VOLODYMYR DAHL EAST UKRAINIAN NATIONAL UNIVERSITY
(Full name of the higher education institution)
FACULTY OF ECONOMICS AND MANAGEMENT
(Faculty name)
DEPARTMENT OF ECONOMICS AND ENTREPRENEURSHIP
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QUALIFICATION THESIS

Master's Level
(Level of Education)

Topic: "Management of Energy Efficiency of Production Systems Based on an Innovation-Driven Approach"

Student: 2nd-year student, group EC-24dmi
Specialty: 051 Economics
Educational Program: Economics

Lin Changfei
(Student's Full Name and Signature)

Supervisor: Prof., D.Sc. Olshanskyi O.V.
(Title, Degree, Full Name and Signature)

Kyiv – 2026

VOLODYMYR DAHL EAST UKRAINIAN NATIONAL UNIVERSITY
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Institute, Faculty, Department: Faculty of Economics and Management
Department of Economics and Entrepreneurship
Educational Level: Master's
Specialty: 051 "Economics"
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Head of the Department of Economics and Entrepreneurship:
__________ Prof. O.V. Olshanskyi, D.Sc.
09.01.2026

TASK
FOR MASTER'S QUALIFICATION THESIS

Student Name: _______Lin Changfei__________

1. Thesis Topic: "Management of Energy Efficiency of Production Systems Based on an Innovation-Driven Approach"
Supervisor: Olshanskyi Oleksandr Viktorovych, Prof., D.Sc.
Approved by University Order: Date 08.01.2026. No.02/14

2. Submission Deadline: 20.03.2026

3. Initial Data for the Thesis: scientific works of domestic and foreign scholars on energy efficiency of production systems, innovative and strategic management, energy management digitalization, renewable energy sources, ESG principles, and sustainable development; statistical and analytical data on the performance, cost structure, and energy consumption of the enterprise under study; materials from the pre-graduation internship report; the company’s financial statements and non-financial reporting; analytical materials on the structure of energy costs, energy intensity, and the economic efficiency of energy-saving measures.

4. Content of the Explanatory Note: 1. Theoretical and methodological foundations of energy efficiency management of production systems based on an innovative approach. 2. Assessment of the current state of economic activity and analysis of the energy efficiency management system of the enterprise. 3. Analysis of the cost structure, energy consumption, energy intensity, and reserves for improving the energy efficiency of the production system. 4. Development of an innovative strategy for managing the energy efficiency of the production system of the enterprise. 5. Economic substantiation of the proposed measures and assessment of their impact on the long-term sustainability, competitiveness, and efficiency of the enterprise.

5. List of Graphic Materials:
Tables, figures and other demonstration material

6. Consultants for Thesis Chapters:

<table>
<tr><td rowspan="2">Chapter</td><td rowspan="2">|Consultant Name, Title</td><td colspan="2">Signature|, Date</td></tr>
<tr><td>The Task is given</td><td>The task is received</td></tr>
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7. Task Issuance Date: 09.01.2026

CALENDAR PLAN

No.	Task Stage	Deadline	Remarks
1	Approval and assignment of thesis topic	January 2026	
2	Justification of the topic's relevance	January 2026	
3	Bibliographic research and material preparation for Chapter 1	January 2026	
4	Submission of Chapter 1 materials	January 2026	
5	Data collection for Chapter 2	January 2026	
6	Submission of Chapter 2 materials	February 2026	
7	Preparation and drafting of Chapter 3	March 2026	
8	Submission of Chapter 3 materials	March 2026	
9	Drafting conclusions and finalizing the thesis	March 2026	
10	Defense presentation preparation	March 2026	

Student: ______________________________ Lin Changfei

Supervisor: ______________________________ O.V. Olshanskyi

ABSTRACT

Master's thesis: 102 p., 30 tables, 1 figures, 23 sources.

The object of the research is the process of managing the energy efficiency of the production system of an industrial enterprise.

The subject of the research is the theoretical, methodological, and applied principles for developing an innovative strategy for managing the energy efficiency of production systems.

The purpose of the qualification thesis is the theoretical substantiation and development of practical recommendations for forming an innovative strategy to improve the energy efficiency of the enterprise’s production system, thereby increasing its economic, environmental, and competitive sustainability.

The theoretical and methodological foundations of energy efficiency management of production systems based on an innovative approach have been examined, and the principles of integrating technological modernization, digital energy management, and renewable energy sources into enterprise management have been generalized. Based on the analysis of PJSC “Obolon”, financial and economic performance, operating and energy costs, fixed and working assets, and the role of energy in the company’s cost model were assessed. Key reserves for improving energy efficiency were identified, an innovative management strategy was developed, and the economic feasibility of the proposed measures was substantiated. The results confirm that technological modernization, digital energy management tools, and renewable energy solutions reduce energy costs, improve efficiency, and strengthen the enterprise’s long-term sustainability and competitiveness.

ENERGY EFFICIENCY, PRODUCTION SYSTEM, INNOVATIVE STRATEGY, ENERGY MANAGEMENT, RENEWABLE ENERGY SOURCES, OPERATING COSTS, COMPETITIVENESS, SUSTAINABLE DEVELOPMENT.

CONTENTS

INTRODUCTION

Modern conditions for the functioning of industrial enterprises are characterized by the growth of the cost of energy resources, instability of the energy market, increased environmental requirements and the integration of Ukraine into the European economic space. For food industry enterprises, in particular such as PJSC "OBOLON", the energy component constitutes a significant share of operating costs, which directly affects the cost of production, the level of profitability and competitiveness.

In the context of the post-war transformation of the Ukrainian economy, the problem of increasing energy efficiency is gaining strategic importance, as it ensures not only cost reduction but also strengthened energy security, reduced carbon footprint, and compliance with the principles of sustainable development. Traditional approaches to energy consumption management, focused mainly on local technical measures, do not provide the required level of effectiveness. This necessitates the formation of an innovative strategy for managing the energy efficiency of production systems, combining technological modernization, digitalization of energy management and the use of renewable energy sources.

Thus, the chosen topic is relevant from the standpoint of economic efficiency, environmental responsibility, and strategic development of enterprises.

The object of the study is the process of managing the energy efficiency of the production system of an industrial enterprise.

The subject of the research is the theoretical, methodological, and applied principles for developing an innovative strategy for managing the energy efficiency of production systems.

The purpose of the study is to substantiate theoretical provisions and develop practical recommendations for developing an innovative strategy to improve the energy efficiency of the enterprise's production system, thereby increasing its economic, environmental, and competitive sustainability.

To achieve the goal, the following tasks have been defined:

To summarize theoretical approaches to determining the essence of energy efficiency of production systems.

To explore innovative mechanisms for managing energy consumption in industry.

Analyze the organizational and economic characteristics and energy consumption structure of the enterprise.

Assess the energy intensity of production processes and identify opportunities to reduce it.

Develop a set of innovative measures to increase energy efficiency.

To substantiate the economic feasibility of implementing the proposed measures.

To form an integrated indicator for assessing energy efficiency and assess the long-term impact of the strategy on the competitiveness of the enterprise.

In the process of carrying out the work, a complex of general scientific and special research methods was used, in particular: methods of theoretical generalization and systems analysis to study the essence of energy efficiency and the formation of conceptual principles of management; economic analysis to assess the financial and economic indicators of the enterprise; methods of comparative analysis and dynamic series to assess changes in energy intensity indicators; economic and mathematical methods (NPV, IRR, profitability index, payback period) to substantiate investment attractiveness; method of scenario and risk analysis to assess the sustainability of the proposed strategy; method of integral assessment to form a general indicator of energy efficiency; graphical and tabular methods to systematize the research results.

The use of these methods ensured the comprehensiveness, scientific validity, and practical significance of the results obtained.

CHAPTER 1 THEORETICAL AND METHODOLOGICAL PRINCIPLES OF ENERGY EFFICIENCY MANAGEMENT OF PRODUCTION SYSTEMS

1.1. The economic essence of energy efficiency of production systems

The issue of energy efficiency in production systems has become particularly relevant in the context of structural transformation of the economy, increasing resource constraints and the need to achieve climate neutrality. In scientific discourse, energy efficiency is considered a multidimensional economic category that reflects the relationship between the useful result obtained from an activity and the costs of energy resources required to achieve it. According to the definition of the International Energy Agency (IEA), energy efficiency means "obtaining the same or greater volume of services using less energy" (IEA, 2022). In the context of production systems, this relationship is specified through indicators of energy intensity of products, specific consumption of energy resources, and energy consumption per unit of value added.

The evolution of the concept of energy efficiency has gone through several stages, reflecting the changing paradigms of economic development. In the 1970s, after the global energy crises, energy efficiency was interpreted mainly as a tool for energy conservation and reducing dependence on imported energy resources (Smil, 2017). At this stage, the emphasis was on technical measures - modernization of equipment, insulation, optimization of operating modes.

In the 1990s, the interpretation was broadened – energy efficiency became a component of a sustainable development strategy. According to the Porter and van der Linde approach (Porter & van der Linde, 1995), increasing resource efficiency, particularly energy efficiency, can generate competitive advantages and stimulate innovation. Thus, energy efficiency ceased to be merely a cost category and became a factor in increasing the productivity and innovativeness of enterprises.

In the 21st century, the concept has become more integrated. In Geels (2019), energy efficiency is seen as an element of socio-technical transformation, encompassing not only technological changes but also institutional, behavioral and managerial aspects. The European Commission, within the framework of the Green Deal policy (European Commission, 2020), defines energy efficiency as the “first energy resource”, emphasizing its strategic role in the decarbonization of the economy.

From an economic perspective, energy efficiency can be interpreted in terms of productivity, cost, and value. If we denote output as Q and energy consumption as E, then the basic energy efficiency indicator would be:

$$EE = Q/E$$

At the same time, in modern research, the energy intensity indicator (Energy Intensity), which is the inverse value, is increasingly used:

$$EI = E/Q$$

A decrease in energy intensity with constant or increasing production volume indicates an increase in the production system's efficiency (Patterson, 1996; Ang, 2006).

The scientific literature identifies several approaches to interpreting energy efficiency (Table 1.1).

Table 1.1

Approaches to determining energy efficiency

Approach	Essence	Key authors
Technical	Minimizing energy losses in the technological process	Smile (2017)
Economic	Optimization of the cost-benefit ratio	Patterson (1996), Ang (2006)
Innovative	Stimulus for technological change and competitive advantage	Porter & van der Linde (1995)
Institutional	An element of sustainable development and decarbonization policy	European Commission (2020), Geels (2019)

Thus, the modern understanding of energy efficiency goes beyond a purely technical indicator and encompasses strategic, managerial, and environmental dimensions.

It is also important to consider the “rebound effect” described by Saunders (2000), where energy efficiency improvements can be partially offset by increased consumption due to cost reductions. This means that economic analysis of energy efficiency needs to take into account behavioural and market factors.

In Ukrainian studies (Geets, 2015; Denisyuk, 2018; Sotnyk, 2020), energy efficiency is defined as a key factor in increasing the competitiveness of the national economy and strengthening energy security. Particular emphasis is placed on integrating energy management into the enterprise's strategic management system.

Within the framework of this study, it is proposed to interpret energy efficiency in production systems as an integral characteristic that reflects an enterprise's ability to achieve maximum economic results with minimal energy consumption, while accounting for innovative and environmental criteria.

The production system in modern economic theory is interpreted as a holistic organizational and technological complex that ensures the transformation of resources into finished products or services. From the standpoint of the system approach, it is an open dynamic system that functions in interaction with the external environment and is characterized by a complex structure of connections between subsystems (Bertalanffy, 1968; Slack et al., 2016). The energy component in this system serves as a basic resource, without which the implementation of technological processes, logistics, auxiliary operations, and management functions is impossible.

