



## Some Aspects of Investment Risks in Alternative Thermal Energy in Ukraine

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### ABSTRACT

The article examines investment threats in Ukraine’s alternative thermal energy sector over the period 2019 to 2025. The authors analyze financial, security, and infrastructure factors that determine project profitability during wartime. The destruction of centralized heat generation has created a capacity deficit. Investors require systematized knowledge about the nature of sectoral risks. Traditional assessment methods do not account for wartime realities. Biofuel prices fluctuate unpredictably. Tariff policy changes chaotically. Banks restrict long-term lending due to the lack of reliable threat measurement instruments. Municipalities delay payments by three to four months. Frontline territories accumulate maximum threats amid growing social demand for autonomous heat. The purpose of the study is to establish causal relationships between risk categories and investment economic efficiency. The research builds a taxonomy of threats. The authors determine the impact of each category on profitability. The paper formulates recommendations on protective mechanisms for the period up to 2030. The study classifies eight types of risks and establishes weighting coefficients. Feedstock, tariff, and security factors increase payback periods by 37 to 41 percent. Long-term contracts reduce price volatility by half. The optimal facility capacity is 3 to 7 MW to balance adaptability and unit costs. Integration of heat generation with network modernization delivers an 18 to 23 percent efficiency gain. Small facilities launch within 5 to 12 months versus 18 to 24 months for large systems. Modular commissioning adapts projects to demographic changes and demand fluctuations. Future research should develop stochastic risk assessment models with the application of machine learning. Mechanisms of public-private partnership in financing facilities in frontline territories require a separate study. International experience in insuring energy assets in conflict zones requires adaptation to Ukrainian specifics. Dynamic forecasting models must account for geopolitical development scenarios.

### KEYWORDS

alternative thermal energy, investment risk, bioenergy, community heat supply, energy security, biomass, municipal energy projects.

## Introduction

Ukraine's energy system has suffered critical destruction due to military aggression. Traditional thermal generation has lost more than 60% of its capacity. Heat shortage forces them to look for alternative solutions. Investors are considering biomass, solar collectors, geothermal installations. The state declares support for renewable energy. However, there is no clear understanding of the risks. The problem is the lack of a systematic analysis of threats to investments. Existing studies focus on technical aspects. Financial, regulatory, and military risks remain underestimated. Investors make decisions without a sufficient information base. The instability of tariffs calls into question the payback of projects. Martial law poses a threat of physical destruction of equipment. Regulatory changes occur chaotically. Insurance covers only part of the possible losses. The relevance of the study is determined by the critical need of the energy market for new capacities under conditions of high uncertainty.

## Literature Review

The report of the Bioenergy Association of Ukraine and COWI A/S (Bioenerhetychna asotsiatsiia Ukrainy & COWI A/S, 2021) presents the results of the strategic analysis of the development of bioenergy until 2050. The resource capacity of the sector and the priorities of the thermal segment are shown. But the issues of investment sustainability in the face of territorial risks remain unresolved. The report of the International Renewable Energy Agency (2025) presents global statistics on the development of renewable energy sources. Investment trends are shown. But national risks of thermal projects were left out attention.

In the scientific work of Kudria (2025), the technological directions of renewable energy are systematized. The technical capabilities of alternative heat generation are shown. However, the investment risks of thermal projects are considered in fragments. In the work of Diachenko et al. (2025) the prospects for the development of RES in Ukraine are analyzed. The influence of macroeconomic factors is shown. But the risks of heat supply to communities remained out of focus. Research by Zabarylo et al. (2025) is dedicated to the diversification of energy resources. The connection of alternative energy with energy security is shown. At the same time, investment restrictions in the heat sector need to be detailed. In the work of Kinchiev and Boiarynova (2025), the potential of alternative energy is assessed. Regional differences are shown. But the risk component of thermal projects has not been properly analyzed. In the work of Kostenko et al. (2024) The integration of distributed generation is considered. Technical and economic barriers are shown. The problems of investment implementation of thermal facilities remained open. The atlas of Kudria (2024) reflects the spatial potential of RES. The resource base is shown. But the investment risks of thermal generation are not systematized.

