

## TRANSFORMATION OF BUSINESS ANALYTICS OF ENERGY EFFICIENCY OF ENTERPRISES UNDER ENERGY RISKS

Modern conditions of enterprise functioning in Ukraine are characterized by a high level of energy instability, manifested in power outages, seasonal shortages of energy resources, and risks of disruption of business continuity. Events of recent winter periods associated with damage to energy infrastructure have demonstrated that traditional approaches to evaluating energy efficiency projects do not reflect real business conditions.

Contemporary research in energy efficiency demonstrates the dominance of traditional investment evaluation approaches based on indicators such as NPV, IRR, and ROI [1]. Even in recent studies applying modern financial approaches to investment assessment, these criteria remain the primary analytical tools [2]. At the same time, modern approaches to energy system evaluation are increasingly developing toward complex optimization models and multi-criteria analysis [3], which complicates their application in practical decision-making. Furthermore, the literature highlights the lack of generalized approaches to integrating economic and operational aspects of energy consumption at the enterprise level [4]. Thus, despite the significant number of studies in the field of energy efficiency, the problem of developing a simple analytical criterion that simultaneously accounts for energy savings and losses from power outages in investment decision-making remains unresolved.

In classical approaches, energy efficiency is considered as a tool for cost reduction, and investment efficiency is assessed using indicators such as net present value (NPV), defined as:

$$NPV = \sum_{t=1}^T \frac{S_t - C_t}{(1+r)^t},$$

where  $S_t$  represents energy savings,  $C_t$  costs, and  $r$  the discount rate.

However, this model does not account for the risks of power supply interruptions, which may lead to significant economic losses. According to the World Bank, power outages are one of the key factors causing economic losses for enterprises, and their impact may constitute a significant share of operating costs. Additionally, studies by IEEE show that economic losses from outages can reach thousands or tens of thousands of dollars per hour depending on the type of activity.

In particular, for manufacturing enterprises, equipment downtime may result in losses exceeding the annual effect of energy efficiency measures, while for office and service companies even short-term outages lead to productivity and revenue losses.

In this regard, the paper proposes an extension of the classical model by integrating the energy risk factor. The modified efficiency indicator is defined as:

$$NPV^* = \sum_{t=1}^T \frac{S_t - C_t - \lambda_t \cdot L_t}{(1+r)^t},$$

where  $L_t$  represents losses due to power outages and  $\lambda_t$  the intensity of energy risks.

For enterprises, losses can be detailed as:

$$L_t = C_d + C_l + C_r,$$

where  $C_d$  are downtime losses,  $C_l$  product losses, and  $C_r$  reputational losses.

Thus, project efficiency is determined not only by resource savings but also by the ability to minimize the risks of business continuity disruption. Rewriting the model, we obtain:

$$NPV^* = NPV - \sum_{t=1}^T \frac{\lambda_t \cdot L_t}{(1+r)^t},$$

which allows interpreting efficiency as the difference between the classical economic effect and expected losses from energy risks.

The proposed approach changes the logic of decision-making: projects that deliver high energy savings but remain highly vulnerable to power outages may be inferior to solutions that ensure energy autonomy (generators, battery systems, solar panels). Practical estimates show that downtime losses can exceed the annual benefits of energy efficiency measures several times, which justifies investments aimed at enhancing resilience.

In simplified approaches, the efficiency of energy efficiency measures is often evaluated as the ratio of savings to investment costs:

$$EE = S/C,$$

which corresponds to the basic understanding of return on investment (ROI). However, this measure does not account for energy supply risks.

Therefore, a new criterion is introduced:

$$EE^* = (S - \lambda L) / C.$$

The proposed approach makes it possible to integrate the factor of energy instability into energy efficiency assessment, which is especially relevant for economies with high infrastructure risks. Unlike classical models, the new criterion reflects real economic conditions and provides a more justified basis for investment decision-making.

To illustrate the proposed approach, consider an enterprise in the logistics or retail sector (warehouse, supermarket, distribution center), characterized by high energy consumption and partial dependence on uninterrupted power supply. The main energy consumers include lighting systems, refrigeration equipment, IT infrastructure, and checkout systems. Power outages do not completely stop operations but lead to significant economic losses.

Annual electricity consumption is assumed at 2,000,000 kWh (e.g., supermarkets such as Сільпо). Under Ukrainian conditions in 2024–2025, the average business electricity tariff ranges between 4.6–7 UAH/kWh; therefore, a value of 5 UAH/kWh is used. Thus, annual energy costs amount to:  $2,000,000 \cdot 5 = 10,000,000$  UAH.

Losses from power outages arise from product spoilage, downtime of IT systems, and customer losses. For such enterprises, realistic losses amount to 150,000–250,000 UAH per hour, corresponding to approximately 2,000,000 UAH annually under regular outages.

Two alternative investment strategies are considered. Project A involves energy efficiency measures providing 15% savings:  $S_A = 1,500,000$  UAH. Project B involves backup energy systems, providing 5% savings:  $S_B = 10,000,000 \cdot 0.05 = 500,000$  UAH, while reducing outage losses by 90%, to:  $L_B = 200,000$  UAH/year. Investment costs for both options are assumed at 2,000,000 UAH, which corresponds to typical expenditures for upgrading the energy infrastructure of a medium-sized enterprise.

Efficiency is evaluated using the risk-adjusted indicator:

$$EE_A^* = (1,500,000 - \lambda \cdot 2,000,000) / 2,000,000;$$

$$EE_B^* = (500,000 - \lambda \cdot 200,000) / 2,000,000.$$

Analytical comparison shows that the critical risk level is  $\lambda^* \approx 0.44$ .

Thus, under relatively stable energy supply ( $\lambda < 0.44$ ) classical energy efficiency measures remain preferable. However, as the frequency or duration of outages increases ( $\lambda > 0.44$ ), investments in energy resilience become economically justified.

Therefore, logistics and retail enterprises in Ukraine represent an intermediate type of systems in terms of sensitivity to energy risks. This confirms the need to move from classical energy efficiency evaluation approaches to risk-oriented decision-making models.

The results show that accounting for energy risks significantly changes efficiency evaluation, reducing the advantage of traditional energy-saving measures and increasing the relative attractiveness of resilience-oriented solutions. The proposed model allows determining a critical risk level  $\lambda^*$ , at which the optimal investment strategy shifts. Sectoral analysis indicates that this threshold varies across industries: it is lowest for manufacturing systems, highest for office activities, and intermediate for logistics and retail.

The findings indicate a transformation of the concept of energy efficiency under energy risks: efficiency is determined not only by cost savings but also by the ability to avoid losses. This forms a new logic of business analytics in energy management.

## References

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