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Regional Asymmetry of Energy Sector Digitalization in Ukraine: The Case of Ivano-Frankivsk Oblast as a Model of Advanced Adoption

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ABSTRACT

The digital transformation of Ukraine's energy sector is highly uneven, and this unevenness is becoming increasingly visible at the regional rather than the national level. With average household smart metering coverage of around 24% at the end of 2025, the gap between the leading oblast and the oblasts of critical lag reaches almost fifteenfold. This raises doubts about the ability of a single regulatory policy to influence all territories equally. The regional dimension of energy digitalization remains underexplored in public administration scholarship, although it is precisely at the oblast and community levels that digital assets may become tools for managing energy resilience. The article aims to identify the factors of regional leadership in the digital modernization of energy infrastructure and to assess the conditions under which technical leadership translates into managerial effectiveness. The study applies comparative inter-regional analysis, the case method, and an original four-factor model explaining the preconditions for advanced adoption. The empirical basis includes data from DiXi Group, NEURC materials, and information from the regional authorities of Ivano-Frankivsk oblast. The results show that Prykarpattia's advanced level of digitalization, where smart metering coverage reached 44.9% at the end of 2025 against a national average of 24%, stems from a combination of four factors: the corporate strategy of the distribution system operator, the regulatory tariff incentive, the presence of certain critical energy infrastructure facilities in the region, and relative rear-area stability under conditions of armed aggression. It is established that technical leadership does not automatically translate into managerial effectiveness. Despite the presence of roughly 7,500 small and distributed generation facilities in the region, this potential has not yet been realized in the form of aggregated flexibility or manageable balancing resources. The article substantiates that scaling regional success requires a shift in regulatory logic: from a model in which operators may invest in digitalization to one in which they have a clear obligation, an economic incentive, and a controlled investment mechanism. Further research should focus on mechanisms for integrating regional distributed generation into the national balancing system through the DataHub platform.

KEYWORDS

public administration, energy digitalization, regional asymmetry, smart metering, distributed generation, energy resilience, distribution system operator, Industry 4.0.

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АНОТАЦІЯ

Цифрова трансформація енергетичної сфери України відбувається вкрай нерівномірно, причому ця нерівномірність дедалі виразніше проявляється саме на регіональному рівні. За середнього охоплення побутових споживачів інтелектуальним обліком близько 24 % наприкінці 2025 р. розрив між областю-лідером і областями критичного відставання сягає майже п'ятнадцятикратного значення. Це ставить під сумнів спроможність єдиної регуляторної політики однаково впливати на всі території. Актуальність дослідження зумовлена тим, що в науці публічного управління регіональний вимір цифровізації енергетики залишається малодослідженим, тоді як саме на рівні областей і громад вирішується, чи перетворюються цифрові активи на інструмент управління енергетичною стійкістю. Метою статті є виявлення чинників регіонального лідерства у цифровій модернізації енергетичної інфраструктури та оцінка умов, за яких технічне лідерство переходить в управлінську ефективність. У дослідженні застосовано порівняльний міжрегіональний аналіз, кейс-метод та авторську чотирифакторну модель пояснення передумов випереджального впровадження. Емпіричною базою стали дані аналітичного центру DiXi Group, матеріали НКРЕКП та обласної влади Івано-Франківщини. Результати показали, що випереджальний рівень цифровізації Прикарпаття, де наприкінці 2025 р. охоплення інтелектуальним обліком досягло 44,9 % проти середніх 24 % по країні, пояснюється поєднанням чотирьох чинників: корпоративної стратегії оператора системи розподілу, регуляторного тарифного стимулу, наявності окремих об'єктів критичної енергетичної інфраструктури та відносної тилової стабільності в умовах збройної агресії. Установлено, що технічне лідерство не переходить в управлінську ефективність автоматично. Попри наявність у регіоні близько 7,5 тис. об'єктів малої та розподіленої генерації, цей потенціал поки не реалізований у форматі агрегованої гнучкості та керованих ресурсів балансування. У статті обґрунтовано, що масштабування регіональних успіхів вимагає зміни регуляторної логіки: від моделі, за якої оператор може інвестувати у цифровізацію, до моделі, за якої він має чіткий обов'язок, економічний стимул і контрольований інвестиційний механізм. Перспективи подальших досліджень пов'язані з розробленням механізмів інтеграції регіональної розподіленої генерації у національну систему балансування через платформу DataHub.

КЛЮЧОВІ СЛОВА

публічне управління, цифровізація енергетики, регіональна асиметрія, інтелектуальний облік, розподілена генерація, енергетична стійкість, оператор системи розподілу, Індустрія 4.0.

1. Introduction

The energy regulator of Ukraine sets the same requirements for distribution system operators (DSOs), although their level of digital development differs significantly. At the end of 2025, the average coverage of household consumers with smart metering in Ukraine approached 24% with a total number of devices of 4.1 million [3], but the meter itself captures only the most visible part of the operator's digital maturity. Behind this figure are the telemetrization of substations, the ability of dispatch centers to process data in real time, the quality of indicator verification and the readiness to integrate distributed generation into the balancing system. None of these characteristics are systematically measured by the regulator today, and the differences between operators are not reduced to differences in financial resources: they reflect both regulatory incentives and the company's management culture and the security situation in the region of its operation.

European experience links the digitalization of networks with transparency of the electricity market, integration of renewable generation and development of energy data exchange. In Ukraine, another dimension has been added: after the start of full-scale armed aggression, the manageability of networks has turned from a purely technical issue into a condition for the stability of the energy system. The World Bank and partners estimate the country's direct losses as a result of the aggression at over 195 billion USD, and the needs for the restoration of the energy sector alone amount to almost 91 billion USD; accordingly, the price of each regulatory decision in this area is increasing.