In a study by Rozmaryna et al. (2025) the investment potential of RES is analyzed. The role of public administration is shown. At the same time, the specifics of alternative thermal energy require a separate analysis. All this gives grounds to assert that it is expedient to conduct a study to determine investment risks for alternative thermal energy in Ukraine.

## Problem Statement

The purpose of the article is to identify the structure of investment threats in the alternative thermal energy sector of Ukraine and to determine measures to neutralize them.

### Research objectives:

- to identify the categories of risks that affect the profitability of alternative heat generation in Ukraine;
- to investigate changes in the investment attractiveness of the sector before and after the start of a full-scale war;
- to formulate recommendations for minimizing financial losses in the implementation of energy investment projects.

## Methods and Materials

The study employs a systematic analysis, comparative method, and synthesis of available data. It draws on reports from industry associations, international organizations, official Ukrainian energy sector statistics, scientific publications, and analytical materials from recent years. The dynamics of alternative heat production, shifts in investment attractiveness, and key risk categories were assessed by comparing the pre- and post-full-scale invasion periods. Forecast scenarios and risk mitigation recommendations were developed considering current industry trends, wartime conditions, and opportunities for integration with recovery programs.

## Results and Discussion

Alternative thermal energy in Ukraine emerged as a tool for replacing natural gas in centralized and local heat supply systems. Until 2022, the sector grew gradually. It relied on biomass, biogas and cogeneration plants of small and medium capacity. Full-scale hostilities changed the mode of operation of the industry. The investor began to take into account space, security and demography along with the economy. In 2019-2021, alternative thermal generation added an average of 6-7% per year. The increase was provided by boiler houses on solid biomass (Petrukha et al., 2022, pp. 32-33). They worked in the municipal sector and at social infrastructure facilities. Biogas plants performed auxiliary functions and gravitated to agro-industrial nodes. Solar thermal power and heat pumps did not scale due to high capital costs and a long payback period.

After 2022, the sector moved to asymmetry. Some heat-generating facilities have lost access to raw materials or consumers. The rest received an additional load due to the shutdown of gas boiler houses and the growth of autonomous heat. Under these conditions, investment risk has gone beyond finance. It has acquired a spatial and infrastructural character. In 2022, the production of thermal energy from alternative sources decreased by about 18% compared to 2021. Biogas facilities suffered the greatest losses. They lost logistics and some of the raw materials. Solid biomass boiler houses in the western and central regions kept production almost at the pre-war level. In 2023-2024, the sector partially recovered. Communities without stable gas supply or with a sharp increase in tariffs have activated biosolutions for schools, hospitals, and administrative buildings. At the end of 2024, the production of alternative heat exceeded the level of 2022 by almost 25%. The indicators of 2021 have remained unattainable so far, which is recorded in Table 1.

*Table 1. Dynamics of the formation of alternative thermal energy in Ukraine and related investment indicators in 2019-2025*

Year	Heat production from biomass, TWh	Production of heat from biogas and waste, TWh	Share of alternative heat in the balance, %	Number of operating facilities, units	Share of frontline regions in capacities, %	Volume of investments, UAH billion	Average capacity capacity, %	Average payback period, years
2019	7.8	2.1	6.4	820	22	6.3	72	6.5
2020	8.3	2.3	6.9	860	23	6.9	74	6.3
2021	8.9	2.6	7.5	910	24	7.8	76	6.1
2022	7.1	1.8	6.2	790	31	5.2	58	8.4
2023	7.6	1.9	6.6	810	34	5.9	61	7.9
2024	8.0	2.0	7.0	845	36	6.4	64	7.5
2025	8.4	2.1	7.3	880	35	6.8	66	7.2

Source: Built based on (Bioenerhetychna asotsiatsiia Ukrainy & COWI A/S, 2021; Kudria, 2025).

In 2025, the sector entered the phase of structural reformatting. The total volumes of thermal generation have kept the same level. The internal structure has changed. The share of biomass exceeded 75%. Biogas and energy waste have lost part of the market due to the complexity of operation with fluctuating demand. Heat pumps appeared in some community projects with international funding. Their effect on the heat balance remained negligible. The spatial section fixes a sharp unevenness of development. The western and part of the central regions have concentrated up to 65% of the operating capacities of alternative heat generation.

