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FINANCIAL MECHANISMS AND DECISION-MAKING TO SUPPORT ENERGY DECENTRALIZATION IN UKRAINE[1]

ФІНАНСОВІ МЕХАНІЗМИ ТА ПРИЙНЯТТЯ РІШЕНЬ ДЛЯ ПІДТРИМКИ ЕНЕРГЕТИЧНОЇ ДЕЦЕНТРАЛІЗАЦІЇ В УКРАЇНІ

The full-scale war in Ukraine has exposed critical vulnerabilities in centralized energy grids, driving the urgent need for decentralized renewable energy solutions. This study investigates the economic efficiency of state financial and investment support for the advancement of distributed green energy systems in Ukraine, particularly through concessional financing initiatives such as the "5-7-9" program. The decision-making analysis focuses on small and medium-sized enterprises investing in 10-, 20-, and 30-kW hybrid wind-solar photovoltaic systems accompanied by storage facilities. Financial viability was assessed using key indicators, including Levelized Cost of Energy, Net Present Value, Internal Rate of Return, Profitability Index, and Discounted Payback Period. Results indicate that with preferential financing, the considered projects achieved strong economic performance, while traditional commercial loans offered by commercial banks rendered small-scale decentralized renewable energy solutions financially

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unfeasible. Based on this, it has been demonstrated that strategic public-private collaboration and effective financial policy frameworks are critical for scaling renewable energy adoption and accelerating Ukraine's green and digital transition. The article presents developed strategies and a roadmap for integrating decentralized power systems into Ukraine's digital economy, which, during and after the war, will help strengthen energy resilience, reduce operational risks, and foster the country's sustainable growth. However, limitations include assumptions of stable macroeconomic conditions and a focus solely on internal energy consumption. Future research should investigate tailored financial mechanisms for different business types and explore the broader socio-economic impacts of investments in decentralized green power systems, as well as the sensitivity of projects' economic indicators for optimal decision-making.

Keywords: *decentralized system, renewable energy, financial incentive, economic efficiency indicator, decision-making, Ukraine, UN SDG #7.*

Повномасштабна війна в Україні виявила критичну вразливість централізованих енергетичних мереж, що зумовлює нагальну потребу у децентралізованих відновлюваних енергетичних рішеннях. У статті аналізується економічна ефективність державної фінансової та інвестиційної підтримки розвитку розподілених систем зеленої енергетики в Україні, зокрема через механізми пільгового фінансування, а саме програму «5-7-9». Аналіз процесу прийняття рішень охоплює малі і середні підприємства, які інвестують у гібридні вітро-сонячні фотоелектричні системи потужністю 10, 20 і 30 кВт із накопичувачами енергії. Фінансову доцільність оцінено за ключовими показниками: середньої приведеної вартості одиниці електроенергії (LCOE), чистої теперішньої вартості (NPV), внутрішньої норми дохідності (IRR), індексу прибутковості (PI) та дисконтованого терміну окупності. Результати свідчать, що за умов пільгового фінансування інвестиційні проєкти демонструють високу економічну ефективність, тоді як традиційні банківські кредити роблять малі децентралізовані рішення фінансово необгрунтованими. На цій підставі доведено, що стратегічне партнерство між державою та бізнесом і ефективна фінансова політика є ключовими для масштабування відновлюваної енергетики та прискорення зеленої та цифрової трансформації України. У статті розроблено стратегії і дорожню карту інтеграції децентралізованих енергосистем в цифрову економіку країни, які під час війни та після неї посилять енергетичну стійкість, зменшать операційні ризики та сприятимуть сталому розвитку України. Водночас дослідження має певні обмеження: припущення щодо стабільності макроекономічної ситуації та зосередження лише на внутрішньому споживанні енергії. У подальших розвідках доцільно дослідити адаптацію фінансових механізмів для різних типів бізнесу, ширші соціально-економічні наслідки інвестицій у децентралізовану зелену енергетику, а також чутливість економічних показників проєктів для оптимального прийняття рішень.