In public administration science, the regional dimension of energy sector digitalization remains understudied. Researchers mostly analyze the national regulatory framework or individual digital technologies, while the question of why some regions achieve advanced results while others remain in the critical lag zone requires a separate explanation. For the NEURC, such asymmetry has not only statistical but also managerial significance, since the same regulatory requirements apply to operators with different investment, technical, and security capabilities. Armed aggression affects this picture in two ways. Mass power outages and the need for backup power supply push communities and businesses to distributed generation and local digital metering, while frontline and de-occupied operators' direct resources mainly to emergency network restoration rather than digital modernization. This dual effect of war can be considered as a military paradox of digitalization: war simultaneously increases the demand for digital control of the energy system and narrows the possibilities of its implementation in the most vulnerable regions. Therefore, the study focuses on identifying factors of regional leadership in the digitalization of the energy sector of Ukraine using the example of the Ivano-Frankivsk region and on assessing the conditions under which the technical leadership of the region can be transformed into managerial efficiency.

2. Literature Review

The issue of digital transformation of public administration and the energy sector is actively studied in domestic and foreign science, but attention to its individual aspects is unevenly distributed: the conceptual principles of digitalization are developed much deeper than its regional dimension. V. Saprykin distinguishes between digitization, digitalization and digital transformation of public administration, showing that these processes are interconnected, but not identical, and digital transformation means a deeper management restructuring, and not just the transfer of information into digital form [15]. N. Sorokina and V. Filatov continue this line, emphasizing that digitalization should be interpreted both narrowly, as a technical transformation, and broadly, as a general trend in the transformation of governance [18]. These works form a theoretical framework within which the digitalization of energy appears as a sectoral manifestation of a broader process of transformation of public administration.

A separate area of research concerns the technological and market modernization of the energy system. R. Zvarych and B. Kharkovsky analyze the smart integration of the Ukrainian energy system into the EU single energy market, noting that deeper integration increases the reliability of electricity supply, but at the same time requires synchronization of networks and harmonization of legislation with European standards [20]. Their approach is valuable for combining technical and managerial views, but the regional unevenness of implementation remains out of focus: integration and technological tasks are described as nationwide, without explaining why some regions are progressing faster than others.

Issues of state policy in the field of renewable and distributed energy are considered by T. Korolyuk and Yu. Zverevych, who draw attention to the contradictions of the state course between supporting nuclear and renewable generation and emphasize that stimulating decentralized sources should create favorable conditions for their implementation and reduce financial barriers for communities [5]. This conclusion directly applies to the regional level, as it is communities and regions that become the environment where distributed generation either develops or is constrained depending on local institutional, financial, and network conditions.

In international studies, the regional dimension of energy transformation has been developed more broadly. H. Trypolska, O. Kubatko, and O. Prokopenko investigate the prerequisites for the creation of solar energy cooperatives in Ukraine, showing that the suitability of regions for cooperative solar generation is determined not only by the level of insolation, but also by the ability of energy companies to operate in the market and the structure of tariffs [19]. This study is methodologically close to the task of this article, as it directly links regional specifics with managerial and economic factors. B. Sovakul and co-authors analyze the global dynamics of the transition to smart metering, emphasizing that national trajectories of smart metering deployment are determined primarily by governance factors, in particular the presence or absence of a legislative mandate, and not only by technological capabilities [17]. R. Alsaig, R. Mehmood and I. Katib consider governance and transparency in the application of artificial intelligence in smart energy systems, emphasizing that the complexity of digital systems puts forward new requirements for their manageability and accountability [2].

An analysis of the available works shows that the conceptual foundations of digital governance, smart grid technologies and general approaches to public policy in renewable energy have been developed in sufficient detail. However, the regional dimension of the digital transformation of the energy sector in Ukraine remains understudied. There is a lack of works that would explain why individual regions become leaders in the digitalization of the energy sector, what management, regulatory and security factors determine this and under what conditions regional experience can be scaled up.

3. Problem Statement

The purpose of the study is to identify management, regulatory and security factors that determine the advanced development of digitalization of the energy sector at the regional level, as well as to assess the conditions under which the technical leadership of the region is transformed into real management efficiency. To achieve this goal, it is necessary to perform several tasks: to assess the scale of regional asymmetry in the coverage of household consumers with smart metering in Ukraine and determine the place of Ivano-Frankivsk region in this distribution; to reveal the factors that provided the region with advanced positions in the digital modernization of energy infrastructure; to substantiate the author's four-factor model of regional leadership, which explains the combination of corporate, regulatory, infrastructure-geographic and security prerequisites; to identify the gap between the availability of digital assets and the ability of public administration entities and operators to use them to increase energy sustainability; to determine the conditions under which the regional experience of the Carpathian region can be transferred to other territories of Ukraine. The object of the study is the processes of digital transformation of the energy sector of Ukraine in the public administration system, and the subject is regional factors of the early implementation of digital solutions in the energy infrastructure using the example of the Ivano-Frankivsk region.

4. Methods and Materials

The study is based on a combination of case studies, comparative interregional analysis and statistical analysis of open data. Ivano-Frankivsk region is considered as an illustrative example of regional leadership in the digitalization of the energy sector, based on which it is possible to trace the connection between regulatory, corporate, infrastructure-geographic and security factors. The case study made it possible not only to describe the state of digitalization of the region, but also to identify connections that explain the different rates of implementation of digital solutions in the regions under the conditions of a single regulatory field. Comparison of the Ivano-Frankivsk region with other regions in terms of the level of coverage of household consumers with smart metering made it possible to determine the scale of regional asymmetry and justify the region's belonging to the group of leaders.

