This study's object is the energy resilience of industrial enterprises in Ukraine under martial law. The task considered relates to the insufficient understanding of the consequences of power outages because of the limited availability of reliable empirical data and the lack of tools for comprehensive assessment of business energy resilience. This study is based on the results of monthly surveys of managers from 400–600 enterprises in eight industries, conducted between 2022 and 2024.

A statistically significant relationship between energy problems and a number of business performance indicators has been confirmed. In particular, in 74.4% of cases (35 out of 47), a positive correlation was found, indicating the effective adaptation of most businesses. Negative correlations were found in only 25.5% of cases (12 variables), mainly in mechanical engineering, light industry, and the production of building materials, where power outages had a significant impact on business operations.

Regression models have shown that in most cases (81%), the issue of power supply interruptions is not a critical predictor of decisions to expand business activities. Industrial enterprises are planning to expand their activities despite energy supply problems.

These results are attributed to the implementation of operational anti-crisis measures, corporate strategies, and government support for improving energy security and business continuity during periods of energy instability.

The findings could be used by public authorities to assess sectoral vulnerabilities to energy threats, devise support programs, and design tools for energy crisis planning at regional or industry levels

Keywords: crisis management, environmental uncertainty, business energy resilience, energy resilience assessment

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ASSESSING THE STATE OF BUSINESS ENERGY RESILIENCE IN THE CONTEXT OF CRISIS MANAGEMENT TASKS IN WARTIME

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1. Introduction

In the 21st century, crises are becoming a constant threat to organizations. The increase in their frequency and the enhanced diversity of crisis factors (from natural disasters to technological failures, pandemics, wars) require organizations to adopt new approaches to crisis management [1]. Organizations must act not only reactively (overcoming the crisis) but also anticipate potential threats and minimize their consequences before they occur [2, 3], and quickly adapt to new challenges [4]. The emphasis should shift to the proactive subsystem – risk forecasting and preventive measures to enable the resilience of socio-economic systems.

Resilience is a multidimensional, interdisciplinary concept. Until recently, this definition was used mainly in psychology. It was interpreted not only as the ability to restore the previous state but also as the preservation of positive adaptation despite significant stress and rapid recovery after traumatic events (windows of opportunity) [5], the ability to post-traumatic growth – proactive adaptation with improved functioning after the crisis experienced [6]. In economic research, this definition characterizes the ability of economic entities and socio-economic systems of different levels to adapt to the challenges of the external environment and recover from negative external influences.

The combination of the concepts of anti-crisis management and resilience allows for mutual enhancement of the effectiveness of their practical use, forming a cyclical system of resilience: resilience becomes the basis and ultimate goal of anti-crisis strategies, proactive anti-crisis management acts as a catalyst for the growth of resilience.

One of its varieties is energy resilience. It is defined as the ability to adapt to changes in the availability of energy resources, respond effectively to energy crises, quickly restore energy supplies, and maintain the sustainable functioning of the economy [7, 8]. It is recognized as a component of national security [9].

The relevance of studying the energy resilience of businesses has especially increased during the war in Ukraine. Massive shelling of energy infrastructure in 2022–2024, power outages have led to unprecedented challenges for enterprises. According to estimates [10], 87% of Ukrainian companies have felt the negative impact of power outages on their activities, with 67% having to temporarily stop work,

and 60% having to face an increase in the cost of production due to energy problems. According to [11], enterprises have lost an average of 18% of working time due to power outages caused by strikes on the power system. Almost half of enterprises (48%) reported a drop in turnover of more than 20% because of power outages [12], and 65% of large companies surveyed indicated that prolonged blackouts put them on the verge of bankruptcy [13]. In some sectors, losses were particularly significant – for example, in retail, electricity shortages led to store downtime of up to 50% of working hours, losses of perishable goods, and a 30% drop in average daily turnover [14]. The DiXi Group think tank assessed the resilience of Ukraine's energy infrastructure to physical and cyber threats, focusing on the vulnerability of the electricity sector and the need for its modernization [15].

The above facts demonstrate the critical importance of increasing the energy resilience of enterprises in wartime. An integral part of corporate, regional, and state energy anti-crisis planning programs is determining the current state of business energy resilience.