In the context of energy management, a production system is considered as a set of energy-consuming elements (equipment, engineering networks, buildings, transport), united with the sole purpose of ensuring a production result with minimal resource consumption. According to the ISO 50001 standard (ISO, 2018), the object of management is the energy performance of the organization, which includes indicators of energy consumption, energy efficiency and use of energy resources.

From the perspective of operations management (Heizer, Render & Munson, 2020), a production system consists of three key blocks:

input resources (materials, energy, labour, information);

transformation process;

output (products, waste, emissions).

Energy permeates all stages of this cycle, performing the function of a universal factor of production. Thus, energy efficiency management cannot be limited to individual technological operations; it must encompass the entire value-creation system.

Scientific studies (Capehart, Turner & Kennedy, 2020; Thollander & Palm, 2013) emphasize that a production system as an energy management object has the following characteristics:

multi-level (strategic, tactical, operational levels of management);

hierarchy (centralized and decentralized energy consumption subsystems);

integration (relationship between energy and production indicators);

adaptability (ability to respond to changes in energy prices and regulatory requirements).

To structure the production system as an object of energy management, it is advisable to identify its main subsystems (Table 1.2).

Table 1.2

Structural elements of a production system in the context of energy management

Subsystem	Characteristic	Energy aspect of management
Technological	Main production equipment	Specific energy consumption, modernization
Infrastructure	Buildings, lighting, ventilation	Thermal insulation, automation
Logistic	Domestic transport, warehouses	Route optimization, electrification
Administrative	Planning, control, accounting	Monitoring systems, KPIs

As shown in Table 1.2, energy management is integrated across all production subsystems, forming a single decision-making system.

In economic terms, the production system is an object of cost optimization. The share of energy costs in production costs can range from 5–10% in the food industry to 40% or more in metallurgy (IEA, 2022). Therefore, energy management directly affects the enterprise's financial performance.

According to the approach of Worrell et al. (2009), the integration of energy management into the production system involves:

Identification of significant energy consumers.

Setting baseline energy consumption levels.

Formation of energy performance indicators (EnPI).

Continuous monitoring and improvement.

Within the concept of Lean production (Womack & Jones, 2003), energy is considered a resource, with its losses equated with other types of "muda." Thus, energy efficiency becomes a component of operational excellence.

From the perspective of system economics, the production system can be described through the cost function:

$$C = f(L, K, E, M)$$

where L is labor, K is capital, E is energy, M is materials.

A decrease in E while maintaining or increasing output means an increase in total factor productivity. This is why energy is increasingly considered as an independent factor of production (Stern, 2011).

In Ukrainian studies (Burkynsky, 2019; Kovalko, 2021; Sotnyk, 2020), the production system is defined as a key object of implementing energy efficiency policy at the micro level. Particular attention is paid to the formation of internal energy management regulations and the implementation of ISO 50001 standards.

Thus, the production system acts as a complex, multi-level management object, in which the energy component is integrated into all value-creation processes. Its efficiency depends not only on the technical characteristics of the equipment, but also on the organizational structure, management culture and innovative activity of the enterprise. Considering the production system as an integral object of energy management allows for a comprehensive approach to increasing energy efficiency and minimizing costs.

Assessing the energy efficiency of production systems requires the development of a set of quantitative and qualitative indicators that enable measurement, comparison, and control of the effectiveness of management decisions. The scientific literature emphasizes that the correct choice of indicators is a key condition for effective energy management (Patterson, 1996; Ang, 2006; Capehart et al., 2020).

In general, energy efficiency indicators are divided into three groups:

technical;

economical;

integral (systemic).

Technical indicators characterize the physical level of energy consumption and losses in technological processes. The most common is the specific energy consumption indicator, which is defined as the ratio of the amount of energy used to the number of products produced:

$$e = E/Q$$

where E is the total amount of energy consumed; Q is the amount of output.

A decrease in the specific indicator indicates an increase in production energy efficiency. In addition, equipment efficiency factors, heat loss factors, and energy capacity utilization factors are used (Smil, 2017; Thollander & Palm, 2013).

Economic indicators reflect the impact of energy consumption on the enterprise's financial results. They include:

the share of energy costs in the cost of production;

energy costs per unit of added value;

cost savings from implementing energy efficiency measures;

return on investment in modernization (ROI).

According to Stern (2011), energy should be considered as a separate factor of production and its efficiency as a component of total factor productivity (TFP). Thus, energy efficiency can be assessed by its impact on the enterprise's profitability and competitiveness.

To systematize the indicators, it is advisable to present their classification (Table 1.3).

Table 1.3

Classification of indicators for assessing the energy efficiency of a production system

Indicator group	Content	Examples
Technical	Physical consumption parameters	Specific energy consumption, efficiency
Economical	Cost characteristics	Share of energy costs in cost price
Environmental	Environmental impact	CO_2 volume per unit of production
Integral	Comprehensive assessment	Energy Performance Index

As shown in Table 1.3, the modern approach to assessing energy efficiency involves integrating technical, economic, and environmental criteria.

Particular attention is paid to Energy Performance Indicators (EnPIs), as defined in ISO 50001 (ISO, 2018). EnPI can be both absolute (total energy consumption) and relative (consumption per unit of product, area or time). Establishing an energy baseline allows us to assess the dynamics of change resulting from the introduction of innovations.

In international practice, the energy intensity of gross domestic product or gross value added is widely used (IEA, 2022). At the micro level, the analogue is the indicator:

$$EIva = E/VA$$

where VA is gross value added

A decrease in this coefficient indicates an increase in the efficiency with which energy resources are used in the process of value creation.

An important criterion is also the environmental component, measured through indicators of greenhouse gas emissions (CO_2e) per unit of production. Within the ESG (Environmental, Social, Governance) concept, energy efficiency is considered as a component of a company's environmental responsibility (European Commission, 2020; Geels, 2019).

In addition to quantitative indicators, qualitative criteria are applied, including:

availability of an energy management system;

level of accounting automation;

compliance with international standards;

innovativeness of technological solutions.

Studies by Ukrainian scientists (Sotnyk, 2020; Denisyuk, 2018; Kovalko, 2021) emphasize the need to form an integrated indicator of the energy efficiency of an enterprise, which takes into account the importance of individual indicators. This approach allows for cross-industry comparisons and strategic planning.

The integral energy efficiency indicator is determined by the formula:

$$I_{EE} = \sum_{i=1}^{n} w_i \cdot x_i$$

where:

w_i– weighting factors;

x_i– normalized values of individual indicators.

Thus, the energy efficiency assessment system should be multi-level, adaptive, and integrated into the enterprise's overall strategic management system. An integrated approach allows not only to record energy consumption levels, but also to assess the economic feasibility of innovative measures and their impact on the competitiveness of the production system.

1.2. Innovative approach to energy efficiency management

Technological innovation in energy consumption is a key tool for increasing the energy efficiency of production systems and reducing their resource dependence. In the modern economy, it is technological innovation that ensures a qualitative transition from an extensive model of energy use to an intensive one, based on the rationalization of processes, digitalization and the introduction of renewable energy sources (Porter & van der Linde, 1995; IEA, 2022).

In the scientific literature, technological innovations in energy consumption are defined as a set of technical solutions aimed at reducing specific energy consumption, minimizing losses and increasing the efficiency of resource use (Worrell et al., 2009; Thollander & Palm, 2013). Their implementation enables achieving both direct economic effects (cost reductions) and strategic advantages (increased competitiveness and compliance with environmental standards).

Technological innovations can be classified by areas of impact (Table 1.4).

Table 1.4

Main directions of technological innovations in the field of energy consumption

Direction	The essence of innovation	Economic effect
Equipment modernization	Installation of energy-saving motors, frequency converters	Reduction of electricity consumption by 10–30%
Energy recovery	Use of secondary energy resources (heat, steam)	Reduction of coolant costs
Cogeneration	Simultaneous production of heat and electricity	Increasing efficiency to 80–90%
RES	Solar, biogas plants	Reducing dependence on external suppliers

As can be seen from Table 1.4, innovations encompass both the modernization of existing processes and the transformation of the energy model of the enterprise.

One of the most common directions is the introduction of highly efficient electric motors of class IE3–IE4 and frequency control systems. According to IEA (2022), up to 70% of industrial electricity consumption is accounted for by electric motors, so their modernization has significant potential for savings. The use of frequency converters allows reducing the energy consumption of pumping and ventilation systems by 20–40% (Capehart et al., 2020).

The second important direction is the recovery of secondary energy resources. In production processes, a significant part of the energy is lost in the form of heat. The use of heat exchangers and waste heat recovery systems enables up to 30% of energy to be returned to the production cycle (Worrell et al., 2009). In the food and processing industry, this is especially relevant due to the presence of thermal processes.

Combined Heat and Power (CHP) plants produce both heat and electricity from a single fuel. Their total efficiency can reach 80-90%, which is significantly higher than that of traditional power plants (Thollander & Palm, 2013). From an economic point of view, this allows reducing energy costs and increasing the energy autonomy of the enterprise.

An important strategic direction is the integration of renewable energy sources (RES). The installation of solar power plants, biogas complexes, or heat pumps allows diversifying the energy mix and reducing the impact of price fluctuations on traditional energy sources (European Commission, 2020). Within the decarbonization framework, this contributes to reducing the enterprise's carbon footprint.

From the standpoint of innovation economics, technological change acts as a catalyst for structural modernization of the production system. Porter and van der Linde (1995) argue that environmental and energy-efficient innovations can generate the so-called “innovation gain”, when the costs of modernization are compensated by an increase in productivity and market value of the company.

In the macroeconomic context, Stern (2011) emphasizes that technological progress in energy consumption is one of the determining factors of long-term economic growth. At the same time, it is necessary to consider the “rebound effect” (Saunders, 2000), which can partially offset the savings achieved from increased production volumes.

In view of the above, technological innovations in the field of energy consumption are of a comprehensive nature and include equipment modernization, the introduction of new energy technologies and the transformation of the energy infrastructure of the enterprise. Their economic feasibility is determined not only by the level of direct savings, but also by strategic effects, including increased competitiveness, investment attractiveness, and environmental sustainability of the production system.

The effectiveness of technological innovations largely depends on the organizational and managerial environment in which they are implemented. That is why the modern concept of energy management emphasizes the need to institutionalize energy management processes (ISO, 2018; Thollander & Palm, 2013).

Organizational and management innovations in the field of energy efficiency can be defined as changes in the management structure, regulations, motivational mechanisms and corporate culture aimed at systematically reducing energy consumption and increasing the energy performance of the enterprise. Unlike technical solutions, they are long-term in nature and form the basis for continuous improvement (Capehart et al., 2020).

One of the key organizational innovations is the implementation of an energy management system in accordance with the ISO 50001 standard. This standard involves the use of the PDCA (Plan–Do–Check–Act) cycle, which ensures systematic and continuous management (ISO, 2018). Within this approach, the enterprise formulates an energy policy, defines goals, establishes performance indicators (EnPI), monitors and adjusts.

Structural changes in the management organization may include the creation of a separate energy management department or the appointment of a responsible energy manager. Research by Thollander & Palm (2013) shows that the presence of a specialized unit increases the level of implementation of energy efficiency measures by 20–30% due to systematic control and coordination of actions.

An important component is integrating energy indicators into the enterprise's strategic and operational planning system. According to the Porter & van der Linde (1995) approach, environmental and energy innovations become a source of competitive advantage only when they are integrated into the overall business strategy. This means including energy efficiency targets in strategic KPIs, budgeting of activities and performance evaluation at the top management level.