The empirical base was formed from open and verified sources. The main source was the data of the DiXi Group analytical center, published on the Energy Map portal based on the responses of the National Commission for the Regulation of Energy and Utilities of Ukraine. According to these data, at the end of 2025, about 4.1 million smart meters were installed in Ukraine, which corresponds to almost 24% of household consumers, while at the end of 2024 this figure was 3.3 million [3]. At the same time, these data require careful interpretation: they primarily reflect the fact of installation of devices, but do not allow for a full assessment of their functionality, quality of remote reading and compliance with the requirements of Directive (EU) 2019/944.

Additionally, official materials of the authorities of Ivano-Frankivsk region on the development of distributed generation, analytical materials of international energy organizations, as well as regulatory and legal acts in the field of commercial metering of electricity and the development of distributed generation were used. The combination of different types of sources made it possible to cross-check the facts and reduce the dependence of conclusions on a single information array. This is especially important in wartime conditions, when access to some detailed data on energy infrastructure is limited for security reasons.

To explain the reasons for regional leadership, the author's four-factor model was used, which combines the corporate strategy of the distribution system operator, the regulatory tariff incentive, the infrastructure and geographical specificity of the region and the relative rear stability in conditions of armed aggression. Unlike purely quantitative index approaches, this model is explanatory in nature: it is aimed not only at fixing a high level of digitalization, but also at identifying the conditions under which the region achieves ahead-of-time implementation. The use of the model together with comparative analysis made it possible to move from stating leadership to analyzing its causes, managerial prerequisites and possible limits of scaling.

The study has several limitations that must be taken into account when interpreting the results. Firstly, the indicator of coverage of smart metering does not fully reflect the quality of remote reading, integration of devices with the operator's information systems and the actual management efficiency of digital solutions. Secondly, the analysis is based on open data, the availability of which is limited during the war period. Thirdly, the case of Ivano-Frankivsk region cannot automatically represent all regions of Ukraine, as it combines specific corporate, regulatory, infrastructure-geographic and security prerequisites. Therefore, the proposed four-factor model is explanatory in nature and requires further testing on materials from other regions of Ukraine.

5. Results and Discussion

Analysis of data on the coverage of household consumers with smart metering by the end of 2025 demonstrates a pronounced regional unevenness in the digital modernization of commercial electricity metering systems in Ukraine. With an average national indicator of about 24%, the gap between the leading region and the regions with a critical lag reaches almost fifteen times the value. The highest level of coverage was recorded in the Ivano-Frankivsk region, where 44.9% of household consumers are equipped with smart meters, which corresponds to 260.8 thousand households [3]. The group of regions with coverage over 40% also included Zakarpattia (44.3%), Dnipropetrovsk (42.3%) and Volyn (41.9%) regions. At the opposite pole are Kharkiv Oblast with an indicator of 6.3%, Cherkasy Oblast – 3.9% and Donetsk Oblast – 3.0%, and in total in these three oblasts only about 128.9 thousand devices are installed. The scale of this gap is illustrated by the comparison of coverage indicators by individual oblasts, shown in Fig. 1.

A graphic comparison shows that the leading regions and the regions of critical lagging behind form two sharply different poles, between which the average national indicator occupies an intermediate position. This is not a gradual distribution of regions along a single scale, but a qualitative gap, in which a small group of regions has advanced significantly further than most other regions. This is precisely what determines the need to explain what factors provide individual regions with leading positions. At first glance, such a gap could be explained by external circumstances, primarily hostilities. Indeed, the lowest positions of Donetsk and Kharkiv regions are largely due to being in the zone of active hostilities or near it. It is significant that in the Donetsk region during 2025 not a single new smart meter was installed, which reflects the actual impossibility of implementing investment programs in conditions of constant shelling [3]. However, the explanation due to proximity to the front is not exhaustive. Cherkasy region, located in the relatively safe center of the country, demonstrates one of the

lowest indicators with negative dynamics: according to the regulator, the coverage level in the area of responsibility of the local operator decreased during the year due to a change in the approach to metering devices and the failure of some data collection equipment [3]. Therefore, the regional asymmetry of digitalization is determined not only by the security factor, but also by the management decisions of operators and the quality of their investment policy. This conclusion is consistent with the analysis of barriers to ensuring the country's energy security in wartime conditions [6].