2. Literature review and problem statement

In [16], the relationship between crisis management and organizational resilience is revealed. It was analyzed how organizations respond to different types of crises (from natural disasters to economic and technological shocks) and what factors affect their ability to recover. Attention is focused on the problem of unclear and ambiguous interpretation of the term "organizational resilience", which leads to fragmented approaches and complicates the comparison of research results. It is proved that resilience requires not only a reaction to crises but also the proactive formation of adaptive structures capable of rapid restoration of functions after disruptions. The study reveals several key limitations of the conventional approach to crisis management: the lack of rational planning under conditions of uncertainty, the gap between theoretical models and practical realities. It is noted that research on crisis management and resilience has developed separately for a long time, which led to the lack of common conceptual foundations and limited use of the achievements of one field in another. Questions remain open regarding the development of standard metrics for assessing organizational resilience. There is a lack of consistency in measurement methods at different levels: individual, group, organizational, and inter-organizational.

In [17], it is demonstrated that the resilience of organizations is based on a combination of crisis management strategies (rapid response) and long-term adaptation mechanisms (learning, innovation). The low integration between research on crisis management and resilience is noted. These two areas have developed separately for a long time, which has led to the lack of common conceptual foundations and limited use of the achievements of one field in the other. This complicates the construction of holistic models of organizational response to adverse.

According to [18], the unresolved issues in the study of organizational resilience are the lack of a comprehensive theoretical understanding of the antecedents and consequences of organizational resilience because of its complex and dynamic nature. Available theoretical approaches are scattered and fragmentary; most empirical studies are based on cross-sectional data, which limits the possibilities for analyzing temporal dynamics and cause-and-effect relationships. The lack of multifactorial, mixed research methods (quantitative+qualitative) for a deeper understanding of the phenomenon; problems with unifying methods for measuring organizational resilience because of the individuality and specificity of each organization; the lack of a single set of "individualized pillars" of organizational resilience that would be applicable to different organizations, taking into account their individual characteristics and contexts. All this complicates the transformation of theoretical knowledge into practical solutions.

In [19], measuring resilience was named one of seven promising areas for future research. Unresolved issues in this area include the design of tools for assessing different types and manifestations of resilience, in particular energy resilience; an urgent task is the transition from theoretical models to practical cases and empirical research.

The concept of energy resilience is based on an interdisciplinary theoretical foundation that encompasses engineering, economics, ecology, and management theory. The first developments in this area appeared in the scientific community twenty years ago in the context of the reliability of energy systems and the resilience of infrastructure to extreme events. For example, within the framework of the resilience thinking concept, energy resilience was considered as the ability of energy systems to withstand external shocks (accidents, natural disasters) and to ensure continuous energy supply to consumers. Scientists have proposed a broader interpretation, including in the definition of energy system resilience adaptation to changing conditions – economic, environmental, social – in order to guarantee sustainable energy supply [7]. They focused on the ability of energy networks to recover after disruptions, maintain critical services, and minimize negative consequences for consumers [8]. The UN ESCAP report (2020) emphasizes that increasing energy sustainability should occur in parallel with the energy transition, i.e., by integrating renewable sources into energy systems, developing smart grids, and reducing the carbon footprint of the energy sector [9]. Thus, the energy resilience of enterprises is recognized as a comprehensive characteristic of the ability of an enterprise to maintain energy supply, ensure flexibility of business processes and economic resilience to energy shocks. That is, the ability to continue to carry out economic and financial activities in planned volumes, ensure business continuity and development.

Paper [20] indicates that the main unresolved issues and research gaps in energy resilience research are the lack of empirical research (a significant part of the reviewed literature is theoretical or conceptual in nature, but real empirical data on the response of organizations to the energy crisis are few or fragmented); inconsistency in definitions and approaches to measuring sustainability (no consensus on concepts, metrics, and indicators of organizational sustainability, especially in the area of the energy crisis).

Ensuring energy resilience requires assessing its level, which is necessary at different stages of anti-crisis management to achieve its objectives. Certain methodological developments of the assessment tool are available.