To systematize the main organizational and managerial innovations, it is advisable to present their classification (Table 1.5).

Table 1.5

Organizational and management innovations in the field of energy efficiency

Direction of innovation	Content	Expected result
Institutionalization of energy management	Implementing ISO 50001	Systematic management
Organizational restructuring	Creation of an energy management service	Coordination of events
KPI integration	Incorporating energy indicators into strategic goals	Increasing responsibility
Motivational mechanisms	Energy saving bonuses	Staff motivation
Energy audit	Regular assessment of energy consumption status	Reserve identification

As can be seen from Table 1.5, organizational innovations form the management environment for the implementation of technical solutions.

The personnel motivation system is of particular importance. Research by Worrell et al. (2009) shows that up to 15% of potential energy savings can be achieved without significant investments, only by changing the behavioral patterns of employees. The introduction of bonus systems for achieving energy indicators contributes to the formation of a culture of economical use of resources.

Organizational and management innovations also include the introduction of internal regulations for accounting and reporting on energy consumption. This ensures transparency of information and improves the quality of management decisions. Within the ESG reporting framework (European Commission, 2020), companies are increasingly publishing energy consumption indicators, thereby enhancing their investment attractiveness.

Ukrainian studies (Denysiuk, 2018; Sotnyk, 2020; Kovalko, 2021) emphasize the need to form an enterprise energy strategy as a component of the overall development strategy. Such a strategy should determine modernization priorities, investment volumes, control mechanisms, and expected economic results.

From an economic perspective, organizational innovations reduce transaction costs, increase decision coherence, and minimize information asymmetry. They create the prerequisites for the transition from fragmented measures to comprehensive energy efficiency policies.

Therefore, organizational and managerial innovations are an integral part of an innovative approach to energy efficiency management of production systems. Their implementation provides an institutional basis for technological change, fosters a culture of rational resource use, and enhances the enterprise's strategic sustainability amid energy and economic challenges.

The current stage of energy management development is characterized by an active digital transformation of production systems. Digitalization in the field of energy consumption means the integration of information and communication technologies, automated data collection systems, analytics of large data sets and elements of artificial intelligence into the processes of managing energy flows of the enterprise (IEA, 2022; Capehart et al., 2020). Within the framework of the innovative approach, Smart energy management acts as a qualitatively new level of organization of control and optimization of energy resources.

Unlike traditional accounting methods, which relied on periodic analysis of aggregated data, digital systems enable continuous, real-time monitoring. This allows you to quickly identify deviations, analyze the causes of cost overruns and make management decisions based on actual indicators. According to research by Thollander & Palm (2013), implementing digital monitoring systems can provide an additional 5–15% reduction in energy consumption without significant capital investment.

Smart energy management is based on the use of the following tools:

automated energy resource accounting systems (AMR/AMI);

sensors and Internet of Things (IoT) networks;

dispatching and SCADA systems;

energy analytics software;

digital twins of production processes.

The Internet of Things (IoT) enables the integration of measuring devices, equipment and information platforms into a single network. This creates the possibility of accumulating large data sets (Big Data), which can be used to forecast consumption and optimize load (Geels, 2019). Within the framework of the Industry 4.0 concept, digital technologies allow synchronizing energy and production processes, minimizing waste of time and resources.

In order to systematize digital tools of Smart energy management, it is advisable to present them in the form of a table (Table 1.6).

Table 1.6

Digital tools for Smart energy management

Tool	Functional purpose	Implementation effect
AMI systems	Automatic data collection	Consumption transparency
IoT sensors	Real-time monitoring	Rapid response
SCADA	Process dispatching	Reduction of accidents
Analytical platforms	Big Data Processing	Cost forecasting
Digital Twin	Process modeling	Optimization of operating modes

As can be seen from Table 1.6, digital technologies cover all levels of management – from operational control to strategic forecasting.

An important element of Smart Energy Management is the use of artificial intelligence algorithms to optimize load and predict peak consumption periods. According to IEA (2022), digitalization of energy processes can reduce an enterprise's operating costs by 10–20% by optimizing equipment operating modes.

Within the framework of the ISO 50001 standard (ISO, 2018), digital systems significantly simplify the procedures for establishing energy baselines and calculating EnPI indicators. Automation of accounting increases the reliability of data and minimizes the risk of errors, which is important for making investment decisions.

From an economic point of view, digitalization allows to reduce information asymmetry between divisions of the enterprise and to ensure the integration of energy indicators into the financial management system. Capehart et al. (2020) emphasize that digital platforms create the basis for the formation of an integrated resource management system (ERP + EMS), which ensures synergy between production and energy processes.

The concept of “smart grids” deserves special attention, which involves integrating the enterprise into the digital energy infrastructure. This allows for demand response management, optimizing consumption during peak hours, and using its own generating capacity (European Commission, 2020).

Ukrainian studies (Kovalko, 2021; Sotnyk, 2020; Denisyuk, 2018) emphasize the need to accelerate the digital transformation of industrial enterprises in order to increase energy efficiency and adapt to European decarbonization requirements. The implementation of Smart energy management is considered a prerequisite for integration into the European energy space. As can be seen, digitalization is a strategic factor in increasing the energy efficiency of production systems. Smart energy management ensures the transition from reactive management to proactive management based on analytics and forecasting. The integration of digital technologies into the energy management system forms the basis for the long-term economic sustainability of the enterprise and increasing its competitiveness in the context of the global energy transformation.

1.3. Methodological approaches to assessing the effectiveness of energy efficiency measures

Economic justification of energy efficiency measures is a key stage in making management decisions regarding the modernization of production systems. Even with significant technical potential for reducing energy consumption, the implementation of relevant projects requires an assessment of their financial feasibility, investment attractiveness, and impact on the financial results of the enterprise (Brealey, Myers & Allen, 2020; Capehart et al., 2020).

In modern practice, economic evaluation is based on discounted cash flow methods that allow for the time value of money. The most common indicators are net present value (NPV), internal rate of return (IRR), payback period (PP), and return on investment (ROI).

Net Present Value (NPV)

NPV (Net Present Value) is defined as the difference between the amount of discounted cash flows from the project and the initial investment costs:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} - I_0$$

where: – cash flow in the period;$CF_t t$

r– discount rate; — initial investment;I_0

T– project implementation period.

A positive NPV indicates that the project is economically feasible. In the field of energy efficiency, cash flows are generated by saving energy costs, reducing maintenance costs and, in some cases, generating additional income from the sale of excess energy (IEA, 2022).

Internal rate of return (IRR)

IRR (Internal Rate of Return) is the discount rate at which NPV is zero:

$$0 = \sum_{t=1}^{T} \frac{CF_t}{(1 + IRR)^t} - I_0$$

where:

CF_t– cash flow in the period;t

I_0– initial investment costs;

T– total project implementation period;

IRR– internal rate of return.

If the IRR exceeds the cost of capital of the enterprise, the project is considered feasible. Research by Worrell et al. (2009) indicates that most energy efficiency projects in industry have IRRs of 15-40%, which exceeds the average return on traditional investments.

Payback period (PP)

The PP (Payback Period) indicator determines the period required to recover the initial investment from accumulated cash flows.

Formally, the simple payback period (PP) indicator is calculated using the formula:

$$PP = \frac{I_0}{CF_{annual}}$$

where:

I_0— initial investment costs;

CF_{annual}— average annual cash inflows (net cash flow) from project implementation

This method is simple to apply, but it does not take into account the discounted value of money and cash flows after the payback period (Brealey et al., 2020). In energy management practice, a finite payback period (2–3 years) is often used, which can discourage the implementation of strategically important but long-term projects (Thollander & Palm, 2013).

Return on investment (ROI)

The ROI indicator is key to assessing the effectiveness of invested capital, especially in modernization projects or the introduction of new technologies. ROI (Return on Investment) is defined as the ratio of net profit (or savings) to the amount of investment:

$$ROI = \frac{Net\ Benefit}{I_0} \times 100\%$$

In the case of energy efficiency measures, the net effect is formed by reducing energy costs. The advantage of the indicator is its visibility, but it does not take into account the time factor.

To summarize the characteristics of economic evaluation methods, it is advisable to present their comparative analysis (Table 1.7).

Table 1.7

Comparative characteristics of methods for economic evaluation of energy efficiency measures

Method	Advantages	Limitation
NPV	Takes into account the time value of money	Depends on the discount rate
IRR	Gives an idea of marginal profitability	Multiple values are possible.
PP	Ease of calculation	Ignores cash flows after payback
ROI	Indicator visibility	Does not take into account the time factor

As can be seen from Table 1.7, to make informed decisions, it is advisable to use an integrated approach, combining several methods.

A feature of energy efficiency projects is that their economic impact often manifests itself in the form of cost reductions rather than revenue increases. This requires correct forecasting of future energy costs and taking into account inflation and currency risks (IEA, 2022).

From the perspective of strategic management (Porter & van der Linde, 1995), economic evaluation should take into account not only direct financial benefits, but also indirect effects: improved reputation, compliance with ESG criteria, reduced regulatory risks. In the long term, such factors can significantly affect the market value of the enterprise.

Ukrainian studies (Denysiuk, 2018; Sotnyk, 2020; Kovalko, 2021) emphasize the need to adapt international methodologies to conditions of high macroeconomic instability. This involves the use of scenario analysis and adjustment of the discount rate taking into account the risk premium.

Thus, the economic assessment of energy efficiency measures is an integral element of an innovative approach to the management of production systems. The use of NPV, IRR, PP and ROI methods allows to ensure the validity of investment decisions and contributes to the formation of a long-term strategy for increasing the energy efficiency of the enterprise.

In the current context of energy sector transformation, the economic feasibility of energy efficiency measures is increasingly linked to their environmental impacts. Reducing energy consumption directly affects the reduction of greenhouse gas emissions, the reduction of anthropogenic load on the environment, and the fulfillment of international climate commitments (European Commission, 2020; IEA, 2022). Therefore, the assessment of the environmental impact becomes an integral part of the methodological support for energy efficiency management of production systems.

The environmental impact of energy efficiency measures is defined as the set of positive changes in the state of the environment resulting from a reduction in energy consumption or a transition to more environmentally friendly technologies. The most common indicator is the reduction in CO_2-equivalent emissions (CO_2e), which is calculated by the formula:

The environmental effect of the project, expressed in the reduction of greenhouse gas emissions (primarily carbon dioxide), is calculated using the formula:

$$\Delta CO_2 = \Delta E \times EF$$

where:

ΔE– reduction in energy consumption (in physical units or kWh);

EF– emission factor for the corresponding type of energy resource

Emission factors are determined in accordance with international IPCC methodologies and national inventories (IEA, 2022). Thus, reducing fossil fuel consumption directly translates into reducing the company's carbon footprint.

In the practice of assessing environmental impact, several approaches are used:

Direct calculation of emissions– determination of reduction of CO_2, NOx, SO_2 and other pollutants.

Life Cycle Assessment (LCA)– assessing the impact of a product or technology throughout its life cycle (Geels, 2019).

Product carbon footprint– determination of the volume of emissions per unit of product.

Environmental performance indices– integrated indicators of environmental impact.

To systematize environmental indicators, it is advisable to present their classification (Table 1.8).

Table 1.8

Main indicators for assessing the environmental impact of energy efficiency measures

Indicator group	Content	Indicator example
Climatic	Reducing greenhouse gases	t CO_2e/year
Atmospheric	Reducing local emissions	kg SO_2, NOx
Resourceful	Reducing fuel use	tons of equivalent fuel
Integral	Cumulative environmental impact	Environmental Performance Index

As can be seen from Table 1.8, environmental assessment covers both global (climatic) and local aspects of the impact of production on the environment.