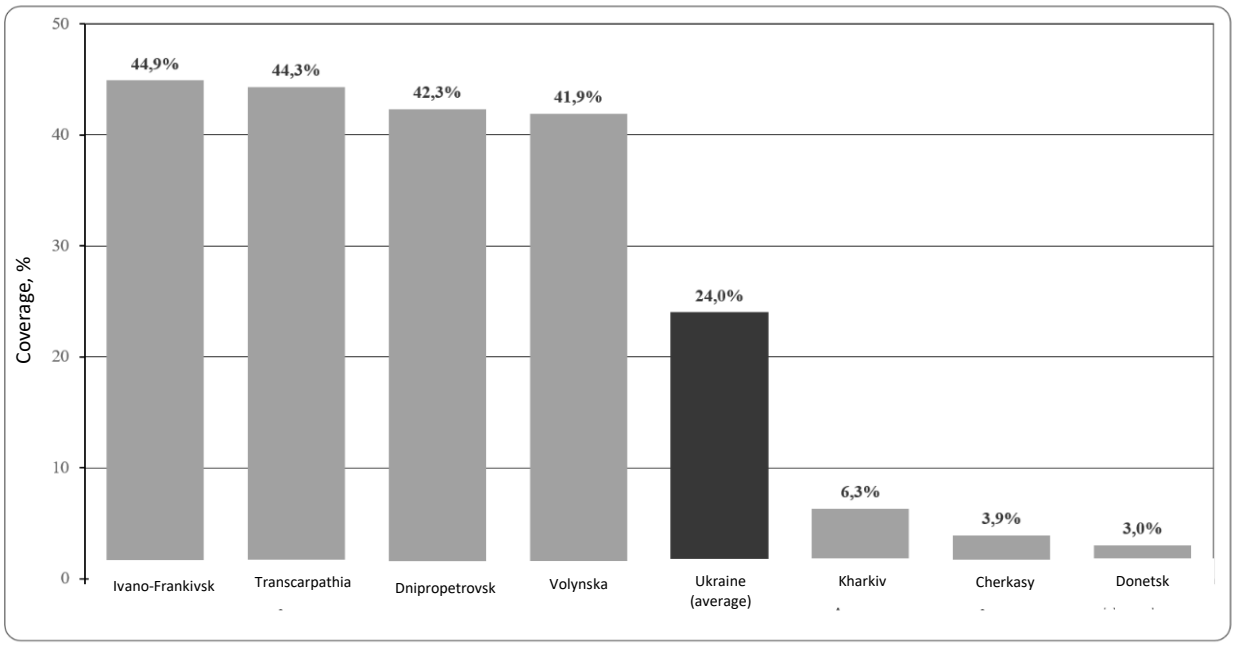

Figure 1. Coverage of household consumers with smart metering by regions of Ukraine (end of 2025), %

Source: Compiled by the author based on [3].

Such a comparison gives rise to a key conclusion: the security situation explains the lag of front-line regions, but does not explain leadership. Ivano-Frankivsk region does not have obvious structural advantages that would automatically put it in first place: it is not the largest in terms of the number of consumers, does not have the highest level of population income, and does not belong to the traditional industrial and energy centers of Ukraine. Therefore, its leading positions require a separate explanation through a combination of factors that operate specifically at the regional level.

These positions should be explained not by a single decisive factor, but by a combination of prerequisites that mutually reinforce each other. To systematize them, a four-factor model of regional leadership has been proposed, which combines corporate, regulatory, infrastructure-geographical and security factors and shows how their coincidence in time and space creates conditions for the accelerated implementation of digital solutions. The generalized structure of the model is shown in Fig. 2.

The proposed model reflects four groups of prerequisites, each of which operates at its own level, but it is their combination that forms the cumulative result. Corporate and regulatory factors set the economic logic of digitalization; that is, they determine who and for what purpose invests in intellectual infrastructure. Infrastructural-geographical and security factors, in turn, form the environment in which these investments can be implemented more consistently. The arrows in the diagram indicate the direction of all four prerequisites towards a common result - the early implementation of digital solutions. The lower level of the model captures a key caveat: the achieved technical leadership does not yet mean managerial efficiency, and the transition from the first to the second becomes the central condition for a sustainable result.

The first factor is related to the corporate strategy and investment policy of the distribution system operator. In Ivano-Frankivsk region, the operator functions are performed by the joint-stock company "Prykarpattyaoblenergo", the investment decisions of which directly affect the pace of installation of smart metering devices. Meter replacement is carried out mainly within the framework of the operator's investment programs approved by the regulator, although the consumer can order

installation at his own expense. Because of this, the regional coverage indicator primarily reflects how actively a particular operator is implementing digital modernization of the network infrastructure. Comparison with regions where operators demonstrated passivity or even negative dynamics, as happened in Cherkasy region, shows that the corporate factor is one of the initial prerequisites for regional leadership.

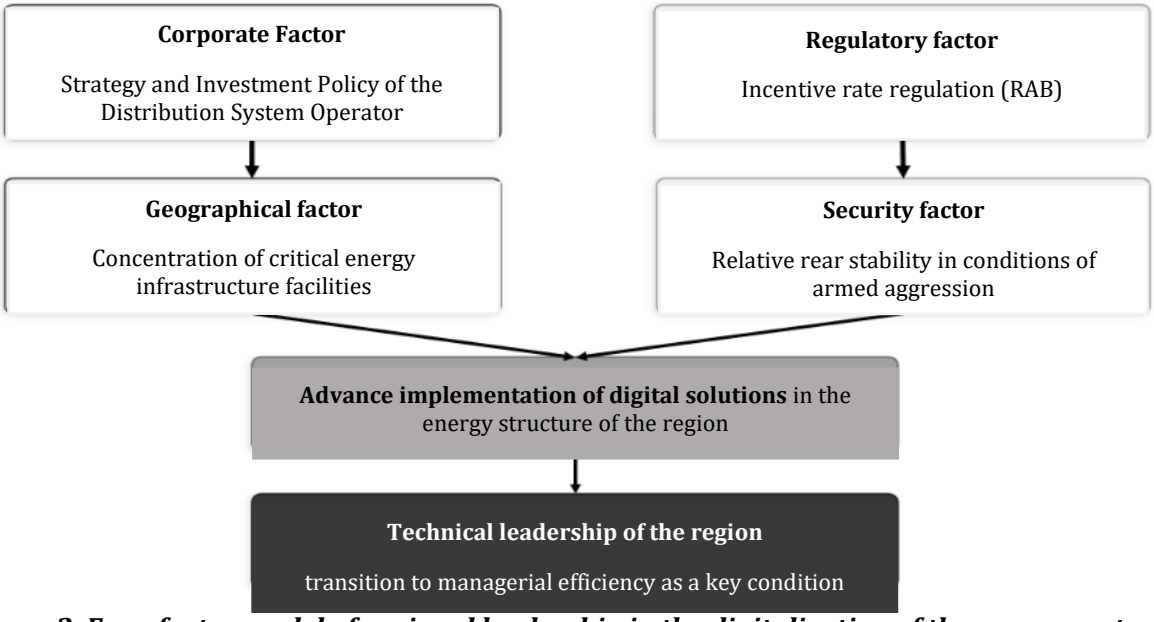

Figure 2. Four-factor model of regional leadership in the digitalization of the energy sector

Source: Compiled by the author.