In [20], modern approaches to assessing energy resilience are systematized, including composite indices, energy efficiency metrics, scenario analysis, SWOT analysis, as well as qualitative methods (surveys, expert assessments). In [21], it is proposed using SWOT analysis to identify weaknesses; risk mapping (probability/consequences), scenario modeling to

test strategies. In [22], the RERA (Regional Energy Resilience Assessment) methodology is reported to assess the energy resilience of regions. The methodology includes an assessment of infrastructure resilience, social factors, and economic consequences of energy crises. A sequence of actions for identifying vulnerabilities of power systems, analyzing risks, and developing adaptation strategies is defined. In [23], the NREL methodology is described in detail, which involves analyzing the basic resilience of power systems, identifying threats (from cyberattacks to natural disasters), prioritizing measures according to the level of risk and cost, and devising action plans to increase adaptability. In [24], a conceptual model for assessing risks in the supply chains of industrial enterprises is proposed to develop strategies to increase their energy resilience.

The proposed methods and techniques for assessment are of a conceptual-theoretical (recommended) nature [23, 24] or are quite subjective (in the case of using expert assessments and judgments) [20, 21]. The methodologies proposed in [22, 23] for quantitative assessment of the level of energy resilience require a large amount of internal technical data, which can be obtained only by conducting special studies or measurements. The latter significantly limits the practical possibilities of applying the proposed tool, especially in wartime.

All this gives grounds to argue that it is advisable to conduct a study aimed at assessing the impact of energy problems (in particular, power outages) on the activities of Ukrainian businesses using public (generally available) information.

3. The aim and objectives of the study

The purpose of our study is to determine the current state of energy resilience in the context of anti-crisis management tasks related to business preservation and development based on public information (in particular, the results of surveys of representatives from the business environment). The results to be obtained could allow state and local authorities to understand the level of energy resilience of businesses to be taken into account in anti-crisis programs and decisions. Representatives of business structures will be able to carry out express assessments of the impact of energy threats on the business activities of their industry, identify and implement best practices for mitigating the negative consequences of energy problems.

To achieve the goal, the following tasks were set:

– to analyze the impact of energy supply problems on various aspects of the activities and development prospects of industrial enterprises in Ukraine (in terms of individual industries) based on the use of correlation analysis tools;

– to conduct a regression analysis of the relationship between energy problems and the dynamics of the main indicators of their economic activity, as well as business expectations for further development.

4. The study materials and methods

The object of our study is the impact of power outages on the dynamics of economic and financial indicators, integral characteristics, and plans for the further development of industrial enterprises in Ukraine.

The main hypothesis of the study assumes a negative, but not catastrophic, impact of power outages on the current activities and development plans of enterprises in the Ukrainian industry.

Assumptions accepted:

– the scale and duration of power outages are such that they disrupt production processes but do not lead to a reduction in production volumes and suspension of the activities of enterprises;

– enterprises have some access to alternative energy sources (diesel generators, batteries, their own power plants, etc.), introduce a number of organizational measures (transition to remote work, flexible work schedules, mobile cash registers, etc.), which allows them to continue operating activities in the absence of centralized energy supply.

Simplifications adopted:

– data generalization is carried out on the basis of the responses of respondents from the relevant industry, which allows us to assess general trends but may not take into account the specificity of individual enterprises;

– economic and mathematical modeling is based on an expert assessment of the energy problem and the existing dynamics of individual business indicators, expectations, and plans for further development;

– scenarios of the impact of power outages are modeled for the conditions of an "average" enterprise in the relevant industry.

The study used a mixed methodology that combines qualitative analysis (literature review, expert interviews, content analysis of public sources) and quantitative analysis (statistical processing and analytical interpretation of survey results, correlation and regression analyses) for a comprehensive assessment of the impact of energy crisis challenges on the activities of industrial enterprises in Ukraine. Information processing was carried out using SPSS.

The principal sources of data on business activity during the war were the results of the monthly survey of enterprises "Ukrainian Business during War", which was conducted during 2022–2024 by the Institute for Economic Research and Policy Consulting (IER) [25]. That study is unique because it regularly – once a month – monitored business activity and problems of enterprises during martial law, including energy supply issues.

The survey sample, in different months, included 400–600 enterprises from different sectors of the economy, covering both large and medium-sized and small businesses. The survey represented enterprises from eight main industries: metallurgy and metal processing, chemical industry, mechanical engineering, woodworking industry, construction materials production, food, light and printing industries. Geographically, respondents covered different regions of Ukraine, with the exception of the zone of active hostilities at the time of the survey. Data were collected through telephone interviews or self-completion of an online questionnaire by enterprise managers; the responses received were summarized by IER analysts.