Within the framework of sustainable development, energy efficiency is seen as a key mechanism for achieving the UN Sustainable Development Goals, in particular

SDG 7 (Affordable and Clean Energy) and SDG 13 (Action on Climate Change). The European Commission (2020) defines the principle of "Energy Efficiency First" as the basis for decarbonization policies.

Environmental impact assessment also has an economic dimension. The EU countries operate an emissions trading system (EU ETS), which provides financial incentives for reducing carbon footprints. In the future, the introduction of the CBAM (Carbon Border Adjustment Mechanism) increases the importance of environmental impact assessment for export-oriented enterprises (European Commission, 2020).

Life Cycle Assessment (LCA) is a method that allows assessing the environmental impacts from raw material extraction to product disposal. According to ISO 14040, LCA involves four stages: goal setting, impact inventory, impact assessment, and interpretation of results. This approach avoids the "transfer" of environmental burdens from one stage of production to another (Geels, 2019).

Worrell et al. (2009) have shown that integrating environmental assessment into decision-making improves the effectiveness of long-term investments in production modernization. Reducing emissions not only improves environmental performance, but also reduces regulatory risks and environmental payment costs.

In Ukrainian conditions (Sotnyk, 2020; Denisyuk, 2018; Kovalko, 2021), the implementation of an emissions monitoring system and the preparation of enterprises for adaptation to European reporting standards are relevant. The formation of environmental indicators within the framework of corporate reporting contributes to increasing the transparency and investment attractiveness of the enterprise.

Thus, assessing the environmental impact of energy efficiency measures is an important element of a comprehensive approach to managing production systems. It allows us to identify not only direct environmental results, but also strategic advantages for the enterprise in the context of strengthening climate policy and global decarbonization of the economy.

In the modern system of strategic management of manufacturing enterprises, the isolated use of individual technical or financial indicators does not provide a complete assessment of the effectiveness of energy-efficient measures. Given the growing role of sustainable development and investment transparency, there is a need to form integrated indicators that combine economic, environmental and management aspects. This approach corresponds to the ESG (Environmental, Social, Governance) concept, which has become a global standard for non-financial assessment of enterprise activities (European Commission, 2020; Geels, 2019).

The integrated energy efficiency indicator allows for the aggregation of disparate indicators into a single coordinate system and for comparative analysis in dynamics or between enterprises in the industry. From a methodological point of view, integration involves the normalization of indicators, determination of weighting factors, and calculation of a composite index (Ang, 2006; Patterson, 1996).

The general formula for the integral index can be represented as follows:

$$I_{EE} = \sum_{i=1}^{n} w_i \cdot z_i$$

where:

w_i– weight coefficient of the -th indicator;i

z_i– normalized indicator value;

n– total number of indicators.

Normalization is carried out by reducing multidimensional indicators to a dimensionless scale (for example, from 0 to 1), which ensures their comparability. Weighting coefficients can be determined by expert method, analytical-hierarchical process or based on statistical analysis.

In order to structure the integrated assessment, it is advisable to distinguish three blocks of indicators (Table 1.9).

Table 1.9

Structure of an integrated assessment of an enterprise's energy efficiency

Bloc	Content	Examples of indicators
Economic	Impact on financial results	Share of energy costs in cost price, NPV of projects
Ecological	Environmental impact	CO_2e per unit of output, energy intensity
Administrative	Energy management organization level	Availability of ISO 50001, monitoring system

As can be seen from Table 1.9, the integral model allows taking into account both quantitative and qualitative characteristics.

In the context of European integration, the company's compliance with ESG criteria is of particular importance. The environmental component (E) involves control over emissions, energy intensity and the use of renewable energy sources. The social component (S) includes issues of occupational safety and environmental responsibility to the community. The governance component (G) covers transparency of reporting, internal control system and anti-corruption mechanisms (European Commission, 2020).

IEA (2022) highlights that investors increasingly consider energy efficiency as a marker of a company’s long-term sustainability. Reducing the energy intensity of production is directly correlated with reducing regulatory risks and potential costs of decarbonization.

Within the framework of international practice, integrated indices can be formed based on GRI (Global Reporting Initiative) standards and sustainable finance principles. Geels (2019) emphasizes that the combination of technological and institutional innovations provides a systemic effect that cannot be assessed only through individual indicators.

In Ukrainian studies (Sotnyk, 2020; Denisyuk, 2018; Kovalko, 2021), an integrated approach is considered as a strategic management tool that allows determining the level of energy sustainability of an enterprise. It is proposed to use a scoring system to assess the enterprise's compliance with international energy efficiency standards.

It is important to emphasize that the integral indicator is not static. Its structure and weights should be adjusted in accordance with the industry characteristics, the scale of the enterprise and the strategic development priorities. From an economic point of view, the integral assessment allows to take into account the multiplicative effect of the combination of financial, environmental and organizational results.

Therefore, the use of integrated indicators and ESG criteria provides a comprehensive approach to assessing the energy efficiency of production systems.

This methodology allows combining the economic feasibility of innovations with the requirements of sustainable development, increasing the investment attractiveness of the enterprise and forming the basis for long-term competitiveness in the context of global energy transformation.

Conclusions to Chapter 1

The first section of the study forms the theoretical and methodological basis for managing the energy efficiency of production systems based on an innovative approach. The analysis of scientific approaches has allowed us to clarify the economic essence of energy efficiency as an integral characteristic of an enterprise's activities, which reflects the ability to ensure maximum production results with minimal consumption of energy resources while taking into account environmental and strategic criteria.

It is established that the evolution of the concept of energy efficiency has gone from a technical and engineering understanding (reduction of energy losses) to a comprehensive management paradigm that covers economic, environmental and institutional aspects of enterprise development. The modern approach involves the integration of energy management into the strategic management system and an orientation towards achieving long-term competitiveness.

It is substantiated that the production system acts as a multi-level object of energy management, within which the energy component is integrated into technological, infrastructure, logistics and management subsystems. Considering the production system as a holistic complex allows us to move from fragmented measures to a systemic approach to increasing energy efficiency.

Within the framework of the innovative approach, three interrelated areas of transformation have been identified: technological innovations, organizational and managerial changes, and digitalization of energy management processes. It has been proven that equipment modernization, implementation of cogeneration and recuperation systems, and integration of renewable energy sources form the technical basis for reducing the energy intensity of production. At the same time, organizational and managerial innovations, in particular the implementation of an energy management system in accordance with ISO 50001, ensure institutional stability and continuous improvement. Digitalization and Smart energy management create the prerequisites for the transition to proactive management based on real-time monitoring and analytics.

Methodological approaches to assessing the effectiveness of energy efficiency measures are disclosed. It is determined that the economic feasibility of investments should be assessed using discounted cash flow methods (NPV, IRR), as well as indicators of the payback period and profitability of investments. The need to take into account not only direct financial effects, but also indirect strategic benefits is emphasized.

It is proven that the assessment of the environmental impact is an integral part of the modern management system, since the reduction of energy consumption is directly related to the reduction of greenhouse gas emissions and compliance with the requirements of climate policy. It is proposed to apply CO_2 reduction indicators, the life cycle method and carbon footprint indicators of products.

Special attention is paid to the formation of integrated indicators and the use of ESG criteria as a tool for comprehensive assessment of the energy efficiency of the enterprise. The integrated approach allows combining economic, environmental and management results, ensuring a strategic orientation towards sustainable development and increasing investment attractiveness.

SECTION 2. ANALYSIS OF THE ENERGY EFFICIENCY MANAGEMENT SYSTEM ON THE EXAMPLE OF AN ENTERPRISE

2.1. Organizational and economic characteristics of the enterprise

The object of research within the framework of this work is PrJSC "Obolon" - one of the leading enterprises of the food industry of Ukraine, specializing in the production of beer, soft drinks, mineral water, cider and low-alcohol products. The company has an extensive production structure, a modern technological base and significant export potential, which determines increased requirements for the efficiency of resource use, in particular energy.

The production complex of the enterprise includes the main plant in Kyiv and regional production sites, equipped with high-tech bottling lines, brewing shops, water treatment systems, refrigeration units and warehouse infrastructure. The full production cycle involves the preparation of raw materials, boiling of wort, fermentation, filtration, pasteurization, bottling and packaging of finished products (Fig. 2.1).

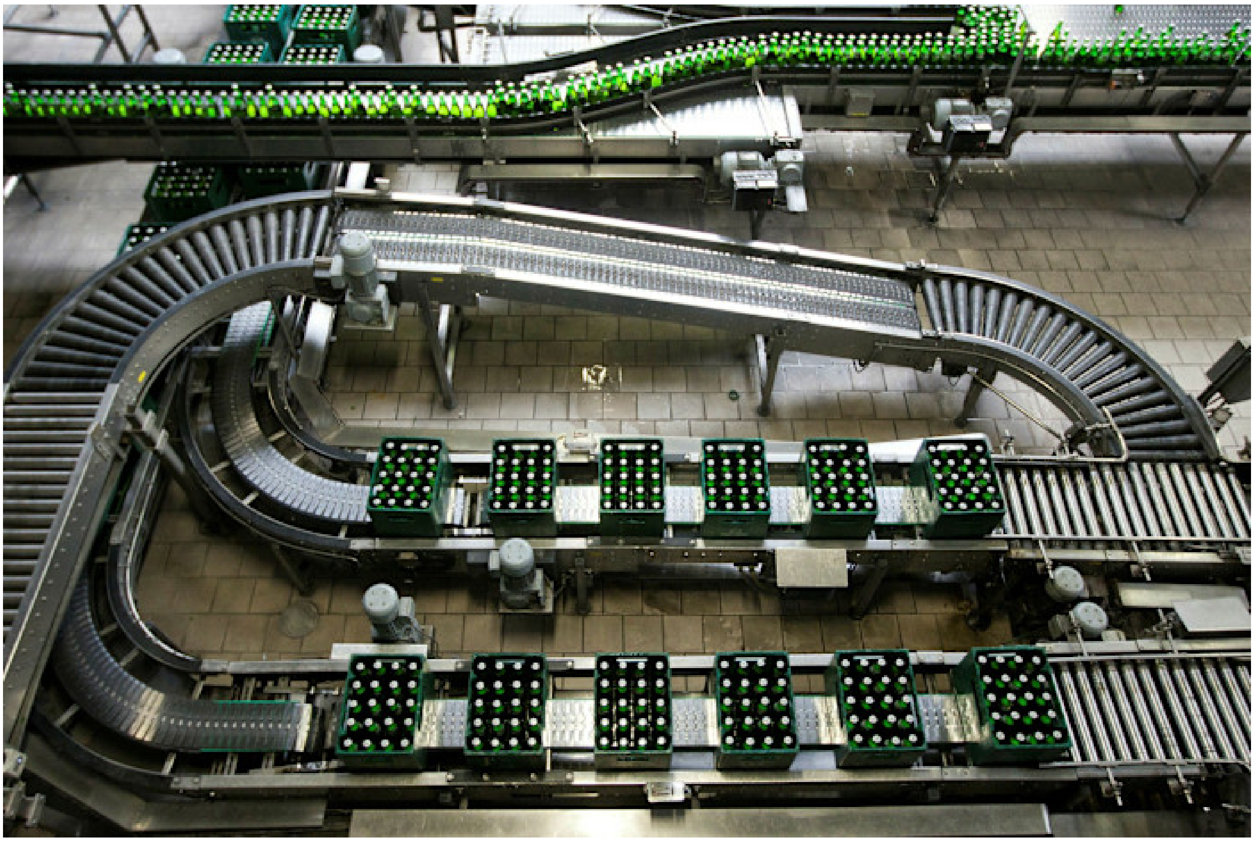

Fig. 2.1. Production complex of PJSC "Obolon"

A feature of production activities is the significant energy intensity of individual technological processes. In particular, the largest consumption of energy resources is accounted for by:

processes of heating and boiling wort;

operation of refrigeration equipment;

pasteurization and sterilization;

compressor and pumping equipment systems;

lighting and climate control of production facilities.