Ключові слова: *децентралізована система, відновлювана енергія, фінансові стимули, показники економічної ефективності, прийняття рішень, Україна, ЦСР ООН №7.*

Introduction. The full-scale Russian aggression in Ukraine, ongoing from February 2022, has brought unprecedented damage to the country's energy infrastructure, posing serious challenges for businesses that rely on a continuous and secure electricity supply. As of late 2024, more than half of Ukraine's electricity generation capacity has been rendered inoperable, with maneuverable hydropower and thermal plants suffering over 70% losses due to sustained missile and drone strikes (Sotnyk et al., 2024, 2025; The World Bank, 2025). These attacks have not only disrupted national energy provision but have also caused widespread blackouts, severely impairing economic activity, particularly in sectors that are highly dependent on stable energy input and digital connectivity.

The ongoing war in Ukraine has exposed the inherent fragility of domestic centralized power systems, which depend on large-scale infrastructure and interconnected grids that are highly susceptible to targeted strikes. The repeated destruction of critical nodes in the electricity network has underscored the strategic risks associated with overreliance on centralized generation. As a result, the urgency to rethink Ukraine's energy paradigm has intensified, driving interest toward decentralized, flexible, and technologically advanced solutions.

Decentralized renewable energy systems (DRES) have emerged as a pivotal component in this transition. By enabling local energy generation through solar photovoltaic, wind, and bioenergy technologies, DRES offer businesses enhanced energy security, operational continuity, and environmental sustainability. Importantly, their development aligns with Ukraine's broader shift toward digitalization and innovation, forming part of the foundational infrastructure for a resilient digital economy. Despite these benefits, the economic issues associated with deploying DRES continue to pose a major obstacle for many businesses.

Literature review. A growing body of research explores the development of DRES from various technical, economic, environmental, political, and social perspectives, while identifying key obstacles and proposing potential solutions for overcoming them (for example, Grosspietsch et al., 2019; Denysiuk & Bielokha, 2024; Hargroves & Newman, 2023; Omar & Saleh 2024). These studies emphasize that a transition to decentralized systems is not merely a technological change, but also a complex socio-economic transformation that requires systemic support.

From a technical and organizational standpoint, Yaqoot et al. (2016) highlight several challenges impeding effective DRES deployment, including limited skilled labor, inadequate technological infrastructure, and the mismatch between imported innovative technologies and local contexts. Phanindra et al. (2024) support this view, underlining persistent technical challenges such as the intermittency of renewables, the need for advanced storage solutions, and integration with existing grid systems. These technical barriers must be addressed in tandem with environmental and social considerations, including potential disruptions to ecosystems and community opposition.

Digitalization is seen as both a driver and a requirement for effective DRES implementation. Gährs et al. (2021) argue that digital tools are essential for managing decentralized systems, enhancing flexibility and enabling the integration of diverse actors. However, they caution that digitalization must be guided by ecological and social principles to avoid exacerbating inequalities. This view aligns with Omar & Saleh (2024), who examine how innovative digital technologies, including artificial intelligence and blockchain, contribute to the optimization of DRES. Their study suggests that smart technologies can enhance system efficiency, enable real-time monitoring, and facilitate peer-to-peer energy trading.

Several scholars explore institutional and regulatory challenges. Shevchuk & Cherniaiev (2024) examine Ukraine's prospects for decentralization based on microgrids and conclude that legislative reform, systemic changes, and international investment are crucial for success. Yatsenko & Mohylna (2023) highlight the socio-economic potential of autonomous energy regions in Ukraine; however, they point out challenges such as inconsistent policy frameworks, limited local initiatives, and difficulties in attracting investment. To foster local energy development, they recommend enhancing community involvement, supporting environmentally friendly startups, and promoting energy efficiency in residential buildings.

Closely related are the challenges surrounding business models and stakeholder coordination. Hargroves & Newman (2023) focus on the configuration of DRES in Australia's example, outlining viable business models and identifying leverage points to accelerate their adoption. Their study underscores that the future success of decentralized systems will be impacted by the ability to adjust service models to shifting economic and policy landscapes.