To achieve the defined research task, a database was built containing information on the share of enterprises that recognize:

1) the presence of the problem "Interruptions in electricity, water, or heat supply" (Energy problem);

2) a reduction in the volume of the corresponding economic indicator (Functional impact);

3) deterioration of the integral characteristics of its financial and economic situation or operating environment (Integral impact);

4) lack of plans to expand its activities in the future (Prospective impact).

A specific list of variables used in the study is given in Table 1.

Table 1

Characteristics of variables used in the research process

Variable ID	Designation	Meaningful interpretation
1. The problem of electricity, water, and heat supply	ProblemElectr	Share of respondents who recognize the existence of the problem «Interruptions in electricity, water, and heat supply for their enterprises»
2. Functional impact – reduction of the volume of the corresponding economic indicator:	FI	Share of respondents who responded to a negative change in relation to the same period last year) of the relevant indicators of economic and financial activity, which actually takes place during the survey period or is expected in the next 3 months
2. 1. Production	Prod	
2. 2. Sales	Sal	
2. 3. Exports	Export	
2. 4. Accounts receivable	AccRec	
2. 5. Accounts payable	AccPay	
2. 6. Tax liabilities	TaxDeb	
2. 7. Raw material inventories	InvMat	
2. 8. Finished goods inventories	ProdStoc	
2. 9. New orders	NewOrd	
2. 10. Raw material and material prices	PriceMater	
2. 11. Prices for finished products (sale prices)	PriceProd	
2. 12. Number of employees	Empl	
2. 13. Number of employees on forced leave	EmplForcLea	
2. 14. Skilled employees	EmplSkil	
2. 15. Unskilled employees	EmpUnskil	
3. Integral influence – deterioration of the integral characteristics of one's position or the environment of functioning:	FES	Share of respondents who provided a deterioration in the expert assessment (in relation to the same period last year) in relation to the integral characteristics of their position or environment of activity
3. 1. Assessment of the financial and economic situation	BE	
3. 2. Assessment of the business environment	AFES	
3. 3. Assessment of the financial and economic situation	PlanExpand	
4. Prospective impact – lack of plans to expand its activities	FES	Share of respondents who provided a negative answer regarding plans to expand activities in the future period

The database contains defined variables for 8 sectors (types of economic activity), including: metal production and metalworking (metal_prod); chemical industry (chem_ind); mechanical engineering (mechan_eng), woodworking industry (woodw_ind), construction materials production (builmat), food industry (food_ind), light industry (light_ind), printing industry (print_ind). The study covers 20 periods (months during 2022–2024), which contain information on all necessary variables.

Hypothesis 1: there is a relationship between the presence of the Energy problem and the parameters of the economic and financial activities of enterprises, its current and prospective integral characteristics. To verify hypothesis 1, an assessment of the closeness of correlations was carried out by calculating the Pearson linear correlation coefficient between the variable "Interruptions in electricity, water supply and heat supply" and the financial and economic parameters of the activities of enterprises in various sectors of the economy during 2023–2024 (Table 3).

5. Results of assessing the energy resilience of industrial enterprises in Ukraine

5. 1. Assessing the impact of energy supply problems based on the use of correlation analysis tools

The results of the monthly research "Ukrainian Business during War" [25] demonstrate limited access to electricity, water, and heat supply during 2022–2024. This issue has become one of the most acute for enterprises in most industries. This is confirmed by the consistently high share of respondents who recognize the presence of such interruptions as a critical factor affecting their operational activities (Table 2).

Table 2

Share of enterprises facing the problem "Interruptions in electricity, water, and heat supply" during 2023—2024 (according to the results of the study)

Time period	metal_prod	chem_ind	mechan_eng	woodw_ind	builmat	food_ind	light_ind	print_ind
2304	48	29	43	23	30	27	33	15
2305	42	25	58	52	52	33	31	40
2306	55	32	59	32	35	29	39	7
2307	39	13	53	33	35	28	38	18
2308	50	30	58	26	33	26	38	14
2309	40	23	53	22	35	26	33	21
2310	32	26	49	16	33	24	30	15
2311	36	32	58	14	31	25	25	15
2312	39	35	50	23	31	26	32	15
2403	57	50	53	25	37	37	30	27
2405	48	52	73	25	35	38	40	N/A
2406	76	81	77	74	47	59	68	N/A
2407	78	87	70	74	82	84	86	N/A
2408	54	70	62	52	59	70	65	N/A