The technological structure of production corresponds to the principles of the current and continuous type of organization. The main production processes are automated and integrated into a single management system, which ensures the stability of product quality and minimization of production losses. The high level of automation leads to significant electricity consumption, which forms a significant share of the enterprise's operating costs.

From an economic point of view, production activity is characterized by the scale of production and a diversified range. The enterprise operates in a competitive environment that requires constant productivity improvement and cost reduction. The energy component in the cost structure is one of the key factors in the formation of competitive advantages.

The enterprise's production system has a complex infrastructure component, including:

own boiler plants;

water supply and wastewater treatment systems;

refrigeration stations;

warehouse complexes;

transport logistics.

In this regard, the enterprise consumes several types of energy resources: electricity, natural gas, thermal energy, water and fuels and lubricants for internal logistics. The multi-component nature of energy consumption determines the complexity of managing energy flows and the need to implement an integrated approach to energy management.

The production cycle of the enterprise is seasonal, which is associated with the increase in demand for products in the summer period. This leads to uneven capacity utilization and, accordingly, fluctuations in energy consumption. Thus, the effectiveness of energy resource management depends on the ability of the enterprise to adapt to seasonal changes and optimize equipment operating modes.

The organizational structure of production management provides for the presence of technical services responsible for the operation of energy equipment, as well as engineering and technological divisions that control the technological parameters of processes. Such a structure creates the prerequisites for the integration of energy management functions into the overall enterprise management system.

In general, the production activities of the enterprise are characterized by:

high level of automation;

energy intensity of the main technological processes;

the scale of production facilities;

seasonal load variability;

the need for constant modernization of equipment.

Financial and economic analysis of the activities of PrJSC "Obolon" allows us to assess the scale of economic activity, the level of profitability, financial stability and the potential for investing in energy efficiency measures. Given that the enterprise operates in conditions of high competition and an unstable macroeconomic environment, the dynamics of its financial indicators have a direct impact on the possibilities of modernization of the production system.

Table 2.1 presents the results of the analysis of the main technical and economic indicators of the activities of the studied enterprise.

The analysis of the main technical and economic indicators of the activities of PrJSC "Obolon" in 2022–2024 gives grounds to assert that the enterprise maintained positive dynamics of the scale of economic activity during the studied period, however, this dynamics was accompanied by a significant increase in the cost burden and a decrease in the efficiency of using certain types of resources. The general logic of the changes indicates that the expansion of sales volumes in itself did not provide a proportional increase in the final financial results, since the rates of increase in costs in certain periods turned out to be higher than the rates of growth of effective indicators.

First of all, it should be noted the steady growth of net sales revenue, which indicates the preservation of the company's market positions, adaptation to difficult operating conditions and the ability to maintain demand for products. Such growth could be due to both the resumption of business activity and the adjustment of pricing policy, changes in the assortment structure, reorientation of sales channels and adaptation to new conditions of the domestic market. At the same time, the positive dynamics of income was not accompanied by a similar dynamic of the financial result, which already at the first stage of the analysis indicates a weakening of the qualitative parameters of growth. In other words, the company sold more, but each hryvnia of sales brought less financial effect than in the previous period.

Table 2.1

Analysis of the main technical and economic indicators of the activities of PJSC "Obolon" in 2022-2024.

Indicator	2022	2023	2024	Absolute deviation		Relative deviation, %	
				2024/ 2022	2024/ 2023	2024/ 2022	2024/ 2023
Net income from the sale of services, thousand UAH	8661928	10763029	12784705	4122777	2021676	47.60	18.78
Cost of services provided, thousand UAH	6030487	7500990	9800435	3769948	2299445	62.51	30.66
Costs per 1 UAH of sold products, UAH	0.6962	0.6969	0.7666	0.0704	0.0697	10.11	9.99
Gross profit, thousand UAH	2631441	3262039	2984270	352829	-277769	13.41	-8.52
Net profit, thousand UAH	1197966	1831590	1248255	50289	-583335	4.20	-31.85
Sales profitability, %	30.38	30,31	23.34	-	-	-7.04	-6.97
Cost efficiency, %	43.64	43.49	30.45	-	-	-13.19	-13.04
Average annual cost of fixed assets, thousand UAH	3741276	4525000	4808711	1067435	283711	28.53	6.27
Return on fixed assets, UAH/UAH	2.32	2.38	2.66	0.34	0.28	14.83	11.78
Average annual cost of working capital, thousand UAH	1994518	3164544	4218057	2223539	1053513	111.48	33.29
Working capital turnover ratio, rev./year	4.34	3.40	3.03	-1.31	-0.37	-30.21	-10.88
Profitability of production assets, %	45.88	42.42	33.06	-	-	-12.82	-9.36
Average number of employees, people	2255	2055	2056	-199	1	-8.82	0.05
Average annual labor productivity of one employee, thousand UAH/person	3841.21	5237.48	6218.24	2377,032	980,758	61.88	18.73
Labor costs, thousand UAH	425058	656942	784372	359313.7	127429.8	84.53	19.40
Average monthly labor costs per employee, UAH	15708	26640	31792	16084	5152	102.39	19.34

The key reason for this was the outstripping growth in the cost of sales compared to revenue. This trend means that the expansion of operating activities required increasingly higher costs for production and sales of products. Economically, this can be explained by the increase in the price of raw materials, energy, logistics, packaging materials, repair services, as well as general inflationary pressure on the production system. As a result, the company's cost per UAH of sales deteriorated, which directly indicates a decrease in cost efficiency. If in the base period the costs per unit of sales were relatively stable, then in 2024 they increased significantly, which means that the company began to spend more resources on the formation of each UAH of revenue. This circumstance was one of the main reasons for the contraction of profitability.

The relationship between the dynamics of gross and net profit is indicative. Despite the increase in gross profit over the entire period under review compared to 2022, in 2024 compared to 2023, it decreased. This indicates that the cost pressure has become so significant that even the growth in revenue could no longer compensate for the deterioration in the cost structure. Net profit reacted even more sensitively to this, which in 2024 significantly decreased compared to the previous year and only slightly exceeded the level of 2022. This situation means that, in addition to production costs, administrative, sales, financial and other operating expenses additionally put pressure on the financial result. Therefore, the trend indicates not just an increase in costs, but a gradual decrease in the overall efficiency of the operational and economic mechanism.

This is also evidenced by the dynamics of profitability indicators. Despite the relatively stable level in 2022–2023, in 2024 the company demonstrated a significant decrease in both sales' profitability and cost profitability. The cause-and-effect relationship here is obvious: when cost and related costs grow faster than revenue, the share of profit in each hryvnia of sales decreases. Accordingly, the company loses part of its financial stability reserve, since even with the preservation of sales volumes, the ability to generate sufficient profit for self-financing, investment, and compensation for external risks deteriorates. It is especially important that a decrease in cost profitability means a deterioration in the return on resources advanced for production, that is, the company began to receive a lower financial result per unit of costs incurred.

The dynamics of fixed assets and indicators of their use deserve special attention. The growth of the average annual cost of fixed assets indicates the preservation of production potential, renewal or reassessment of the material and technical base, as well as a significant capital intensity of the enterprise's activities. At the same time, the return on assets did not decrease; on the contrary, it improved. This means that each hryvnia invested in fixed assets provided a greater volume of sales than in previous years. This situation characterizes a positive trend in the use of production capacities: the enterprise was able to increase the efficiency of the operation of the existing material base, which may indicate a better organization of production processes, a higher level of capacity utilization or more effective management of product output. However, even the positive dynamics of return on assets could not offset the negative impact of increased costs, and therefore the enterprise's problem lies not so much in insufficient utilization of fixed assets, but in the high cost of the current functioning of the production system.

Even more telling is the situation with current assets. Their average annual value grew much faster than sales, resulting in a decrease in the turnover ratio. This means that the company was forced to advance increasingly large amounts to inventories, work in progress, receivables or other elements of current assets to ensure current activities. Slowing down turnover and increasing the duration of one turnover have important managerial consequences: funds remain out of circulation for longer, the need to finance current assets increases, the burden on liquidity increases and the flexibility of the company in responding to market changes decreases. Combined with increasing costs, this creates additional pressure on profitability, since significant resources are not only consumed in the production process, but also return to cash more slowly.

The decrease in the profitability of production assets logically summarizes the above trends. On the one hand, the enterprise increased the resource base, maintained and developed fixed assets, and increased the volume of working capital. On the other hand, the increase in profit did not correspond to the scale of this resource expansion. Therefore, the overall return on the entire production asset base decreased. This means that the resource provision of the activity grew faster than the financial result, and therefore the economic efficiency of using advanced capital deteriorated.

The dynamics of labor indicators is quite contradictory, but at the same time indicative. A reduction in the average number of employees with a simultaneous significant increase in labor productivity indicates an increase in the effectiveness of using labor potential. In general, this may mean a more intensive workload for personnel, optimization of staff numbers, redistribution of functions, improvement of labor organization or an increase in the technical equipment of workplaces. The enterprise was able to achieve a higher sales volume with fewer employees, a positive productivity metric. At the same time, a sharp increase in labor costs and average monthly payments per employee indicates an increase in the cost of labor resources. This could be due to both inflationary processes and the need to retain qualified personnel, as well as to wage increases in conditions of staff shortage. Thus, the enterprise simultaneously achieved greater labor efficiency and faced an increase in the cost of labor. If productivity gains partially offset this increase, then, in combination with other cost factors, it could still increase overall pressure on costs.

Summarizing the results of the analysis, it is appropriate to note that in 2022–2024, PrJSC "Obolon" demonstrated quantitative growth in activity, which turned out to be insufficiently qualitative from the standpoint of final economic efficiency. The enterprise was able to increase sales volumes, increase labor productivity and improve the return on fixed assets, however, these positive changes were significantly weakened by the outpacing growth in cost, the rise in the price of labor resources, the accumulation of working capital and the slowdown in their turnover. That is why the increase in income was not transformed into a proportional increase in net profit, and profitability indicators in 2024 deteriorated. Therefore, the key conclusion is that the main problem of the enterprise at the studied stage is not associated with a lack of resources or insufficient scale of activity, but with a decrease in the efficiency of their current use and an increase in the cost-effectiveness of economic processes.

The next logical step is to investigate the enterprise's provision of fixed assets and the dynamics of the efficiency of their use (Table 2.2).

Table 2.2

Analysis of fixed assets of Obolon PJSC

period.

