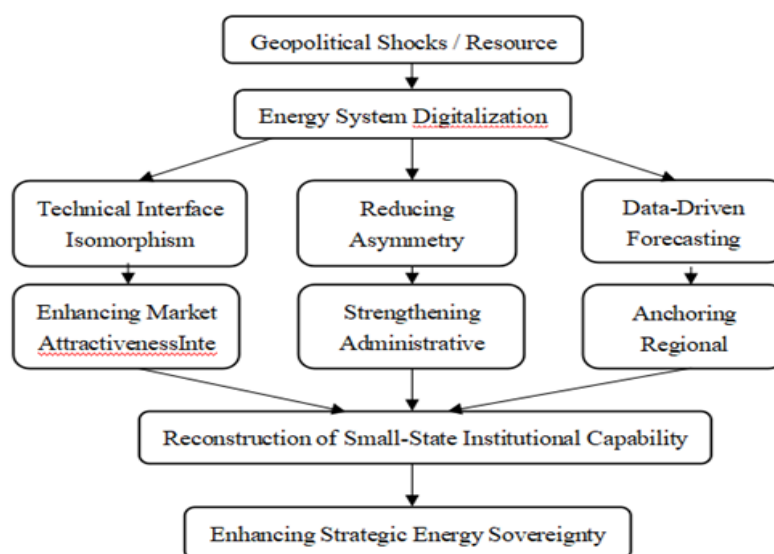


Figure 1. Logical Framework: Digitalization as an Institutional Capability
 Source: Compiled by the author

Methodology

This study employs a single-case study approach, using Moldova's recent energy transition practices as an in-depth empirical example. Single-case research offers substantial explanatory power for investigating "how" and "why" questions, particularly when analyzing highly complex processes of institutional change and policy innovation (Yin, 2018). Moldova, as a small economy under intense geopolitical pressure and severe resource constraints, provides a representative and critical case for examining the rapid digital-driven transformation of energy governance. This design allows the study to closely observe the internal logic of policy implementation and to analyze how digitalization functions as an institutional variable that is activated under specific external pressures and translated into enhanced state governance capacity. By qualitatively exploring this illustrative case, the research aims to extract generalizable insights into how small states can achieve significant leaps in energy governance despite structural vulnerabilities.

In terms of data collection and processing, this study adheres strictly to a multi-source triangulation approach to ensure the reliability and validity of its findings. The empirical materials are composed of three main components. First, official policy documents are analyzed, with particular emphasis on the Moldovan government's recently approved "Digital Transformation Plan for the Energy Sector 2026–2030," which provides a primary basis for understanding national strategic intent. Second, third-party international assessment reports are incorporated, notably those produced by the United Nations Development Programme (UNDP) and the International Energy Agency (IEA), which offer systematic evaluations of Moldova's energy reforms and document institutional feedback as well as external appraisals during policy implementation (UNDP, 2024). Third, cross-dimensional statistical data are utilized, including the latest figures on energy structure and installed capacity published by the National Sustainable Energy Center of Moldova. By triangulating governmental strategic narratives, expert assessments from international organizations, and objective market evolution data, this study seeks to reconstruct a dynamic and multidimensional picture of digital energy governance. To ensure analytical rigor, this study employs content analysis and process tracing in examining the collected qualitative data (Lee et al., 2022). By identifying key terms and underlying logics in policy texts, particularly those related to power reconfiguration, market transparency, and regulatory alignment, it investigates the pathways through which digitalization evolves from technical deployment into institutional capacity. This research design goes beyond assessing the introduction of digital technologies per se, focusing instead on how these technologies are embedded within Moldova's existing governance structures and how they ultimately reshape the boundaries of energy security under conditions of complex interdependence, thereby offering a deeper interpretation of the logic of institutional evolution.

Case Analysis: Digitalization and Institutional Reconstruction in Moldova's Energy Transition

Moldova's energy transition exemplifies the extreme sensitivity and vulnerability described in complex interdependence theory. For a long time, the country's natural gas and electricity supplies were almost entirely dependent on a single dominant external supplier, creating a highly asymmetric interdependence. This left Moldova with minimal physical buffers to withstand supply disruptions or price spikes in the face of geopolitical shocks such as the Russia–Ukraine crisis. In response, the Moldovan government demonstrated strong strategic execution by aggressively expanding the domestic renewable energy system. Installed capacity grew from approximately 77 MW in 2020 to an anticipated near 1 GW by the end of 2025, representing more than a twelvefold increase within just five years (NSEC, 2025). Solar energy (approximately 72%) and wind energy (approximately 25%), driven primarily by fixed-price and net-metering policies, have become the core pillars replacing traditional fossil fuels (UNDP, 2023). However, this rapid physical transformation, aimed at reducing external vulnerability, has generated new systemic risks at the national grid level. The highly intermittent and fragmented nature of renewable integration exceeds the physical absorption

capacity of Moldova's traditional, coarse-grid infrastructure. These technological bottlenecks have compelled Moldova to pursue governance solutions that extend beyond mere infrastructure expansion, seeking mechanisms capable of sustaining its geopolitical objective of energy independence.