Furthermore, Kostenko et al. (2024) examine how integrating renewable distributed generation into Ukraine's energy supply can reduce reliance on centralized systems, enhance grid stability, and yield economic benefits. However, they stress that these outcomes depend heavily on effective management systems and strategic coordination among stakeholders.

Despite technical and institutional progress, economic barriers remain a significant constraint to the adoption of DRES. High upfront investment costs, limited access to affordable financing, and weak incentive structures are commonly cited challenges (Yaqoot et al., 2016; Iurchenko et al., 2024; Pryiatelchuk, 2025). For instance, Iurchenko et al. (2024) point to the lack of targeted policy support and financial mechanisms as a critical limitation in Ukraine's renewable energy landscape, calling for community engagement and a stronger institutional framework. Pryiatelchuk (2025) adds that, despite DRES aligning with broader national goals of innovation and digital transition, their deployment is unlikely to scale without targeted financial interventions.

Similarly, Shevchuk & Cherniaiev (2024) underline the need for international capital to de-risk investments and stimulate the adoption of modern renewable technologies. Yatsenko & Mohylna (2023) propose supporting local initiatives and creating an "ecological brand" to attract green investment. These findings collectively underscore the importance of financial incentives, such as grants, subsidies, green bonds, and concessional lending, as enablers of DRES development.

Overall, while the literature provides robust evidence on the technical feasibility and socio-environmental value of DRES, economic viability remains a critical bottleneck. Addressing this requires more in-depth research into innovative financial instruments, investment models, and public-private partnerships tailored to Ukraine's post-war recovery context. Therefore, this article explores the economic efficiency of state financial and investment support for the advancement of DRES in Ukraine and offers recommendations for enhancing government mechanisms to economically stimulate these systems both during and after the period of martial law.

Main research results. Many Ukrainian businesses are actively considering DRES, including solar photovoltaic panels, wind power turbines, and battery storage systems, as a solution to address energy security and reduce reliance on the national grid. To support this shift, the government introduced the "5-7-9" loan program in 2020, aimed at facilitating investment in sustainable technologies primarily across small and medium enterprises (SMEs) (Ministry, 2022). This initiative plays a crucial role in advancing national energy diversification and contributes to the long-term sustainability objectives of Ukraine.

The program offers preferential loans ranging from UAH 100,000 to UAH 50 million (approximately EUR 2'000–1055'000 as of April 2025), with interest rates of 5%, 7% and 9%. These rates vary based on the size and type of business activity, employment retention, and loan duration (Chubka & Kurylo, 2022; National Bank of Ukraine, 2025).

Managed through a network of partner banks, it ensures streamlined access to funding while maintaining public-private cooperation.

During the wartime period (2022–2024), the loan program played a pivotal role in supporting Ukrainian enterprises amid unprecedented operational challenges. Notably:

- over 2,500 businesses benefited from the program by the end of 2024, many investing in DRES;
- around 350 MW of decentralized renewable energy capacity was installed, significantly boosting energy resilience;
- the initiative contributed to local economic development and job creation in the clean energy sector (Ministry of Finance, 2025).

However, the program faces financial risks. As of March 2025, the government debt to banks for issued loans reached UAH 7 billion (approximately EUR 160 million) (Pavlenko, 2025). Without the timely resolution of these funding issues, investor and lender confidence could be undermined, jeopardizing the program's future.

To make informed decisions on DRES investments, businesses must assess project feasibility. The most popular financial metrics for these purposes are presented in Table 1.

To assess the efficiency of state financial support under the 5-7-9% program, this paper examined investment cases involving SMEs installing autonomous hybrid wind-solar photovoltaic systems with storage facilities. Hybrid technologies, due to their complementary energy profiles and relatively low cost, are a popular DRES option. Three capacity scenarios (with DRES configurations of 10, 20, and 30 kW) were analyzed based on wind-to-solar ratios of 20:80, 30:70, and 40:60. Technical and financial parameters for these systems were based on data from Kurbatova et al. (2024; 2024a), with an assumed 25-year operational lifespan (Table 2). Plants were expected to