Indicator	2022	2023	2024
Initial cost of fixed assets at the beginning of the year, thousand UAH	10591555	10598816	11956205
Original cost of fixed assets at the end of the year, thousand UAH	10598816	11956205	12530785
Residual value of fixed assets at the beginning of the year, thousand UAH	3464064	3741276	4525000
Residual value of fixed assets at the end of the year, thousand UAH	3741276	4525000	4808711
Depreciation amount at the end of the year, thousand UAH	6857540	7431205	7722074
Absolute increase in original cost, thousand UAH	7261	1357389	574580
Absolute increase in residual value, thousand UAH	277212	783724	283711
Wear coefficient, %	64.70	62.15	61.62
Suitability coefficient, %	35.30	37.85	38.38
Growth rate at original cost, %	0.07	12.81	4.81
Growth rate on residual value, %	8.00	20.95	6.27
Average annual residual value of fixed assets, thousand UAH	3602670	4133138	4666856
Return on investment, UAH/UAH	2.40	2.60	2.74
Capital intensity, UAH/UAH	0.416	0.384	0.365
Return on fixed assets, %	33.25	44.31	26.75

The results obtained show that in 2022–2024, Obolon PJSC generally provided positive dynamics of the condition and use of fixed assets, although the intensity of their renewal at the end of the period weakened somewhat. In particular, the initial cost of fixed assets at the end of the year increased by 18.23% compared to 2022 and by 4.81% compared to 2023, and the residual value increased even more significantly - by 28.53% compared to 2022 and by 6.27% compared to 2023. This indicates an increase in the enterprise's material and technical base and a general strengthening of its production potential. At the same time, the amount of depreciation for the period also increased by 12.61%, which is a natural consequence of the operation of existing assets, however, the growth rate of the residual value outpaced the rate of depreciation accumulation, which should be assessed positively overall.

The indicators of the technical condition of fixed assets confirm this trend. Thus, the depreciation rate decreased from 64.70% to 61.62%, i.e. by 3.08 percentage points, or approximately 4.76% in relative terms, while the suitability rate increased from 35.30% to 38.38%, i.e. by 3.08 percentage points, or by 8.73%. Thus, despite the significant degree of physical and moral obsolescence of fixed assets, their qualitative condition improved somewhat in the studied period. At the same time, the indicators of asset turnover show that the most significant increase occurred in 2023, when the growth rate at original cost increased to 12.81%, while in 2024 it decreased to 4.81%, i.e., by 8.00 percentage points. Similarly, the growth rate by residual value after 20.95% in 2023 decreased to 6.27% in 2024, i.e. by 14.68 pp. This means that the process of renewal and expansion of fixed assets continued, but at a much slower pace.

The dynamics of the efficiency indicators for the use of fixed assets are positive. The average annual residual value increased by 29.52% compared to 2022 and by 12.91% compared to 2023, however, this growth was accompanied by an even higher efficiency of using assets in the process of generating revenue. In particular, the return on assets increased from 2.40 to 2.74 UAH/UAH, i.e. by 14.17% compared to 2022 and by 5.38% compared to 2023. Accordingly, capital intensity decreased by 12.26% compared to 2022 and by 4.95% compared to 2023, indicating a reduction in the need for fixed assets to generate 1 UAH of net income. This means that the enterprise not only expanded its production base, but also increased the return on its use, that is, for every hryvnia invested in fixed assets, in 2024 there was more income than in previous years.

At the same time, not all indicators had positive dynamics. The profitability of fixed assets in 2024 was 26.75%, which was 19.55% lower than in 2022 and 39.63% lower than in 2023. This change indicates that the growth in sales volumes and improvement in return on assets were not accompanied by a corresponding increase in net profit. Thus, fixed assets began to be used more efficiently for generating income, but less efficiently for final profitability, which is probably due to higher costs, an increased overall cost burden, and reduced operating margins. As a result, we can conclude that in the studied period, PrJSC "Obolon" ensured quantitative growth and improvement of the technical condition of fixed assets, as well as an increase in their production efficiency, but at the same time faced a decrease in the profitable efficiency of their use, which indicates the need for further improvement of cost management and the effectiveness of the production system.

Next, we should move on to studying working capital (Tables 2.3 and 2.4).

Analysis of the composition and structure of working capital of PrJSC "Obolon" in 2022–2024 gives grounds to assert that during the period under study, the enterprise significantly increased the volume of current assets, however, this growth was accompanied by noticeable structural shifts. The total value of working capital increased from UAH 1,994,518 thousand in 2022 to UAH 4,218,057 thousand in 2024, i.e. by 111.48%, and compared to 2023 - by 33.29%.

This indicates a significant expansion of the resource base supporting the enterprise's current activities, and at the same time an increasing need to finance the operating cycle.

The largest share of working capital throughout the period was held by inventories, which is typical of a manufacturing enterprise with a material-intensive technological process. Their value increased by 71.81% compared to 2022 and by 9.84% compared to 2023, however, the share in the composition of current assets decreased from 49.27% to 40.02%. Such dynamics indicate that, despite the absolute increase in inventories, other elements of working capital grew faster. This may indicate the simultaneous influence of several factors: the need to build larger production inventories in conditions of unstable supply, rising prices for raw materials and finished goods, as well as an increase in the role of financial and settlement components in ensuring current operations. A decrease in the share of inventories in the structure of working capital with their absolute growth generally indicates not a weakening of the production function, but a structural expansion of other components of current assets.

Table 2.3

Composition and structure of working capital of Obolon PJSC in 2022–2024.

Working capital element	2022, thousand UAH	Specific gravity, %	2023, thousand UAH	Specific gravity, %	2024, thousand UAH	Specific gravity, %	Abs. deviation 2024/2022, thousand UAH	Abs. deviation 2024/2023, thousand UAH	Relative deviation 2024/2022, %	Relative deviation 2024/2023, %
Stocks	982646	49.27	1537020	48.57	1688266	40.02	705,620	151246	71.81	9.84
Accounts receivable for products, goods, works, services	650854	32.63	947078	29.93	1154958	27.38	504104	207880	77.45	21.95
Prepayments and other current assets (lines 1130, 1135, 1190)	204909	10.27	188195	5.95	466652	11.06	261743	278457	127.74	147.96
Other current receivables	17362	0.87	17572	0.56	17147	0.41	-215	-425	-1.24	-2.42
Money and its equivalents	138747	6.96	474679	15.00	891034	21.12	752287	416355	542.20	87.71
Total working capital	1994518	100.00	3164544	100.00	4218057	100.00	2223539	1053513	111.48	33.29

Table 2.4

Indicators of the efficiency of the use of working capital of Obolon PJSC in 2022–2024.

Indicator	2022	2023	2024	Absolute deviation 2024/2022	Absolute deviation 2024/2023	Relative deviation 2024/2022, %	Relative deviation 2024/2023, %
Net income from product sales, thousand UAH	8661928	10763029	12784705	4122777	2021676	47.60	18.78
Net profit, thousand UAH	1197966	1831590	1248255	50289	-583335	4.20	-31.85
Average annual cost of working capital, thousand UAH	1994518	3164544	4218057	2223539	1053513	111.48	33.29
Working capital turnover ratio, rev./year	4.34	3.40	3.03	-1.31	-0.37	-30.21	-10.88
Working capital load ratio, UAH/UAH	0.2303	0.2940	0.3299	0.0997	0.0359	43.28	12.21
Duration of one revolution, days	84.05	107.32	120.42	36.38	13.11	43.28	12.21
Return on working capital, %	60.06	57.88	29.59	-30.47	-28.29	-50.73	-48.87

An important component of working capital was accounts receivable for products, goods, works, and services. Its volume during the studied period increased by 77.45%, and compared to 2023 - by 21.95%. At the same time, the specific weight of this item decreased from 32.63% in 2022 to 27.38% in 2024. This trend indicates an expansion in the scale of sales on deferred payment terms, a typical consequence of the intensification of commercial activity and the need to maintain competitive positions in the market. At the same time, an increase in accounts receivable means diverting part of the funds from circulation and can therefore create an additional burden on liquidity and slow down the turnover of current assets. A decrease in its share in the overall structure indicates that accounts receivable did not grow as fast as other components, primarily cash and other current assets.

Particularly noticeable is the dynamics of the item "Prepayments and other current assets", whose value increased by 127.74% compared to 2022 and by 147.96% compared to 2023. Its share, which decreased to 5.95% in 2023, increased to 11.06% in 2024. Such changes may indicate a significant increase in the advance payment of current operations, the expansion of prepayment settlements, the accumulation of tax or other current assets related to the provision of production and sales activities. The growth of this component, on the one hand, demonstrates the enterprise's activity in maintaining the continuity of the operational process, and, on the other hand, indicates an additional diversion of funds that temporarily do not directly contribute to the formation of cash receipts.

Other current receivables remained insignificant in volume, and their share in the structure of working capital decreased from 0.87% to 0.41%. The absolute reduction of this item is minimal, but the trend itself is positive, as it indicates the absence of a significant accumulation of secondary settlement requirements and, accordingly, a relatively restrained level of immobilization of resources in illiquid elements of current assets.

The most dynamic growth was demonstrated by cash and cash equivalents. Their volume in 2024 increased by 542.20% compared to 2022, and by 87.71% compared to 2023, while the share in the structure of working capital increased from

6.96% to 21.12%. This is one of the most important structural changes in the period under study. Such dynamics may indicate a strengthening of the company's liquidity position, the accumulation of free cash resources, a change in financial policy to increase solvency, and the formation of a financial stability reserve in an unstable external environment. At the same time, an excessive increase in the share of cash may also indicate that part of the resources is temporarily not involved in active operational turnover, which requires additional assessment of the optimality of the current asset structure.

Summarizing the results of the analysis, it should be noted that in 2022-2024 the structure of working capital of PrJSC "Obolon" underwent a significant transformation. If at the beginning of the period it was more concentrated in inventories and receivables, then in 2024 the role of cash and other current assets increased significantly. This indicates a complication of the structure of current assets and a change in priorities in their formation. On the one hand, such a trend can be considered a result of the enterprise's adaptation to changes in the external environment, increased attention to solvency, and the need to ensure the continuity of the production process. On the other hand, an increase in working capital volume, as well as in settlement and advance components, creates a risk of slowing turnover and increasing the need for additional financing of current activities. Therefore, the results obtained give reason to believe that it is relevant for the enterprise not only to increase working capital, but also to improve the management of their structure in order to ensure greater turnover speed, liquidity and overall economic efficiency.

Analysis of indicators of the efficiency of working capital use at PrJSC "Obolon" for 2022-2024 shows that during the period under study, the enterprise significantly increased the volume of current assets, but this was not accompanied by a corresponding increase in their effectiveness. The general trend is that working capital grew faster than net income from sales, resulting in a gradual decrease in the efficiency of their functioning in the operating cycle. This means that, to ensure each additional hryvnia in sales, the enterprise needed to attract an increasingly large amount of working capital.

First of all, this is indicated by a decrease in the working capital turnover ratio. Its dynamics indicate a slowdown in the speed of funds through the supply, production, sale, and cash return stages. In other words, resources have become more long-term in circulation, a sign of a decrease in the mobility of current assets. This situation may be associated with increased inventories, increased receivables, complications in logistics processes, and an increased need to form insurance reserves in an unstable external environment. For an enterprise, this means that part of the funds remains diverted from active cash circulation for a longer time, and therefore, the need for additional financing of current activities increases.

The logical consequence of this was an increase in the working capital utilization ratio. If turnover slows, more working assets are required to generate a unit of income. In practical terms, this means an increase in the capital intensity of current activities. The enterprise is forced to allocate larger amounts of resources to inventories, settlements, and other elements of working capital to maintain the existing scale of operating activities. This trend is not critical in itself, but it indicates a decrease in the economic return on current assets and requires tighter control over their structure and turnover rate.

Another important indicator is the increase in the duration of one turnover. The lengthening of the operating cycle means that more time passes between the investment in current assets and their return as revenue. This negatively affects liquidity, reduces flexibility in decision-making, and can create an additional burden on the enterprise's financial stability. This is especially important for a manufacturing enterprise, where the continuity of supply, production and sales directly depends on the adequacy of working capital. Accordingly, the slowdown of one turnover not only worsens current efficiency, but also increases the risk of a shortage of free resources for a prompt response to market changes.