Table 3

Pearson correlation between the variable "Energy problem" and financial and economic parameters of the activities (expectations) of enterprises during 2023—2024

Designation	metal_prod	chem_ind	mechan_eng	woodw_ind	builmat	food_ind	light_ind	print_ind
Sal	0.360*	0.379	0.215	0.619**	–0.219	–0.135	–0.442	0.059
NewOrd	0.269	0.308	0.171	0.569**	–0.324	–0.303	–0.470*	–0.210
Export	0.245	0.307	0.577**	0.635**	–0.348	0.232	–0.056	–0.112
PriceProd	–0.452*	–0.585*	–0.509	–0.374	–0.573*	–0.308	–0.561*	–0.347
Prod	0.350*	0.353	0.076	0.496*	–0.227	–0.160	–0.454*	–0.144
ProdStoc	0.240	0.439	0.008	0.594**	0.339	0.756**	0.846**	0.361
InvMat	0.410*	0.451*	0.447*	0.572**	–0.321	–0.132	–0.451*	–0.256
PriceMater	–0.462*	–0.598*	–0.814**	–0.417	0.218	–0.422	–0.350	0.232
Empl	0.170	0.247	0.018	0.162	–0.120	–0.185	–0.103	0.049
EmplSkil	0.321	0.443	0.491*	0.470*	0.683**	0.814**	0.451*	0.511*
EmpUnskil	0.262	0.416	0.414	0.131	0.233	0.807**	0.392	0.422
EmplForcLea act	0.070	0.046	–0.170	0.422	0.162	0.813**	0.676**	0.447*
AccRec act	0.022	0.270	–0.262	0.176	–0.412	0.589**	.630**	0.247
AccPay act	–0.117	–0.156	–0.429	0.446*	–0.516*	0.548*	0.507*	0.225
TaxDeb act	–0.214	–0.420	–0.120	0.297	–0.236	0.608**	0.415	0.265
FES act	0.581**	0.691**	0.650**	0.425	0.292	0.711**	0.849**	–0.235
BE act	0.613**	0.703**	0.635**	0.642**	0.417	0.598**	0.410	–0.310
AFES	0.335	0.437	0.453	–0.319	–0.530*	–0.423	–0.705**	–0.242
PlanExpand	–0.071	–0.274	0.242	–0.099	–0.395	0.173	–0.026	–0.249

*Note: * – correlation is significant at the 0.05 level (two-sided); ** – correlation is significant at the 0.01 level (two-sided).*

Based on our correlation analysis, a correlation matrix was compiled (Table 4). It represents the parameters of economic and financial activity (research variables) that have a statistically significant level of correlation (* – significance level 0.05; ** – significance level 0.010)) with the variable "Interruptions in electricity, water, and heat supply". Empty cells and the absence of certain variables mean that the correlation between the corresponding variables is not statistically significant at the levels of 0.05 or 0.01. Positive values of the correlation coefficients indicate a direct relationship between the variables, while negative values indicate an inverse relationship.

Based on the recommendations set out in [26], the strength of the relationship between variables can be assessed on the basis of the defined Pearson correlation coefficients. The values of the correlation coefficient are interpreted as follows:

– 0.0–0.2: very weak or absent relationship;

– 0.2–0.4: weak relationship;

– 0.4–0.6: moderate relationship;

– 0.6–0.8: strong relationship;

– 0.8–1.0: very strong relationship.

Table 4 demonstrates that there is a moderate or strong positive linear relationship between the variable (factor) "Energy problems" and most of the variables that characterize the financial and economic performance indicators and integral characteristics of the state of enterprises. 74.4% (35 out of 47) of the studied relationships have a statistically significant Pearson coefficient greater than 0.4. That is, despite the presence of an energy problem, business indicators are growing, and integral characteristics of the state are improving.

At the same time, negative impacts of the energy problem were also identified, the sign of which is a moderate or strong negative correlation coefficient:

– mechanical engineering industry – prices for raw materials (–0.814**);

– building materials – prices for finished products (–0.573*); financial and economic situation (–0.530*); accounts payable (–0.516*);

– light industry – prices for finished products (–0.561*); new orders (–0.470*), production volume (–0.454*), raw material stocks (–0.451*);

– metalworking – prices for raw materials (–0.462*); prices for finished products (–0.452*);

– chemical industry – prices for raw materials (–0.598*) and prices for finished products (–0.585*).