Table 1

Key financial metrics for assessing the investment project's feasibility

Indicator	Definition	Source
Levelized Cost of Energy (LCOE)	Represents the average cost per unit of electricity generated over the system's lifespan. Competitive LCOEs enhance the attractiveness of DRES projects.	(Lazard, 2024)
Net Present Value (NPV)	Measures the difference between discounted cash inflows and outflows; a positive NPV indicates that the project is financially viable.	(Cleartax, 2024)
Profitability Index (PI)	The ratio of the present value of benefits to the present value of costs; a PI greater than 1 signifies a worthwhile investment	(Wallstreetmojo, 2019)
Discounted Payback Period (DPP)	The time needed to recoup the investment, adjusted for the time value of money.	(Project-Management.info, 2021)
Internal Rate of Return (IRR)	The discount rate at which the NPV becomes zero; IRRs exceeding 10% are typically considered favorable.	(Melnyk, 2012)

Table 2

Initial performance and cost estimates for autonomous hybrid wind-solar photovoltaic power systems integrated with energy battery storage (Kurbatova et al., 2024; 2024a)

Indicator	Wind-to-solar power ratio, %		
	20:80	30:70	40:60
Total installed capacity: 10 kW			
Annual volume of electricity generation, kWh/year	14416	16364	18312
Initial investment costs, EUR	14340	15259	16178
Operating and maintenance costs, EUR /year	287	305	324
Decommissioning costs, EUR	717	763	809
Total installed capacity: 20 kW			
Annual volume of electricity generation, kWh/year	29310	33046	39046
Initial investment costs, EUR	22466	23868	27291
Operating and maintenance costs, EUR /year	449	477	546
Decommissioning costs, EUR	1123	1193	1365
Total installed capacity: 30 kW			
Annual volume of electricity generation, kWh/year	44362	49967	55585
Initial investment costs, EUR	30038	32514	35416
Operating and maintenance costs, EUR /year	601	650	708
Decommissioning costs, EUR	1502	1626	1771

begin operation in July 2025 and continue through June 2050, with an annual efficiency decline of 0.08% due to equipment aging.

To determine the appropriate discount rates for DRES investment projects, calculations were based on the financing terms of the “5-7-9%” loan program offered by Oschadbank (2025a). The program requires a minimum equity contribution of 15%, while the remaining 85% of the investment can be financed through concessional loans. The average annual deposit rate in UAH at Oschadbank (11% as of December 2024) was assumed as the cost of equity capital for performing the calculations. The cost of debt corresponded to the preferential loan rates of 5%, 7%, or 9%, depending on specific loan conditions.

To calculate the overall cost of capital, the Weighted Average Cost of Capital (WACC) method was applied. WACC reflects the average rate a company pays for financing a project through a mix of equity and debt, weighted by each component’s proportion (Frankel, 2024; Kurbatova et al., 2024). Under the 15% equity / 85% debt structure, the effective discount rates were as follows:

- at 5% loan rate: WACC = 11% × 0.15 + 5% × × 0.85 = 5.9%;
- at 7% loan rate: WACC = 11% × 0.15 + 7% × × 0.85 = 7.6%;
- at 9% loan rate: WACC = 11% × 0.15 + 9% × × 0.85 = 9.3%.

These discount rates were used to calculate LCOE for autonomous hybrid wind-solar photovoltaic systems, as summarized in Table 3. Subsequently, we assessed the economic viability of installing such systems by computing other key financial metrics, including NPV, PI, IRR and DPP (Table 3). The analysis assumed all electricity produced by the DRES would be consumed internally, i.e., the system capacity was optimized to match the business’s energy demand. The storage capacity of the DRES was designed to ensure at least eight hours of uninterrupted power in case of insufficient generation.

For the financial model, the cost savings from DRES were based on the prevailing market electricity price, which averaged 0.14 EUR/kWh for SMEs in December 2024 (Minfin, 2025). This benchmark price represents the avoided cost for businesses and thus the economic value of self-generated energy.

In all system configurations, the calculated LCOE was consistently lower than the average market electricity price, demonstrating positive economic effect of the projects. In the most favorable case (a 30-kW system, a 40% wind share, and a 5.9% discount rate), the LCOE was 2.3 times lower than the prevailing market rate. Even under the least advantageous conditions, the LCOE remained competitive, being 14% lower than the market price.