The dynamics of the profitability of working capital is particularly indicative. Despite increased activity, the return on current assets has significantly decreased. This means that each hryvnia invested in working capital in 2024 yielded the enterprise a significantly lower net profit than in previous years. The cause-and-effect relationship here is quite obvious: on the one hand, the volume of resources involved in turnover has increased, and on the other hand, the growth rate of profit turned out to be much weaker, and in 2024, the net profit even decreased significantly compared to the previous year. As a result, this led to a sharp deterioration in the profitable efficiency of working capital use.

The totality of the indicators considered allows us to conclude that during the studied period, PrJSC "Obolon" did not face a deficit of working capital, but rather a problem with the reduction in its effectiveness. The enterprise increased current assets, supporting the expansion of operating activities, however, the speed of their turnover decreased, and the economic return worsened. This indicates the need to improve working capital management, in particular in terms of optimizing inventories, accelerating the collection of receivables, increasing the balance of the structure of working assets and strengthening cost control. Therefore, the key task for the enterprise is not only to maintain a sufficient amount of working capital, but also to ensure their faster and more profitable turnover.

An assessment of the composition, dynamics, and structure of an enterprise's operating costs allows us to understand or confirm its tendency toward a material-intensive type of production (Table 2.5).

Analysis of the composition, dynamics, and structure of operating expenses of PrJSC "Obolon" in 2022–2024 shows that the enterprise operated in conditions of a noticeable increase in the total cost burden, with the production component remaining the main driver of this growth. By its economic nature, the model of the enterprise's operating expenses is clearly production-oriented, since the predominant share of their structure throughout the entire period was stably accounted for by the cost of products sold. This means that the enterprise's financial result depended to the greatest extent on the levels of material, energy, technological, and logistical costs associated with manufacturing and bringing products to the stage of sale.

Table 2.5

Composition, dynamics and structure of operating expenses of Obolon PJSC in 2022–2024.

Operating expense item	2022, thousand UAH	Structure, %	2023, thousand UAH	Structure, %	2024, thousand UAH	Structure, %	Absolute deviation 2024/2022, thousand UAH	Absolute deviation 2024/2023, thousand UAH	Relative deviation 2024/2022, %	Relative deviation 2024/2023, %
Cost of goods sold	6030487	86.07	7500990	86.37	9800435	86.05	3769948	2299445	62.51	30.66
Administrative costs	376851	5.38	458709	5.28	531853	4.67	155002	73144	41.13	15.95
Selling expenses	542663	7.75	670728	7.72	956097	8.39	413434	285369	76.19	42.55
Other operating expenses	56526	0.81	54768	0.63	101074	0.89	44548	46306	78.81	84.55
Total operating expenses	7006527	100.00	8685195	100.00	11389459	100.00	4382932	2704264	62.55	31.14

The most important conclusion is that the total amount of operating expenses grew faster than the scale of the enterprise's activities, and therefore the expansion of sales volumes was not accompanied by a proportional increase in cost efficiency. Such dynamics indicate an increase in pressure on the operating margin: each additional hryvnia of income required increasingly large expenses for its formation. In practical terms, this means that the enterprise, even while maintaining a stable market position and increasing sales volumes, simultaneously lost part of its financial returns due to rising operating costs. The main reason for this was the outstripping growth in cost, which actually determines the general nature of the company's cost model.

The dominance of cost of goods sold in the structure of operating expenses indicates the enterprise's high sensitivity to changes in the costs of raw materials, packaging, transport support, and production services. The fact that its share remained almost unchanged indicates the preservation of the overall cost configuration, but at the same time shows that the production stage remained the main focus of cost pressure. In other words, the problem was not so much in changing the structure of operating expenses as in the general increase in their absolute level within the already formed production model. That is why any fluctuations in resource prices or an increase in production costs directly transformed into a weakening of the profitability of the activity.

A certain positive signal is observed in the dynamics of administrative expenses. Despite their absolute growth, their share of total operating expenses gradually decreased. This may indicate relative restraint in administrative expenses and the absence of excessive expansion of the administrative apparatus relative to the scale of operating activities. That is, the enterprise did not lose efficiency primarily due to the general management system, and the main pressure on the results was at the production and sales levels. A decrease in the specific weight of administrative expenses can be seen as a sign of a more rational allocation of resources, but it was not enough to offset the overall increase in costs and commercial expenses.

Special attention is paid to the dynamics of sales costs, whose share in operating costs has increased. This indicates a strengthening of the commercial component in

PrJSC "Obolon" 's activities. Such a trend may be associated with the expansion of logistics routes, the complication of delivery conditions, the increase in transport tariffs, the increase in costs for product promotion, maintenance of sales infrastructure and the adaptation of sales channels to new market conditions. In a causal sense, this means the company was forced to spend more resources not only on manufacturing products but also on promoting them to the end consumer. On the one hand, such dynamics may indicate an active struggle for the market and maintaining sales volumes, on the other hand, it increases the overall burden on the operating result, especially if the growth rate of sales costs outpaces the growth of marginal income.

Although other operating expenses occupied a minor place in the overall structure, their accelerated growth at the end of the period is also indicative. This indicates the emergence or strengthening of additional operating factors that previously had little impact on the overall financial result but began to play a more noticeable role in 2024. Since this item usually covers expenses of a heterogeneous nature, its increase can be considered an indicator of the complexity of the enterprise's external and internal operating conditions. Even with a small specific weight, such dynamics are important, since they reflect the accumulation of additional current expenses that are not directly related to either the production process or classic administrative functions, but still reduce the financial result from operating activities.

Summarizing the results, it is appropriate to note that in 2022–2024, PrJSC "Obolon" maintained a stable structure of operating expenses, however, this structure functioned in conditions of a significant increase in the cost of operating activities. The production component remained decisive, administrative expenses were relatively restrained, however, the sales component was strengthened, and other operating expenses showed signs of increasing instability. As a result, the key problem of the enterprise was not the disproportionality of the cost structure as such, but the general increase in their absolute level and the insufficient compensation of this growth by income. That is why the enterprise's operating model during the studied period required not so much a radical change in the cost structure as increased control over the most resource-intensive items, primarily cost of goods sold and sales expenses.

An analysis of the composition, dynamics and structure of operating expenses of Obolon PJSC by elements is presented in Table 2.6.

Analysis of the composition, dynamics, and structure of operating expenses of PrJSC "Obolon" by elements shows that during 2022-2024 the enterprise operated in conditions of steady growth in total expenses, which was not random but systemic. The total value of operating expense elements during the studied period increased significantly, reflecting both the expansion of the enterprise's activities and increased cost pressure across all key components of the operational process. At the same time, the changes concerned not only the absolute volumes of expenses but also their internal structure, enabling a deeper assessment of the transformation of the enterprise's cost model.

The largest share of the structure of operating expenses elements throughout the entire period was consistently accounted for by material costs. Their predominance is natural for a manufacturing enterprise, whose activity directly depends on the use of raw materials, auxiliary materials, packaging, fuel and energy resources, and other components of the production cycle. The dominance of this item indicates the high material intensity of the activities of PrJSC "Obolon" and at the same time the significant sensitivity of the results of its operation to changes in resource prices.

Although the share of material costs in the cost structure decreased somewhat over the period, in absolute terms they increased significantly. This means that the company continued to operate in conditions of rising resource prices, but in structural terms other cost elements began to grow even faster. Thus, the company did not reduce its dependence on material resources, but the cost model itself became more complex and multi-component.

The second important area of analysis is labor costs. Their absolute growth indicates an increase in the cost of labor resources, which may be associated both with general economic inflationary processes and with the need to retain qualified personnel, adapt the motivation system and compensate for personnel risks.

Table 2.6

Assessment of the composition, dynamics and structure of operating expenses of Obolon PJSC by operating expense elements for 2022–2024.

Operating cost elements	2022, thousand UAH	Structure, %	2023, thousand UAH	Structure, %	2024, thousand UAH	Structure, %	Absolute deviation 2024/2022, thousand UAH	Absolute deviation 2024/2023, thousand UAH	Relative deviation 2024/2022, %	Relative deviation 2024/2023, %
Material costs	3373782	57.45	4124933	57.62	5164530	55.38	1790748	1039597	53.08	25.20
Labor costs	656949	11.19	784366	10.96	966878	10.37	309929	182512	47.18	23.27
Deductions for social events	144490	2.46	161241	2.25	200297	2.15	55807	39056	38.62	24.22
Amortization	313993	5.35	441293	6.16	492687	5.28	178694	51394	56.91	11.65
Other operating expenses	1383799	23.56	1646553	23.00	2501790	26.83	1117991	855237	80.79	51.94
Together	5873013	100.00	7158386	100.00	9326182	100.00	3453169	2167796	58.80	30.28

At the same time, the share of labor costs in the total amount of operating cost elements gradually decreased. This indicates that the labor factor, although it remained important, was not the main source of accelerated cost growth. In the causal aspect, such a trend may mean that the enterprise was relatively restrained in increasing personnel costs compared to material and other operating components, and therefore the main pressure on the cost price was formed not so much through labor costs, but through resource-technological and related costs.

A similar logic is reflected in the dynamics of social security contributions. Their changes are derived from the movement of labor costs, so the growth of this item seems natural. However, as in the case of labor costs, its share in the cost structure gradually decreased. This means that social contributions were not a determining factor in the overall cost burden. Such dynamics emphasise that the centre of cost pressure was moving towards resource, technological, and related operating costs, rather than into the sphere of social and labour payments.

Special attention should be paid to depreciation. Its growth in absolute terms indicates a significant production base, the renewal or revaluation of individual fixed assets, and an increase in the role of the capital-intensive component in operational activities. The fact that the share of depreciation in the overall cost structure did not demonstrate a stable upward trend means that there was no sharp transformation of the cost model in the direction of excessive capitalization. In other words, the enterprise increased or maintained the cost of fixed assets, while depreciation grew more moderately than other cost elements. This gives reason to believe that technical support for activities remained important, but did not become the main source of growth in operating expenses in the period under study.

The most indicative from the standpoint of structural shifts is the dynamics of other operating expenses. It is this item that has demonstrated the most noticeable increase in its share in the total amount of cost elements. This trend indicates an increase in the influence of heterogeneous factors that are not directly included in material costs, wages, social charges, or depreciation, but are increasingly shaping the enterprise's cost profile. This may be a consequence of the complexity of logistics, an increase in the cost of servicing operational activities, an increase in the cost of third-party services, changes in business conditions, or the emergence of additional costs associated with the enterprise's adaptation to an unstable external environment. In the structural dimension, the growth of this item indicates that the cost system of the enterprise has become less homogeneous, and the formation of the final result is increasingly influenced not only by classical production factors, but also by a wider range of related operational factors.

In general, the structure of operating cost elements gives grounds to assert that PrJSC "Obolon" retained the production-oriented nature of its activities, however, important internal changes took place within this model. If at the beginning of the period the cost system was more concentrated on the material component, then later the role of other operating costs increased, while the share of labor and social elements decreased somewhat. This means the enterprise faced not only the traditional challenges of material-intensive production but also increased costs due to the general complexity of the operating environment.

Thus, the analysis indicates that the main feature of the cost dynamics of PrJSC "Obolon" in 2022-2024 was the combination of maintaining a material-intensive production model with a gradual strengthening of the role of other operational components. This allows us to conclude that the enterprise needs not only control over traditional resource costs, but also more detailed management of costs arising outside the basic production elements. This approach is necessary to increase overall cost efficiency and enhance economic performance in subsequent periods.

An important aspect is the enterprise's investment activity. In previous years, the company has modernized production lines, introduced energy-saving equipment and optimized logistics processes. This indicates the presence of a long-term development strategy, within which increasing energy efficiency can be considered as a tool for reducing costs and increasing competitiveness.