Table 4

Matrix of statistically significant correlations between the variable "Interruptions in electricity, water, and heat supply" and financial and economic indicators by industry sector in Ukraine

Industry (type of activity)	Sal	NewOrd	Export	PriceProd	Prod	ProdStoc	InvMat	PriceMater	EmplSkil	EmpUnskil	EmplForcLea act	AccRec act	AccPay act	TaxDeb act	FES act	BE act
metal_prod	0.360*	N/A		–0.452*	0.350*	N/A	0.410*	–0.462*	N/A	N/A	N/A	N/A	N/A	N/A	0.581**	0.613**
chem_ind	N/A	N/A		–0.585*	N/A	N/A	N/A	–0.598*	N/A	N/A	N/A	N/A	N/A	N/A	0.691**	0.703**
mechan_eng	N/A	N/A	0.577*	N/A	N/A	N/A	N/A	–0.814**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
woodw_ind	0.619**	0.569**	0.635**	–0.573*	N/A	0.594**	0.572**	N/A	0.470*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Builmat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.683**	N/A	N/A	N/A	–0.516*	–	–0.530*	
food_ind	N/A	N/A	N/A	N/A	N/A	0.756**	N/A	N/A	0.814**	0.807**	0.813**	0.589**	0.548*	0.608**	0.711**	0.598**
light_ind	N/A	–0.470*	N/A	–0.561*	–0.454*	0.846**	–0.451*	N/A	0.451*	0.392*	0.676**	0.630**	0.507*	N/A	0.849**	N/A
print_ind	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.511*	N/A	0.447*	N/A	N/A	N/A	N/A	N/A

Negative correlations were not found in such industries as the food, woodworking, and printing industries.

Thus, it can be stated that negative impacts occur only in 12 out of 47 variables or in 25.5% of cases. Most often, negative impacts were found for variables such as prices for raw materials and finished products, which over time may have a negative impact on other economic indicators.

5. 2. Regression analysis of the impact of energy supply problems on the plans for further development of enterprises

Our analysis of correlation relationships allows us to formulate hypothesis 2 – the problem of energy supply does not critically affect the plans for further development of enterprises in the Ukrainian industry.

Considering that the presence of correlation does not necessarily mean a causal relationship, confirmation or refutation of the stated hypothesis prompted us to continue our research and use other methods of economic and mathematical analysis, in particular regression analysis.

The result of testing the hypothesis regarding the impact of the variable (factor) "Energy problem" on the variable "Plan to expand your activities" (resultant variable) was the construction of 16 models. The models are represented in tabular form (Table 5), taking into account a large number of variables. Empty cells at the intersection of model code and model parameters mean that these variables were rejected by SPSS as statistically insignificant when building the corresponding model. The regression coefficients necessary to assess their quality are given in Table 6.

Table 5

Parameters for linear regression models that estimate the impact of study variables on the outcome variable "Are you planning to expand your business?"

Model code/model parameters	Metal 1	Metal 2	Chem 1	Mash 1	Mash 2	Derev 1	Derev 2	Bud mater	Xarch 1	Xarch 2	Xarch 3	Legk	Poligr 1	Poligr 2	Polig r 3	Poligr 4
(Constant)	–0.048	0.176		0.095	0.254	0.138	0.180	–1.096	0.157	0.168	0.171	2.453	0.429	0.367	0.048	–0.133
Sal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–0.426	N/A	N/A	N/A	N/A				
AccRec	–0.442	N/A	N/A	N/A	N/A	N/A	0.460	N/A	N/A	N/A	N/A	N/A				
Export	–0.412	N/A	N/A	N/A	N/A	N/A		–0.497	N/A	N/A	N/A	0.536				
ProdStoc	–0.043	N/A	N/A	N/A	N/A	N/A	N/A	–1.864	N/A	N/A	N/A	1.547				
InvMat	0.591	N/A	–0.442	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–3.090	0.616	0.573	0.329	
EmplSkil	–0.640	N/A	N/A	N/A	N/A	N/A	N/A	0.712	N/A	N/A	N/A	N/A				
Empl	0.011	N/A	N/A	N/A	N/A	N/A	N/A	–1.750	N/A	0.252	0.251	–1.208				
EmplForcLea	0.713	N/A	N/A	–0.638	–0.787	– 0.998	–1.112	N/A	N/A	N/A	N/A	0.017		–0.506	–0.651	–0.731
AccPay	1.141	–0.442	N/A	N/A	N/A	N/A	N/A	0.377	N/A	N/A	N/A	1.670				
EmpUnskil	1.038	N/A	N/A	N/A	N/A	N/A	N/A	–0.439	N/A	N/A	N/A	–1.331				
NewOrd	–0.749	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–0.090	N/A				
TaxDeb	–0.069	N/A	N/A	N/A	0.698	N/A	N/A	0.277	–0.100	–0.085	–0.055	–2.340				
PlanExpand	0.003	N/A	N/A	N/A	N/A	N/A	N/A	0.768	N/A	N/A	N/A	N/A				
PriceProd	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.906	N/A	N/A	N/A	–1.177				
PriceMater	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A	0.602			0.743	1.048
AFES	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.885	N/A	N/A	N/A	0.137				
BE	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–0.347	N/A	N/A	N/A	2.386				
ProblemElectr	0.005	N/A	N/A	N/A	N/A	N/A	N/A	0.004	N/A	N/A	N/A	–0.031				