Faced with the physical limitations of the traditional grid and constrained national fiscal capital, the Moldovan government, with international support, introduced the Digital Transformation Plan for the Energy Sector (2026–2030) (Ministerul Energiei al Republicii Moldova, 2024), which carries implications beyond mere technological upgrades. From the perspective of Susan Strange's structural power, the passive position of small states in international energy competition stems from their relative weakness in financial and security structures. Unable to invest in large-scale storage facilities or redundant pipelines as major powers can, Moldova has opted to leverage digital policies to reshape the knowledge structure—specifically, the control over data and information flows—as an institutional compensation for physical shortcomings. The strategic core of this initiative involves the large-scale deployment of 500,000 smart meters by 2030 (covering at least 40% of key users) and the establishment of a national energy data hub, representing a governance-driven restructuring of authority aimed at eliminating information asymmetries (UNDP, 2024). By collecting and integrating real-time data on energy production, imports, and consumption, national regulatory agencies have shifted from a traditionally reactive, fragmented approach to proactive, algorithm-based management. This process of data transparency not only effectively reduces rent-seeking opportunities in conventional energy transactions and keeps grid losses below 10%, but more importantly, it consolidates energy dispatch authority within the state governance platform, significantly enhancing administrative control over energy flows and distribution.

The comprehensive deployment of digital infrastructure has ultimately translated into tangible governance capacity for Moldova to hedge against external risks. Within the framework of energy governance theory, this capacity manifests as the integrated management of system agility and market rules. Under traditional physical constraints, power grids face instability when intermittent renewables exceed approximately 15% of the energy mix (IEA, 2017). Moldova, however, has successfully surpassed this limit through digital-enabled demand-side management and intelligent dispatch. Data indicate that, supported by digital mechanisms, renewable electricity accounted for 16.7% of total consumption in 2024 and rose to approximately 24.5% by 2025, with instantaneous generation during peak seasons covering more than 48% of domestic demand (NSEC, 2025). This high level of grid integration reflects the role of digitalization as a "virtual balancing tool," where precise control over consumption behaviors substitutes information flows for physical storage, upgrading national energy system resilience at minimal economic cost.

Strategically, digital platforms have also served as critical technical interfaces for Moldova's institutional alignment with the European energy community (Petelca et al., 2024). By binding domestic data standards to EU transparency rules, such as those of ENTSO-E, Moldova has not only achieved cross-border grid integration physically but also accomplished deep regulatory harmonization with European governance frameworks. Anchoring national energy security within broader regional rules, this strategic approach demonstrates that digital transformation is not merely a tool for enhancing technological efficiency in small states; it is a central vehicle through which they can assert sovereignty and evolve institutional capacity within volatile geopolitical fault lines.

Conclusion

This study, through an in-depth analysis of Moldova's energy transition, highlights the central role of digitalization in enabling small states to address structural vulnerabilities (Nica, Georgescu & Kinnunen, 2026). The findings indicate that, amid the rapid restructuring of the global energy system, Moldova has successfully shifted the logic of energy security from mere physical resource expansion to data-driven, precision governance by deploying smart grids, national data hubs, and smart metering

devices. This transformation has not only resolved the technical challenge of integrating high shares of intermittent renewables but also digitally empowered the state's sovereign capacity at the institutional level. By functioning as an institutional compensation mechanism, digitalization allows Moldova to leverage the mobility of information flows to hedge against external geopolitical risks, thereby enhancing strategic resilience within asymmetric interdependence.

Building on Moldova's successful experience, this study offers policy insights for other small economies facing similar structural vulnerabilities. First, small states should elevate energy digitalization to a national security priority. In an international environment where energy is increasingly weaponized, establishing real-time monitoring and predictive systems for energy flows can effectively reduce sensitivity to external suppliers while preserving essential administrative control. Data sovereignty is becoming an integral component of energy sovereignty; by exercising autonomous control over energy production and consumption data, small states can transform from passive rule-takers into agile governance actors (Proedrou, 2018). Second, digital transformation should be leveraged as a technological bridge for alignment with mainstream international institutions. By achieving mandatory harmonization of digital standards with regional multilateral mechanisms, such as the European energy community, small states can substantially lower institutional entry barriers and risk premiums in international energy markets, breaking the long-standing structural constraints imposed by limited financial capacity. Finally, digital governance must be closely integrated with social equity and justice. Using precise data to identify and support energy-vulnerable populations ensures that the social costs of energy transition are distributed fairly, thereby maintaining overall national resilience under high-pressure conditions (Sovacool, 2016).

While this study offers a framework for understanding Moldova's digital energy governance, several boundary conditions must be acknowledged. Primary among these is the specificity of the Moldovan case. The country's trajectory is inextricably linked to its unique geopolitical position and the institutional "pull" of EU integration. Consequently, the extent to which these digital strategies can be replicated in small states outside the European orbit warrants further comparative inquiry. Furthermore, while the narrative here emphasizes institutional empowerment, it arguably underplays the "shadow side" of digitalization. Issues such as cybersecurity vulnerabilities, data privacy, and the risk of path dependency on external technology providers remain critical gaps. Lastly, as Moldova's energy transition is a "living" process, these findings represent a snapshot in time. Only longitudinal observation will reveal whether these digital gains can withstand long-term political and economic pressures.

Ultimately, Moldova's trajectory in digital energy governance offers a vital lens through which to view the survival strategies of small states operating within the friction of geopolitical fault lines. While the structural tension between technological autonomy and external reliance remains a persistent challenge, the Moldovan experience demonstrates that leveraging digital upgrades to catalyze institutional "leaps" is a potent, and perhaps essential, mechanism for securing energy sovereignty in a fragmented international order. Moving forward, the scholarly agenda must expand to interrogate how these digital governance models fluctuate across diverse political regimes and the extent to which emerging transnational technical standards might fundamentally reorder the global hierarchy of energy power.

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