The NPV increased with greater installed capacity and a higher proportion of wind energy. All projects achieved a positive NPV, confirming their financial profitability, although higher discount rates negatively impacted NPV by increasing the cost of capital.

The PI exceeded 1 across all projects, affirming their financial soundness. The most attractive

Table 3

Key financial metrics for investment projects of autonomous hybrid wind-solar power systems integrated with energy battery storage

Discount rate (WACC), %	LCOE, EUR/kWh			NPV, EUR			PI			IRR, %			DPP, years		
	Wind-to-solar power ratio, %														
	20:80	30:70	40:60	20:80	30:70	40:60	20:80	30:70	40:60	20:80	30:70	40:60	20:80	30:70	40:60
Total installed capacity: 10 kW															
5.9	0.10	0.09	0.09	7494	9808	12123	1.52	1.64	1.74	11.4	12.6	13.6	12.60	11.37	10.47
7.6	0.11	0.10	0.10	4554	6430	8306	1.32	1.42	1.51				14.32	12.68	11.53
9.3	0.12	0.11	0.11	2223	3752	5282	1.15	1.24	1.32				17.08	14.61	13.00
Total installed capacity: 20 kW															
5.9	0.07	0.07	0.07	23783	28682	35054	2.05	2.19	2.27	16.6	17.9	18.7	8.56	7.91	7.58
7.6	0.08	0.08	0.08	17537	21581	26627	1.77	1.90	1.97				9.19	8.43	8.04
9.3	0.09	0.09	0.08	12589	15956	19951	1.56	1.66	1.73				9.99	9.07	8.62
Total installed capacity: 30 kW															
5.9	0.07	0.06	0.06	41064	47937	54290	2.35	2.46	2.51	19.5	20.5	21.1	7.28	6.92	6.75
7.6	0.07	0.07	0.07	31450	37056	42155	2.04	2.13	2.18				7.70	7.29	7.09
9.3	0.08	0.08	0.08	23836	28439	32545	1.79	1.87	1.91				8.21	7.74	7.51

project (a 30-kW system, a 40% wind share, and a 5.9% discount rate) achieved a PI of 2.51, while the lowest PI of 1.15 was observed for a 10-kW system with a 20:80 wind-solar configuration at a 9.3% discount rate. Profitability improved in systems featuring larger capacities and a higher proportion of wind energy.

Payback periods varied between nearly 7 and 17 years within the expected 25-year operational lifespan. The shortest payback (6 years and 9 months) was recorded for a 30-kW system with a 40:60 wind-solar ratio and a 5.9% WACC. The longest, exceeding 17 years, was associated with a 10-kW system at a 20:80 wind-solar ratio and a 9.3% WACC. On average, 10 kW systems reached breakeven within 10.5–17.1 years, 20 kW systems within 7.6–10 years, and 30 kW systems within 6.8–8.2 years.

IRRs ranged from 11.4% to 21.2%, comfortably surpassing the highest WACC of 9.3%, thereby ensuring strong profitability across all cases. Systems with larger capacities and a higher share of wind energy delivered the highest returns, providing a significant buffer against economic uncertainties.

To sum up, while wind and solar generation are variable and seasonally dependent, their combined use, complemented by battery storage, can reliably cover a portion of a business's electricity demand. However, fully replacing grid consumption with self-generated power remains challenging due to intermittency. Storage systems provide flexibility but also add to overall costs. Nevertheless, these estimates exclude the losses businesses incur during blackouts, such as halted production, equipment damage, or labor downtime. Avoiding such disruptions represents additional value.

Ultimately, investing in DRES through Ukraine's concessional "5-7-9" loan program enables companies to reduce energy costs, improve energy resilience, and protect against power outages, while potentially generating long-term profits. However, an analysis of loan offerings by Ukrainian banks reveals that interest rates for financing DRES installations outside the government's support programs are prohibitively high. For instance, Oschadbank's "Green Energy" program offers a 19.5% annual interest rate, limited loan amounts, and shorter repayment terms (Oschadbank, 2025). While two DRES projects (with a 30-kW capacity and wind-solar ratios of 30:70 and 40:60) demonstrate IRRs exceeding 19.5%, smaller-scale projects, such as those with 10 and 20 kW capacities, become unfeasible under such terms. With a 20:80 wind-solar ratio, a 30-kW capacity system may pay back; however, this period is much longer than the loan term.