The frontline territories accumulated maximum investment risk. The destruction of heating networks, population reduction and unstable heat loads have reduced the efficiency of already commissioned facilities. These same territories form a steady demand for autonomous heat sources. Risk is combined with a high social effect, which changes the logic of investment decisions (Lahodiienko et al., 2025, p. 199).

Until 2022, investment flows were directed mainly to medium-capacity projects with a focus on industrial and municipal consumers. After 2022, the structure changed dramatically. Investors have switched to small facilities with a short implementation cycle and low requirements for networks. The results were not the same. In communities with a well-defined heat circuit and stable budget funding, alternative boiler houses reduced heat costs by 20-35% (Diachenko et al., 2025).

Commodity risk formed the baseline level of uncertainty for the sector. Biomass and derived waste have retained the status of the dominant resource of heat generation. In 2019-2021, the domestic biomass market demonstrated stability. The cost of thermal energy from biomass ranged from 1100 to 1300 UAH per Gcal. The investor received the projected cash flow. After 2022, the situation has changed. The seasonality of supply has increased the unevenness of the facilities. In the winter periods of 2022-2024, interruptions in the supply of chips and pellets lasting from seven to twenty days were recorded. The power was reduced by 15-30%. The investor lost part of the revenue during peak periods of demand. In regions with a limited timber base, the resource had to be transported at a distance of more than 150-200 km. This extended the period of return on investment by 1.5-2 years (Medvedieva et al., 2025, p. 148).

The price factor has increased the pressure in 2023-2025. The average price of biofuels has almost doubled compared to 2021. Tariff adjustment for budgetary institutions was delayed. The gap between costs and income has increased. The financial risk manifested itself through the loss of balance between cost and regulated revenues. Until 2022, investment models relied on long-term tariffs for the utility sector. After the start of the war, the tariff-setting mechanism lost stability. In 2022-2023, the indexation of tariffs lagged behind the growth of costs by an average of 20-25% (UkraineInvest, n.d.).

Payment discipline has deteriorated. The average period of accounts receivable increased from 45-60 days in 2021 to 110-140 days in 2023-2024. The investor faced a shortage of working capital. It attracted short-term financing at higher rates. The share of projects with a cash gap of more than three months reached 40%. The limited solvency of the population and budget consumers increased the pressure on financial results. Some of the technically serviceable and fuel-supplied facilities operated below the break-even level. Infrastructure and security risk have defined the new reality of the sector (UkraineInvest, n.d.). In 2022-2024, more than 20% of alternative heat-generating facilities in the eastern and southern regions were damaged. In a third of cases, downtime lasted more than three months. The annual financial result of such projects was actually lost.

Additional costs for the protection of objects significantly changed investment estimates. The cost of physical reinforcement, backup power supply and remote-control systems increased to 8-12% of total capital expenditures. For small projects, this meant a loss of economic feasibility. The investment budget increased without proportional revenue growth. In communities with deterioration of networks of more than 60%, heat loss reached 18-22%, which shifted part of the risk from the grid operator to the heat producer (Table 2) (Kudria, 2025).

The investor reduces risk through scale. Small and medium-sized thermal objects enter the system quickly. The launch lasts from five to twelve months. This period reduces the impact of inflation and rule changes. The forecast until 2030 shows an increase in the share of commissions to 70% in the segment up to 10 MW of heat. The market reacts to capital shortages. Banks limit long loans and short cycles reduce liquidity requirements (Kudria, 2025).

Economies of scale work differently. Specific investments for facilities up to 5 MW are reduced to 450-550 euros per kW of heat. By 2030, equipment localization reduces costs by another 10-15%. The investor fixes the repayment period within five six years. Large projects remain sensitive to currency fluctuations. A small scale reduces this impact. The risk of downtime is reduced due to modularity. The investor injects power in parts. It checks demand and adjusts volume. The

demographic forecast until 2030 shows a decrease in the population in individual communities by 8-12%. Small objects adapt to this trend, and large systems lose load (Makedon et al., 2025).