The second factor is related to the regulatory environment, primarily to the tariff formation model. A key role is played by stimulating regulation, also known as RAB regulation, i.e., a system of long-term tariff formation aimed at attracting investments in the modernization of electricity networks and increasing the operator's cost efficiency. Unlike the traditional "cost plus" model, where the regulator approves all cost items each year, incentive regulation allows the operator to retain part of the achieved savings and plan capital investments for a longer period. It is significant that the tariffs for electricity distribution services for JSC "Prykarpattyaoblenergo" were set using incentive regulation [9]. This creates an economic interest in investing in digital infrastructure, since network modernization and the implementation of smart metering become not only a cost item, but also a way to increase the operational efficiency of the DSO.

The third factor is of an infrastructural and geographical nature and is associated with the presence of certain critical energy infrastructure facilities in the region. Prykarpattia has historically been an important node of the country's gas transportation infrastructure. In particular, the Bogorodchansky underground gas storage facility with an active capacity of about 2.3 billion cubic meters is located here, which is part of a system of twelve underground storage facilities with a total design capacity of 31 billion cubic meters and is capable of covering peak daily needs of up to 50 million cubic meters [4]. The reconstruction of this facility provided for the automation of gas supply regulation and switching, as well as the implementation of automated metering, i.e., digital solutions that meet the logic of Industry 4.0 in the energy sector. The presence of such facilities creates increased requirements for the reliability and manageability of energy supply, and therefore indirectly stimulates the digitalization of local infrastructure. At the same time, this increases the requirements for its cybersecurity, since the complexity of digital systems expands the surface of possible cyber attacks on critical infrastructure [13].

The fourth factor is security and becomes especially important in conditions of armed aggression. The western location of the Ivano-Frankivsk region and its remoteness from the front line provide relative rear stability compared to front-line regions. This circumstance has direct managerial significance: investment programs for network modernization can be implemented more systematically, without directing major resources to emergency restoration of destroyed facilities. The contrast with the Donetsk region, where not a single new meter has been installed during the year, illustrates how the security situation determines the very possibility of digital development. This is where the military paradox of digitalization manifests itself: armed aggression destroys the digital

infrastructure in frontline regions and at the same time indirectly strengthens the relative advantages of rear areas, which can become sites for early implementation. Strengthening the security dimension of digitalization of public administration corresponds to global trends in state response to modern threats [1].

The combination of these four factors explains why the Ivano-Frankivsk region is ahead of other regions, but it does not yet prove that technical leadership automatically translates into managerial efficiency. This issue requires separate consideration, since the main limitation of the regional model lies precisely in the gap between the availability of digital assets and the ability to use them as a managerial resource.

The high level of coverage of smart metering and the rapid growth of distributed generation may create the impression that Ivano-Frankivsk region has already formed a modern digital energy system. The dynamics are truly indicative. If in February 2025 there were 5290 home solar power plants in the region with a total capacity of 137 MW and 156 industrial plants with a capacity of 263 MW, then as of June 2026 the number of home solar power plants had increased to 7289 units with a capacity of 178 MW, and industrial plants to 217 facilities with a total capacity of 354 MW [13]. The change in these indicators for the period from February 2025 to June 2026 is illustrated in Fig. 3.