Table 6

Characteristics of regression models that assess the impact of study variables on the variable "Are you planning to expand your activities?"

Sector	Method	Model code	*R*	*R*-Square	Corrected *R*-square	Standardestimation error
metal_prod	ENTER	Metal 1	1.000	1.000	N/A	N/A
	step-by-step	Metal 2	0.602	0.362	0.309	0.11489
chem_ind	step-by-step	Хім1	0.613	0.376	0.324	0.07501
mechan_eng	step-by-step	Маш1	0.537	0.289	0.230	0.08795
	step-by-step	Маш 2	0.768	0.590	0.515	0.06976
woodw_ind	step-by-step	Derev1	0.664	0.441	0.394	0.07759
	step-by-step	Derev2	0.818	0.669	0.609	0.06235
builmat	ENTER	Bud mater	1.000	1.000	N/A	N/A
food_ind	step-by-step	Xarch 1	0.732	0.535	0.493	0.01680
	step-by-step	Xarch 2	0.841	0.707	0.649	0.01398
	step-by-step	Xarch 3	0.912	0.831	0.775	0.01120
light_ind	ENTER	Legk	1.000	1.000	N/A	N/A
print_ind	step-by-step	Poligr 1	0.618	0.382	0.330	0.15899
	step-by-step	Poligr 2	0.792	0.627	0.560	0.12894
	step-by-step	Poligr3	0.874	0.763	0.692	0.10779
	step-by-step	Poligr 4	0.829	0.688	0.631	0.11796

Tables 5, 6 demonstrate that the variable "Energy problem" was rejected as statistically insignificant in 13 regression models built for such industries as mechanical engineering (Mash 1, Mash 2), chemical (Chem 1), food industry (Xarch 1, Xarch 2, Xarch 3), woodworking (Derev 1, Derev 2), and printing (Poligr 1, Poligr 2, Poligr 3, Poligr 4).

Instead, the variable was included in the equations of 3 models:

– Metal 1, developed for enterprises in the metalworking industry;

– Bud mater, which concerns the production of building materials;

– Legk, which models dependences for enterprises in light industry.

In these cases, the variable "Energy problem" (power outages) received non-zero coefficients and was retained in the final set of predictors, which indicates the presence of a minimal impact on the dependent variable – "Planning for expansion of activities".

Thus, the results of the regression analysis allow us to state the following. Ukrainian business has adapted quite effectively to the current restrictions on electricity consumption. This factor is not a predictor of making decisions on expanding the volume of their economic activity in most industries. Assessing the impact of the energy problem on enterprises in the metalworking, building materials, and light industry sectors requires additional empirical research.

6. Discussion of results based on the energy resilience assessment

The high level of energy supply problems is explained by the massive shelling of energy infrastructure and the shortage of energy resources in 2022–2024. To solve our first research task, an assessment of the relationships between energy problems and the dynamics of the main indicators of their economic activity was performed (correlation analysis (Tables 3, 4). Table 3 shows that 74.4% of the relationships recorded a positive correlation, which indicates the effective adaptation of enterprises. At the same time, 25.5% of the relationships demonstrate a negative impact, mainly on pricing policy, which is explained by the increase in the cost of products as a result of investments in alternative means of energy supply.