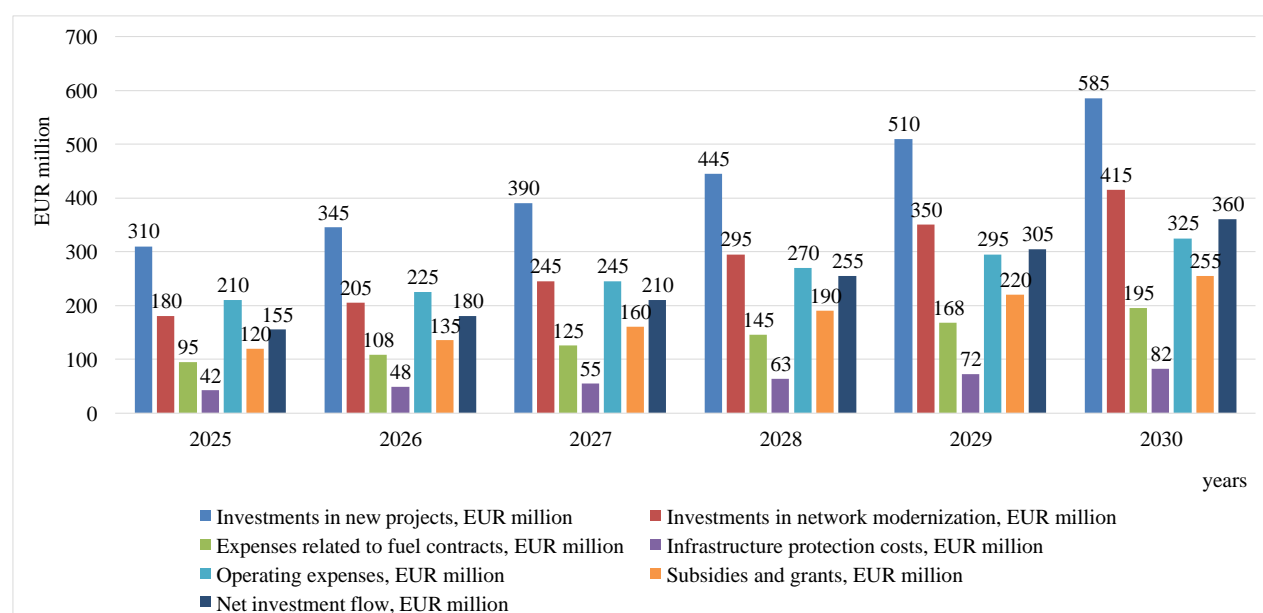
**Table 2. Investment risks of alternative thermal energy in Ukraine and their impact on key indicators**

No	Type of risk	Main source of risk	Quantitative manifestation in 2019–2021	Quantitative manifestation in 2022–2025	Impact on the cost of heat	Impact on payback period	Spatial effect	Cumulative impact on investment attractiveness
1	Raw material	Biomass deficiency	Logistics 15–20 %	Logistics 35–45%	+20–30 %	+1.5–2 years	Regional	High
2	Pricing	Rising fuel prices	+8–10% per year	+25–40 % for the period	+15–25 %	+1–1.5 years	Nationwide	High
3	Seasonal	Supply interruptions	Local	System	Unevenness	+0.5 years	Local	Medium
4	Tariff	Freezing tariffs	Isolated cases	Mass phenomenon	-10-20% of revenue	+1–2 years	Nationwide	High
5	Payment	Indebtedness	45–60 days	110–140 days	Rising costs	+0.8 years	Municipal	Medium
6	Demand	Reduction of consumption	-5–7 %	-25–30 %	Underloading	+1.5 years	Deindustrialized regions	High
7	Infrastructure	Worn networks	Up to 15% loss	Up to 22% losses	+10 %	+0.7 years	Urban	Medium
8	Security	Physical damage	Single	More than 20% of objects	Full stop	Undefined	Frontline regions	Critical

Source: Based on (Kudria, 2025; Ministry of Economy, Environment and Agriculture of Ukraine, 2024).

Moving to another plane explains the effect. A quick launch shortens the period without income. Capital works earlier. The financial model is becoming more sustainable. The investor reduces risk through integration. Alternative thermal generation works more stably as part of recovery programs. The forecast until 2030 provides for more than UAH 200 billion of investments in networks and boiler houses of communities. Where generation is synchronized with the grid, heat loss is reduced to 9-11%. Without integration, losses are kept at the level of 18-22% (Makedon et al., 2024).