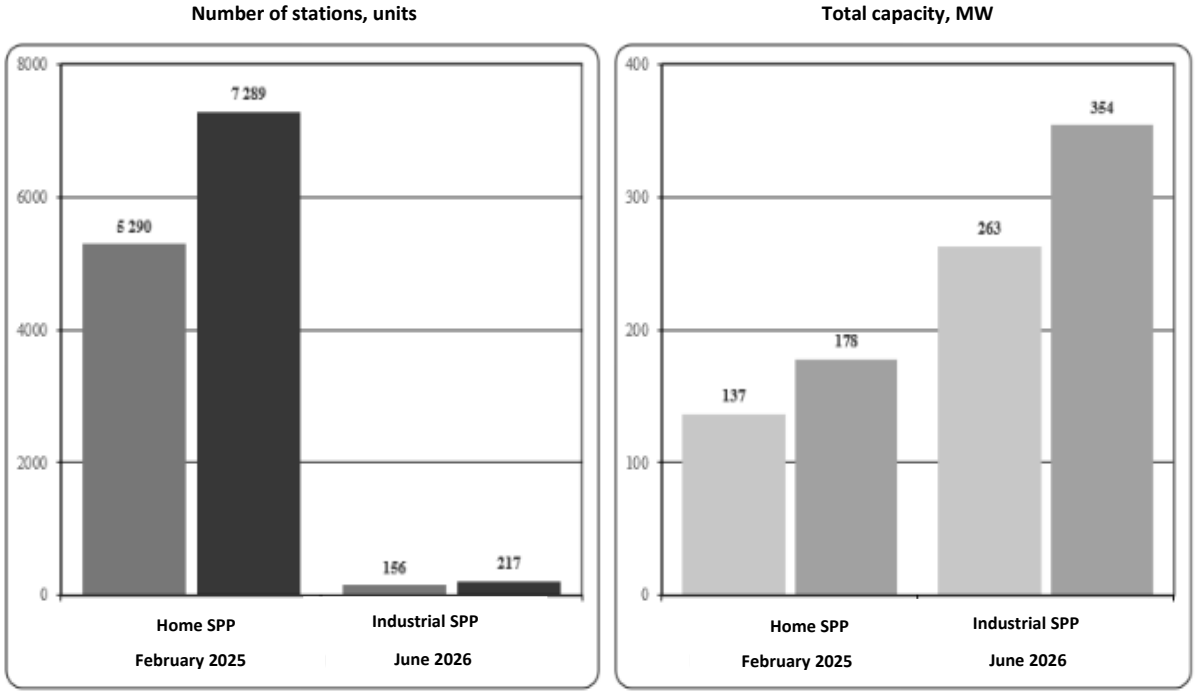

Figure 3. Dynamics of distributed solar generation in Ivano-Frankivsk region (February 2025 – June 2026)

Source: Compiled by the author based on [13].

A comparison of the two time periods shows that the growth covered both the segment of home stations and the segment of industrial facilities. At the same time, the increase in industrial generation capacity in absolute terms exceeded the increase in home generation. This indicates that distributed generation in the Carpathian region is developing not only at the expense of the population, but also due to the activity of business entities that are increasing their own energy capacities. The increase in the number of home stations by almost 40% for the period from February 2025 to June 2026 indicates a more active involvement of the population in electricity production and the formation of a layer of prosumers, that is, consumers who are simultaneously electricity producers. The transition to green energy is changing the management models of business entities operating in this area [11]. In total, there are about 7.5 thousand distributed and small generation facilities operating in the region.

However, this resource in itself does not mean that the region has acquired the ability to manage it effectively. Here, a fundamental difference between technical leadership and managerial efficiency is manifested. The presence of smart meters and thousands of solar installations creates a technical prerequisite for active demand management, aggregation of distributed sources and formation of managed balancing resources, but this prerequisite remains largely unrealized. Smart metering

provides the operator with consumption data, but the data itself does not turn into manageability without institutional mechanisms for their use. The role of territorial communities in digital transformation becomes important for consolidating regional successes, since it is at the local level that the demand for energy sustainability, local generation and digital services is formed [16]. Similarly, thousands of home solar stations operate mainly in individual mode under the "green tariff" scheme: they sell excess electricity, but are not combined into virtual power plants and are not involved in the provision of system balancing services. A comparison of the available potential and the actual level of its use gives grounds to speak of a significant gap, summarized in Table 1.

Table 1. The gap between the existing digital potential and the level of its managerial implementation in the energy sector of Ivano-Frankivsk region

Direction	Available potential	Level of managerial implementation
Smart metering	44.9% coverage of household consumers, over 260 thousand devices	Data is collected but poorly used for active demand management
Distributed solar generation	7289 household solar power plants (178 MW)	Operate individually under a "green tariff", not aggregated
Industrial solar generation	217 stations (354 MW)	Not integrated into regional balancing mechanisms
Demand management	Technical readiness based on intelligent metering	Flexible tariff incentive mechanisms are limited
Virtual power plants	Sufficient number of distributed sources for aggregation	No operational source aggregation projects

Source: Compiled by the author based on [3; 13].

The security factor also depends on circumstances that are not controlled at the regional level, since proximity to the front line is determined by the course of hostilities, not by local politics. Thus, the infrastructural, geographical and security prerequisites form the context of digitalization, which cannot be mechanically reproduced in other regions.

Instead, the distribution system operator's corporate strategy and the regulatory environment are controllable variables, and therefore form the basis of the scaling policy. If geography and the security situation cannot be changed, then the operator's investment activity and tariff incentives can be adjusted by means of state policy. Reproducing the Carpathian model should not be based on copying unique territorial conditions, but on a targeted impact on those factors that are subject to regulation. The key lever here is the tariff formation model, since stimulating regulation creates an economic interest in digital modernization for the operator.

At the same time, the reproduction of corporate and regulatory factors does not in itself eliminate the gap between technical leadership and managerial efficiency. Scaling requires not only investments in equipment, but also the formation of mechanisms that transform this equipment into real manageability. Therefore, scaling policies should combine economic incentives for investment, institutional mechanisms for data use, the involvement of distributed generation in forecasting and balancing, as well as training personnel with digital competencies. This requires improving the legal regulation of renewable energy in the context of European integration [7].

This leads to a key conclusion regarding the logic of scaling: the current model, in which an operator can invest in digitalization only if favorable conditions are met, is insufficient. A transition to a model is needed in which the digital modernization of energy infrastructure is based on a clear obligation, a predictable economic incentive, and a controlled investment mechanism. Only under such conditions can regional successes like the one in the Carpathian region turn from an isolated exception into a reproducible result of the state policy of digitalization of the energy sector [10].