Conditions worsened under Ukrgasbank's "Eco-Energy" program, which offered loans at 23.5% interest for up to five years (Ukrgasbank, 2025), making all considered DRES projects financially unsustainable. Raiffeisen Bank provides unsecured loans for solar photovoltaic installations with interest rates ranging from 17% to 19%, but they do not cover hybrid systems (Raiffeisenbank, 2024). In this context, the state-backed "5-7-9" program remains the most attractive option for Ukrainian businesses aiming to implement DRES. This highlights the importance of maintaining and expanding government support to help enterprises achieve energy independence, ensure production continuity, and enhance tax revenues. The "5-7-9" initiative demonstrates the vital role of public policy in accelerating the adoption of renewable energy and enhancing national resilience.

The study results confirm that sustained success in the DRES sector hinges on strong collaboration between the government and the private sector. Public institutions must offer consistent policies, supportive measures, and regulatory frameworks, while companies contribute new technologies, investment, and practical expertise. Table 4 outlines three key strategies designed to foster effective interaction between these sectors.

Based on the strategies mentioned, the following strategic roadmap addressing technical, financial, and regulatory challenges can be suggested for DRES implementation (Fig. 1).

Table 4

Key strategies for effective collaboration of businesses and public authorities in the DRES sphere

Direction of collaboration	Measures
Incentivizing investment	- extend and improve programs like "5-7-9" by ensuring access to low-interest loans; - provide tax breaks and grants to make DRES projects more attractive; - stabilize energy policy frameworks to support long-term business planning.
Promoting public-private partnerships	- share investment risks between state and private actors; - enable government co-financing for infrastructure development, with private sector operation and maintenance.
Energy market reforms	- simplify regulations to better accommodate DRES integration; - introduce updated and faire feed-in tariffs, net metering and net billing systems, and energy trading platforms; - reform energy pricing to reflect true costs by removing subsidies and aligning tariffs with market rates