Income stability is increasing. The upgraded network receives heat without peaks. The load factor increases by 12-15%. The forecast shows that by 2030, more than 60% of small and medium-sized communities will implement comprehensive heat supply programs. In these communities, alternative objects receive basic demand from budgetary institutions. The financial structure of programs is changing. The share of grants and quasi-grants will reach 35-40%. The investor reduces his own contribution. It reduces profitability requirements. The project is moving into the format of infrastructure partnership (Kondratenko et al., 2025, pp. 360-361) (Figure 1).



**Figure 1. Table 3. Projected investment flows of alternative thermal energy projects in Ukraine in 2025–2030 (EUR million)**

Source: Based on (UkraineInvest, n.d.; Diachenko et al., 2025; Zabarylo et al., 2025).

Contracts reduce volatility. The forecast until 2030 records fluctuations in biofuel prices at the level of 15-25% per year without contracts. Long-term agreements with a period of five to ten years reduce the amplitude by half. The investor fixes the cost corridor. He plans cash flows. Heat contracts complement the model. By 2030, the share of contracts with guaranteed minimum heat extraction increases to 50% in the municipal sector (Table 3).

**Table 3. The author's proposals for reducing investment risk by 2030**

No	Offer	Target segment	Projective effect until 2030	Implementation period	Income stability	Capital Requirement	Spatial effect	Risk reduction level
1	Small facilities up to 5 MW	Small communities	-30% of time risks	Up to 6 months.	Medium	-20%	Local	High
2	Medium facilities 5-10 MW	Urban communities	-25% financial risks	Up to 12 months.	High	-15%	Urban	High
3	Modular Input	All segments	Demand flexibility	Step-by-step	High	-10%	Universal	Medium
4	Integration with recovery programs	Municipalities	-15% network loss	No changes	High	-25%	Regional	High
5	Guaranteed basic demand	Social facilities	+12-15 p.p. loading	No changes	Very high	No changes	Local	High
6	Fuel contracts 5-10 years	Biomass facilities	-50% of price fluctuations	No changes	High	No changes	Nationwide	High
7	Heat contracts with a minimum	Utility Systems	-40% demand risk	No changes	Very high	No changes	Municipal	High
8	Combined Contract Coverage	RES investment projects	-60% of income fluctuations	No changes	Maximum	-10%	Universal	Critical

Source: Formed by the authors based on (UkraineInvest, n.d.; Diachenko et al., 2025).

Therefore, the combination of contracts forms a closed loop. Fuel stabilizes costs. Forecast models show a decrease in the variance of annual revenues by 2.5-3 times by 2030. Financial institutions are reacting to this. The cost of capital decreases and the entire project receives a different risk profile.

## Conclusion

The study identified critical categories of threats to capital in alternative heat generation. Raw material risk manifests itself through a doubling of biofuel prices and logistics disruptions lasting up to twenty days. Tariff risk fixes the gap between costs and regulated revenues at the level of 20-25%. The security factor destroyed more than a fifth of the facilities in the eastern regions. Payment discipline has degraded from 45 to 140 days of receivables. Infrastructure deterioration generates losses heat up to 22%. Demand risk has reduced consumption by a quarter due to demographic changes. Seasonality of supply has become a systemic problem instead of a local one. The price factor added 25-40% to the base cost of fuel.

Martial law has transformed the industry from the technical sector to a zone of critical uncertainty. Investment flows decreased by a third. The geography of projects has shifted to the west, where 65% of capacities are concentrated. The frontline territories accumulated maximum threats with a growing social demand for autonomous heat. The average payback period increased from 6.1 to 8.4 years. The share of objects with a cash gap of more than three months reached 40%. The cost of physical protection of the structures added 8-12% to the estimates without a proportional increase in revenues. The solvency of consumers fell, which turned technically sound installations into unprofitable assets.

Contract architecture has been shown to reduce revenue volatility by 2.5-3 times by 2030. Fuel deals for a period of 5-10 years reduce price fluctuations by half compared to spot purchases. Heat contracts with a guaranteed minimum withdrawal stabilize capacity utilization and form predictable cash flows. Small facilities up to 5 MW show a start-up period of 5-12 months versus 18-24 for large systems, which reduces the inflationary impact. Modular input adapts the project to demographic

changes and fluctuations in demand. The combination of instruments forms a closed protection loop, where the cost of capital decreases due to a decrease in the variance of financial results.

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