Scaling the Carpathian experience requires a clear coordination of the functions of key public administration entities. The Ministry of Energy should define the digitalization of distribution networks and the development of managed distributed generation as components of the state policy of energy sustainability. The National Commission for Energy and Power Generation should establish measurable regulatory indicators for DSOs: the share of metering points with remote reading, the level of network telemetry, data quality, time to detect accidents, and the integration of small generating facilities into

forecasting and balancing processes. Regional military administrations can coordinate regional digitalization programs, critical infrastructure needs, and local energy projects, while communities should shape demand for local energy sustainability solutions. With such coordination, smart metering ceases to be just a separate DSO investment measure and becomes a tool for evidence-based regulation, monitoring, and crisis management. The results obtained show that the Ivano-Frankivsk region is not only a region with a high level of smart metering coverage, but also a case of combining a corporate DSO initiative, a tariff incentive, infrastructural and geographical specificity, and relative logistics stability. At the same time, this case shows the limits of technical leadership: the installation of smart meters and the growth of the number of distributed generation facilities do not guarantee an automatic transition to managed energy flexibility. Therefore, it is advisable to consider the Carpathian experience not as a ready-made template for other regions, but as a management model that can be scaled only by taking into account the security, financial and institutional characteristics of a specific region.

6. Conclusions

The study showed that the digital transformation of the energy sector of Ukraine is unfolding with pronounced regional asymmetry, which cannot be explained only by differences in the financial capabilities of operators or the security situation. With an average national level of coverage of household consumers with smart metering of about 24% at the end of 2025, the gap between the leading region and regions of critical lag reaches almost fifteen times the value. It was established that proximity to the front line explains the lag of individual front-line regions, but does not explain leadership, and therefore, the leading positions of individual regions require a separate explanation through a combination of factors operating at the regional level.

Using the example of the Ivano-Frankivsk region, the author's four-factor model of regional leadership is substantiated, which combines corporate, regulatory, infrastructure-geographic and security factors. It is shown that the advanced level of digitalization of the Carpathian region, where the coverage of smart metering by the end of 2025 reached 44.9%, is explained by the coincidence of the active investment policy of the distribution system operator, stimulating tariff regulation, the presence of individual critical energy infrastructure facilities and relative logistics stability in conditions of armed aggression. It is the combination of these prerequisites, and not the action of one of them, that creates the conditions for the accelerated implementation of digital solutions.

A separate result of the study was the identification of the gap between technical leadership and managerial efficiency. Despite the high level of coverage of smart metering and the presence of about 7.5 thousand distributed and small generation facilities, this potential remains largely unrealized: distributed sources operate mainly in individual mode, are not aggregated into virtual power plants and are not involved in system balancing. This gives grounds to consider the technical leadership of the region not as a finished result, but as a formed base, the potential of which has yet to be revealed through appropriate management and institutional mechanisms.

Analysis of the conditions for scaling regional experience showed that the factors of the model have different transfer potential. Infrastructural, geographical and security factors form the context of digitalization and cannot be mechanically reproduced in other areas. Instead, the operator's corporate strategy and regulatory environment are controllable variables, and therefore form the basis of the policy of scaling digitalization. It follows that the reproduction of regional successes is possible not through copying unique conditions, but through targeted influence on factors subject to regulation, primarily through an appropriate tariff model in combination with the development of management mechanisms and personnel training.

The overall conclusion of the study is that the current model, in which the distribution system operator can invest in digitalization under favorable conditions, is insufficient, as it makes the pace of transformation dependent on the random coincidence of regional circumstances. The transition to a model in which digital modernization is based on a clear obligation, a predictable economic incentive and a controlled investment mechanism would allow transforming regional successes from an exception into a reproducible result of public policy. Prospects for further research are related to the development of mechanisms for integrating regional distributed generation into the national balancing system, in particular through an energy data exchange platform, as well as the development of a methodology for assessing the digital maturity of distribution system operators as a tool for differentiated regulatory influence.