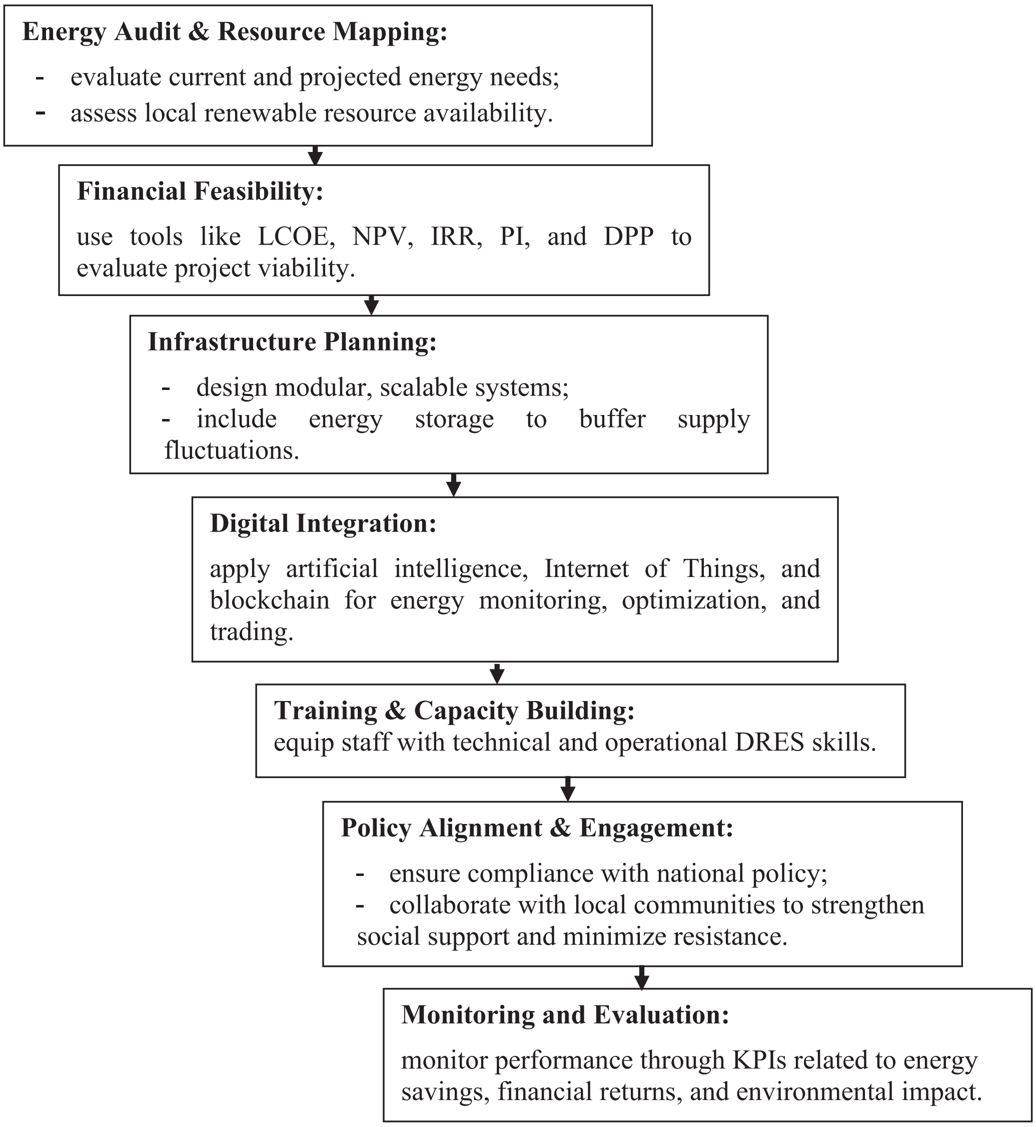

Fig. 1. The strategic roadmap for DRES implementation

Overall, the deployment of DRES in Ukraine offers a promising route toward achieving energy efficiency and autonomy, strengthening positive economic impacts, and promoting sustainable development. State initiatives, such as the "5-7-9" program, play a critical role in helping businesses contribute to DRES advancement even under unfavorable interest rates of commercial banks. To drive wider adoption and maximize benefits, it is essential to combine encouraging policy instruments and strategic business planning and ensure advancements in technologies. Strengthening partnerships between government entities and businesses, along with implementing a carefully structured roadmap, will help fully implement the business potential of DRES. This approach will enable Ukraine not only to recover from the effects of the war but also to position itself as a leader in green power integration and management.

Conclusions. The advancement of DRES in Ukraine addresses not only the immediate need for energy decentralization and resilience but also strengthens the country's long-term innovation agenda. By integrating DRES into a digitalized and flexible energy ecosystem, Ukrainian businesses can establish future-ready operations that are adaptable, sustainable, and more resilient to geopolitical and environmental disruptions.

The findings of this study confirm that investing in autonomous hybrid wind-solar photovoltaic systems, supported by concessional financing programs such as the "5-7-9" initiative, is a viable strategy for enhancing energy security, reducing operational risks, and promoting economic recovery. Government support mechanisms play a crucial role in ensuring that DRES remain accessible and profitable, especially for SMEs.

However, this study has several limitations. The adopted financial indicators assumed stable macroeconomic conditions and did not fully account for potential risks such as currency fluctuations, regulatory changes, prolonged periods of low renewable energy generation, or future shifts in electricity pricing. Additionally, the analysis focused on internal energy consumption, without considering opportunities for grid feed-in or participation in energy markets. Therefore, future research should explore differentiated financial support mechanisms tailored to various business scales, sectors, and regional contexts. Moreover, comprehensive evaluations of the long-term socio-economic impacts of decentralized energy investments, including job creation, regional development, and environmental benefits, are necessary. Such insights will be critical for shaping more effective public policies and private sector strategies to accelerate Ukraine's green energy transition.

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