Since the presence of a correlation does not always mean a causal relationship, a regression analysis was conducted to confirm or refute the previous assumptions. Analyzing Tables 5, 6, it can be stated that power supply interruptions (the value of "electricity interruptions" is from –0.031 to 0.005) are not a decisive factor for making strategic decisions on expansion.

A conclusion drawn on the energy resilience of enterprises in the Ukrainian industry can be confirmed by other studies, in particular the results of a survey conducted by the American Chamber of Commerce in Ukraine together with Deloitte (Ukraine) in September 2024 [27]:

– 88% of companies stated their readiness for power outages;

– 94% of surveyed companies already have or are in the process of devising action plans in the case of long outages;

– 33% of respondents reported that they are able to independently enable uninterrupted power supply for 24 hours or more;

– 86% of companies use generators as the main source of backup power, of which 40% have additionally implemented solar panels or gas generators.

The achieved results were made possible by a set of anti-crisis measures (use of generators and uninterruptible power supplies, introduction of renewable energy sources, change of work schedules, remote employment, etc.), which were implemented during 2022–2024 and described in [10–12, 14, 15, 27]. The implementation of corporate strategies to increase energy security and continuity of business processes was supported by relevant government decisions.

Although the conclusion formed regarding ensuring energy resilience is confirmed by numerous business cases, our study has certain limitations. The sample of enterprises that participated in the IER survey [25], although representative, does not cover all sectors of industrial production. Using only survey data does not allow for cross-verification. The variable "Energy problem" is included in the models with minimal (compared to other changes) impact coefficients (0.003–0.005) for metalworking, building materials, and light industry enterprises, but the estimated quality of these models does not allow us to recognize them as requiring additional verification and empirical research.

Analysis of the regression models Metal 1, Bud mater, and Legk revealed formally high quality (the coefficients of determination R and R^2 in all cases are equal to 1.000). This result, on the one hand, demonstrates the ability of the included predictors to fully explain the variation of the dependent variable. On the other hand, the full compliance of the model with the sample is atypical for socio-economic research and requires careful interpretation, as it may be a consequence of overfitting, an excessive number of variables, or an insufficient amount of empirical observations. That is, these models require additional verification using alternative statistical procedures.

Our results can be practically implemented for the operational assessment of the vulnerability of enterprises to energy challenges, to support decisions in the field of state industrial policy and anti-crisis management.

The lack of simulation predictive modeling is a disadvantage of the study. The assessment of the impact of the problem of limited energy supply is based on the actual time of electricity outages that occurred during the study period and may change significantly in the event of longer outages.

Further development of our study may involve the development of an integral index of energy resilience of an enterprise, which should take into account various technical, economic, and financial parameters. However, such an assessment will require internal information from individual organizations – objects of assessment.

7. Conclusions

1. The number and share of enterprises for which the electricity supply situation is recognized as problematic is growing; the negative impact is selective and not critical. Our assessment of correlations has shown the presence of a statistically significant negative impact of power supply interruptions on individual economic indicators in some industries, in particular mechanical engineering, light industry, and construction materials production. A moderate or strong positive linear relationship was found between the variable "Energy problem" and most of the variables characterizing financial and economic performance indicators and integral characteristics of the state of enterprises. 35 out of 47 studied relationships (74.4%) have a statistically significant Pearson coefficient greater than 0.4.

The negative impacts of the Energy problem (which are characterized by a moderate or strong negative correlation

coefficient) occur only in 12 out of 47 variables or in 25.5% of cases. The prices of raw materials and finished products, as well as the dynamics of orders, were particularly sensitive to the problem of energy supply.

2. As our correlation-regression analysis revealed, most industrial enterprises in Ukraine were able to effectively adapt to crisis challenges, demonstrating a high level of adaptability and resilience to energy supply disruptions. The regression models built proved that the factor of energy disruptions is not decisive for making decisions on further business expansion. The variable "Energy problem" is not a predictor of making decisions on expanding the volume of their economic activity in models built for mechanical engineering, chemical and food industries, woodworking, and printing. Thus, it can be stated that industrial enterprises in Ukraine, owing to the implementation of a set of anti-crisis measures, managed to ensure an acceptable level of their energy resilience. They plan to further develop their activities, despite the presence and current level of the energy supply problem. This will have a positive impact on the implementation of the tasks of anti-crisis management to preserve and develop Ukrainian business.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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