References

1. Aliiev, M. (2025). Tsyfrovizatsiia publichnoho upravlinnia u sferi natsionalnoi bezpeky: svitovi tendentsii ta rekomendatsii dlia Ukrainy [Digitalization of public administration in the field of national security: Global trends and recommendations for Ukraine]. *Tavriiskyi naukovyi visnyk. Seriia: Ekonomika – Tavriiskyi naukovyi visnyk. Series: Economics*, (25), 156–164. https://doi.org/10.32782/2708-0366/2025.25.18 (in Ukrainian)
2. Alsaigh, R., Mehmood, R., & Katib, I. (2023). AI explainability and governance in smart energy systems: A review. *Frontiers in Energy Research*, (11), 1071291. https://doi.org/10.3389/fenrg.2023.1071291
3. DiXi Group. (2026). *Ukraine increases smart electricity metering: 24% of consumers already have smart meters. Energy Map*. https://dixigroup.org/en/ukraine-increases-smart-electricity-metering-24-of-consumers-already-have-smart-meters/
4. JSC Ukrtransgaz. (n.d.). *Underground gas storage facilities*. https://utg.ua/utg/psg/underground-gas-storages/
5. Koroliuk, T., & Zvierievych, Yu. (2024). Derzhavna polityka rozvytku vidnovliuvalnoi enerhetyky v Ukraini [State policy of renewable energy development in Ukraine]. *Derzhavne budivnytstvo – State Formation, 2*(36), 83–99. https://doi.org/10.26565/1992-2337-2024-2-06 (in Ukrainian)
6. Kovalenko, Yu., Lazarenko, D., & Marchenko, O. (2024). Enerhetychna bezpeka krainy pid chas viiny: bariery ta perspektyvy podolannia [Energy security of the country during the war: Barriers and prospects for overcoming]. *Visnyk Khmelnytskoho natsionalnoho universytetu. Seriia: Ekonomichni nauky – Herald of Khmelnytskyi National University. Economic Sciences*, (1), 262–266. https://doi.org/10.31891/2307-5740-2024-326-41 (in Ukrainian)
7. Kurylo, I. (2025). Okremi aspekty pravovoho rehuliuvannia u sferi vidnovliuvanoi enerhetyky v konteksti yevrointehratsii [Certain aspects of legal regulation in the field of renewable energy in the context of European integration]. *Pravovi novely – Legal Novels*, (26). https://doi.org/10.32782/ln.2025.26.10 (in Ukrainian)
8. Kvitka, S., Korsun, V., & Mahylias, Yu. (2024). Tsyfrova transformatsiia publichnoho upravlinnia: perspektyvni napriamy doslidzhen [Digital transformation of public administration: Promising areas of research]. *Aspekty publichnoho upravlinnia – Public Administration Aspects, 12*(3), 50–58. https://doi.org/10.15421/152437 (in Ukrainian)
9. Lisovyi, A. (2024). Enerhetychna bezpeka Ukrainy: druhyi rik viiny [Energy security of Ukraine: The second year of the war]. *Modeling the Development of the Economic Systems*, (1), 124–129. https://doi.org/10.31891/mdes/2024-11-17 (in Ukrainian)
10. Lisovyi, A., & Andrukh, O. (2025). Enerhetychna bezpeka Ukrainy: vyklyky viiny ta perspektyvy vidnovlennia ekonomichnoho potentsialu [Energy security of Ukraine: Challenges of the war and prospects for restoring economic potential]. *Ukrainskyi ekonomichnyi chasopys – Ukrainian Economic Journal*, (8), 40–43. https://doi.org/10.32782/2786-8273/2025-8-7 (in Ukrainian)
11. Maslak, O., & Kuz, A. (2024). Napriamky transformatsii upravlinnia pidpryiemstvamy v umovakh perekhodu do zelenoi enerhetyky [Directions of enterprise management transformation in the context of transition to green energy]. *Ekonomika ta suspilstvo – Economy and Society*, (61), 55–59. https://doi.org/10.32782/2524-0072/2024-61-97 (in Ukrainian)
12. Murasov, R., Faraon, S., & Huk, O. (2025). Kiberbezpeka krytychnoi infrastruktury: otsiniuvannia ta upravlinnia ryzykamy kiberatak [Critical infrastructure cybersecurity: Assessment and management of cyberattack risks]. *Suchasni informatsiini tekhnolohii u sferi bezpeky ta oborony – Modern Information Technologies in the Sphere of Security and Defence, 54*(3), 75–83. https://doi.org/10.33099/2311-7249/2025-54-3-75-83 (in Ukrainian)
13. Na Frankivshchyni kilkist soniachnykh elektrostantsii zrosla maizhe na 40% [In the Frankivsk region, the number of solar power plants has increased by almost 40%]. (2026). *Ratusha*. https://www.ratusha.if.ua/na-prykarpatti-za-rik-kilkist-soniachnykh-elektrostantsij-zrosla-majzhe-na-40/ (in Ukrainian)
14. Pro vstanovlennia taryfiv na posluhy z rozpodilu elektrychnoi enerhii AT "Prykarpattiaoblenerho" iz zastosuvanniam stymuliuiuchoho rehuliuvannia [On setting tariffs for electricity distribution services of JSC Prykarpattiaoblenergo with the application of incentive regulation] (Resolution No. 2216 of December 19, 2024). (2024). *National Energy and Utilities Regulatory Commission of Ukraine.* https://www.nerc.gov.ua/ (in Ukrainian)
15. Saprykin, V. (2024). Otsyfrovuvannia, tsyfrovizatsiia ta tsyfrova transformatsiia publichnoho upravlinnia v Ukraini [Digitization, digitalization and digital transformation of public administration in Ukraine]. *Visnyk Kyivskoho natsionalnoho universytetu imeni Tarasa Shevchenka. Derzhavne upravlinnia – Bulletin of Taras Shevchenko National University of Kyiv. Public Administration, 19*(1), 116–121. https://doi.org/10.17721/2616-9193.2024/19-19/22 (in Ukrainian)

16. Shulzhyk, Yu., Kvasnii, Z., Melnyk, O.-A., & Strohush, Yu. (2025). Tsyfrova transformatsiia terytorialnykh hromad Ukrainy: vyklyky ta perspektyvy [Digital transformation of territorial communities of Ukraine: Challenges and prospects]. *Aktualni pytannia ekonomichnykh nauk – Topical Issues of Economic Sciences*, (8). https://doi.org/10.5281/zenodo.14942699 (in Ukrainian)
17. Sovacool, B. K., Hook, A., Sareen, S., & Geels, F. W. (2021). Global sustainability, innovation and governance dynamics of national smart electricity meter transitions. *Global Environmental Change*, (68), 102272. https://doi.org/10.1016/j.gloenvcha.2021.102272
18. Sorokina, N., & Filatov, V. (2025). Tsyfrovizatsiia publichnoho upravlinnia v Ukraini: teoretychnyi aspekt [Digitalization of public administration in Ukraine: Theoretical aspect]. *Aspekty publichnoho upravlinnia – Public Administration Aspects, 1*3(1), 77–81. https://doi.org/10.15421/152509 (in Ukrainian)
19. Trypolska, G., Kubatko, O., & Prokopenko, O. (2025). Establishing Solar Energy Cooperatives in Ukraine: Regional Considerations and a Practical Guide. *Energies, 18*(14). https://doi.org/10.3390/en18143623
20. Zvarych, R., & Kharkovskyi, B. (2025). Smart integration of Ukraine's energy system into the single energy market of the EU: Challenges and prospects. *Journal of European Economy, 24*(2), 246–266. https://doi.org/10.35774/jee2025.02.246