Energy costs are a significant component of operating costs of food industry enterprises, in particular in the production of beer and soft drinks, where technological processes are associated with heating, cooling, pasteurization and continuous operation of automated lines. For PrJSC "Obolon", the structure of energy costs is complex and includes electricity, natural gas, thermal energy, water, and fuel for internal logistics (Table 2.7).

In the overall structure of production costs, the share of energy costs, according to industry statistics, can range from 8 to 15%, depending on the technological equipment and level of automation of the enterprise. The results obtained show that in 2022-2024, the material and energy component of the costs of PrJSC "Obolon" was characterized by a steady growth trend, reflecting both the expansion of the scale of the enterprise's operational activities and the increase in the resource load on the production process. The total amount of material and energy costs for the period under study increased by 66.04%, and compared to 2023 - by 27.78%, which indicates a significant increase in the cost of resource support for activities. At the same time, the basis of this block throughout the entire period was formed by costs for raw materials and supplies, the share of which remained dominant, although it gradually decreased: from 89.12% in 2022 to 82.16% in 2024. This means that the enterprise retained a distinctly material-intensive nature of production, however, within this cost component, the role of energy costs increased.

The most significant trend was the rapid rise in energy costs. In 2022-2024, their volume increased by 172.20%, and compared to 2023, by another 41.15%. As a result, their share in the material and energy block increased from 10.88% to 17.84%, an increase of 6.96 percentage points. Such dynamics indicate that the energy component has become one of the most significant factors driving the enterprise's cost growth. If at the beginning of the period the main pressure on costs was driven mainly by the raw material component, then in 2024 the costs of water, gas, steam, and electricity began to play an increasingly significant role. Therefore, changes in the structure of material and energy costs indicate an increase in the energy intensity of the enterprise's cost model or, at least, an increase in the impact of energy resource costs on the overall financial result.

Table 2.7

Composition, dynamics and structure of the material and energy component of expenses of PrJSC "Obolon" in 2022-2024.

Expense items	2022, thousand UAH	Specific weight in the material and energy block, %	2023, thousand UAH	Specific weight in the material and energy block, %	2024, thousand UAH	Specific weight in the material and energy block, %	Absolute deviation 2024/2022, thousand UAH	Absolute deviation 2024/2023, thousand UAH	Relative deviation 2024/2022, %	Relative deviation 2024/2023, %
Raw materials and supplies	3373782	89.12	4124933	83.85	5164530	82.16	1790748	1039597	53.08	25.20
Energy costs (water, gas, steam, electricity)	411997	10.88	794515	16.15	1121452	17.84	709455	326937	172.20	41.15
Total material and energy component	3785779	100.00	4919448	100.00	6285982	100.00	2500203	1366534	66.04	27.78

Summing up, it is appropriate to note that during the studied period, PrJSC "Obolon" not only increased the material and resource support of production, but also faced an outpacing increase in energy costs. This allows us to conclude that the energy component is gradually becoming one of the key factors in cost pressure on the enterprise. Accordingly, further improvement of the economic efficiency of PrJSC "Obolon" should be associated not only with control of costs for raw materials and materials, but also with increased attention to the rational use of energy resources, since it is in this area that the most pronounced structural changes are observed.

To systematise energy costs, it is advisable to consider their structure by type of resource (Table 2.8).

Table 2.8

Structure of energy costs of the enterprise

Type of energy resource	Main areas of use	Share in total energy costs (approximate)
Electricity	Production line operation, refrigeration equipment, lighting	38
Natural gas	Wort heating, boiler plants	27
Thermal energy	Pasteurization, washing, sterilization	21
Water (as a resource)	Technological processes and cooling	9
Fuel and lubricants	Internal logistics	5

As can be seen from Table 2.8, the greatest load falls on electricity and natural gas. Electricity is used at almost all stages of the production cycle - from malt grinding to bottling of finished products. A significant share of consumption is formed by refrigeration units, which operate continuously to maintain temperature parameters of fermentation and storage.

Natural gas is used primarily for cooking and for boiler operation. Its consumption is seasonal and depends on ambient temperature conditions and production volumes.

Analysis of cost dynamics shows that, under rising tariffs, the energy component of product costs tends to increase even with relatively stable physical consumption volumes. This means that increasing energy efficiency becomes not only a tool for reducing costs, but also a mechanism for minimizing financial risks.

An important aspect is the ratio between fixed and variable energy costs. Some costs (lighting, cooling systems, minimum technological modes) are relatively constant, while heating and pasteurization costs directly depend on production volumes. Thus, increasing the utilization of production capacities contributes to reducing specific energy costs per unit of production.

To assess the impact of energy costs on cost, it is advisable to use the specific energy consumption indicator:

$$e_c = \frac{C_{energy}}{Q}\text{d}$$

where:

C_{energy}– total costs of the enterprise for energy resources in monetary terms;

Q– the volume of products produced (in physical units or in monetary equivalent).

Reducing this indicator is a strategic goal of energy management, as it directly affects the enterprise's competitiveness.

Analysis of the cost structure also allows us to identify the enterprise's most energy-intensive divisions. As a rule, these include the brewing plant, the refrigeration plant, and the pasteurization section. It is these areas that form the main potential for implementing energy-saving measures - modernization of heat exchangers, heat recovery, and optimization of compressor operating modes.

2.2. Analysis of energy consumption of the production system

Analysis of the energy balance structure is a key stage in the study of the energy efficiency management system of the production activities of PrJSC "Obolon" as it allows to determine the sources of energy resources, directions of their use and the ratio between individual types of energy. The energy balance reflects the quantitative and qualitative parameters of the enterprise's energy consumption and serves as the basis for identifying opportunities to improve efficiency.

Given the specifics of beer and soft drinks production, the energy balance of the enterprise is multi-component and includes the following main types of energy resources:

electricity;

natural gas;

thermal energy (own or centralized production);

water as an energy carrier in cooling systems;

fuels and lubricants.

Structurally, the energy balance can be considered in two aspects: by types of energy resources (input balance) and by areas of their consumption (internal distribution).

1. Structure of the energy balance by type of energy resources

In the enterprise's total energy consumption, the largest share is electricity, used to operate technological equipment, compressors, pumps, refrigeration units, automated bottling lines, and lighting systems. The second place in terms of specific weight is occupied by natural gas, which is used for cooking and in boiler plants to produce thermal energy.

The generalized structure of the energy balance is presented in Table 2.9.

Table 2.9

Approximate structure of the enterprise's energy balance by type of resources

Type of energy resource	Main purpose	Share in total energy consumption
Electricity	Technological equipment, cooling	20
Natural gas	Cooking processes, boiler rooms	42
Thermal energy	Pasteurization, sanitation	33
Fuel	Domestic transport	5

As can be seen from Table 2.3, the structure of the energy balance is characterized by the dominance of electricity and gas, which is due to the high level of automation of production and the need to maintain stable temperature regimes.

2. Internal distribution of energy consumption

Internal distribution analysis allows you to identify the most energy-intensive units of the production system. These include:

brewing shop (heating and boiling processes);

refrigeration (maintaining fermentation temperature);

pasteurization and sterilization area;

compressor stations;

water treatment system.

Significant energy consumption in refrigeration systems is driven by the need for continuous product cooling and the maintenance of stable technological parameters. In the summer, the load on these systems increases, which leads to seasonal fluctuations in the energy balance.

3. Balance of primary and secondary energy

A separate aspect of the analysis is the ratio of primary and secondary energy. By implementing heat recovery systems or using waste heat from boilers, the enterprise can partially replace primary energy consumption. The presence of such systems reduces the total consumption and increases the energy efficiency coefficient of the production cycle.

4. Seasonal and production variability of the energy balance

The structure of the energy balance varies with production volumes and seasonal demand. During peak load periods, electricity and natural gas consumption increases, while in the off-season the share of fixed energy costs becomes more significant. Such variability requires flexible management of equipment operating modes.

Thus, the structure of the enterprise's energy balance is characterized by:

multicomponent nature of energy sources;

the dominance of electricity and natural gas;

high share of energy consumption in technological processes;

seasonal load dynamics;

the presence of the potential for replacing primary energy with secondary resources.

Energy balance analysis provides a basis for further research into the dynamics of energy intensity indicators and the efficiency of resource use.

Assessing the dynamics of energy intensity indicators enables us to determine the efficiency of energy resource use in PJSC "OBOLON" 's production system and identify trends in specific energy consumption relative to output volumes. Unlike absolute consumption indicators, energy intensity reflects the level of rational use of energy resources and is a more informative indicator for strategic analysis.

The basic indicator for assessing efficiency is the total energy intensity of production:

$$EI = \frac{E_{total}}{Q}$$

where:

E_{total}– total consumption of energy resources for the reporting period (in terms of energy units, for example, kWh, GJ or tons of equivalent fuel - tcf);

Q– the volume of products produced in kind or monetary terms.

The dynamics of energy costs is presented in Table 2.10.

The results obtained show that in 2022-2024, the energy costs of PrJSC "Obolon" grew rapidly and gradually increased their impact on the overall level of the enterprise's costs. Their absolute volume during the period under study increased by 709,455 thousand UAH, or by 172.20%, and compared to 2023 - by another 326,937 thousand UAH, or by 41.15%. Such dynamics indicate not only an increase in the price of energy resources, but also an increase in the energy component's role in ensuring the enterprise's production and sales processes.

It is significant that energy costs grew faster than total production and sales costs. As a result, their share of total costs increased from 5.67% in 2022 to 9.84% in 2024, an increase of 4.17 percentage points. This means that the energy factor has become one of the most noticeable sources of cost pressure on the enterprise. If at the beginning of the period its impact was relatively moderate, then at the end of the studied interval it acquired much greater importance in the formation of costs and the overall financial result.

Table 2.10

Dynamics and role of energy costs of PJSC "Obolon" in 2022-2024.

Indicator	2022	2023	2024	Absolute deviation 2024/2022	Absolute deviation 2024/2023	Relative deviation 2024/2022, %	Relative deviation 2024/2023, %
Energy costs (water, gas, steam, electricity), thousand UAH	411997	794515	1121452	709455	326937	172.20	41.15
Share of energy costs in total production and sales costs, %	5.67	9.12	9.84	4.17 pp.	0.72 pp.	73.54	7.89
Share of energy costs in the material and energy block, %	10.88	16.15	17.84	6.96 pp.	1.69 pp.	63.98	10.46
Energy costs per 1 UAH of net sales revenue, UAH	0.0476	0.0738	0.0877	0.0402	0.0139	84.42	18.83

A similar trend is observed within the material and energy cost block. The share of energy costs in its structure increased from 10.88% to 17.84%, i.e. by 6.96 percentage points. This indicates that structural shifts in favor of the energy component took place within the resource component of costs. In other words, along with traditionally significant costs for raw materials and materials, the cost of water, gas, steam and electricity became increasingly significant. Thus, the enterprise faced not only a general increase in costs but also a transformation of its internal structure, in which energy resources took on a much more important role.

The increase in energy costs per UAH 1 of net sales revenue is particularly significant. An increase in this indicator from UAH 0.0476 to UAH 0.0877 means that to generate each UAH of revenue in 2024, the company spent almost twice as much on energy resources as in 2022. This indicates a decrease in the energy efficiency of the cost model and an increase in the dependence of performance results on the cost of energy resources. Such dynamics may be a consequence of both an increase in tariffs and prices for energy carriers, and insufficiently rapid adaptation of production processes to new energy consumption conditions.

In summary, it should be noted that in 2022-2024, the energy costs of PrJSC "Obolon" have become one of the key factors in the formation of the cost burden. Their accelerated growth, an increase in the share in general and material and energy costs, as well as an increase in energy costs per unit of income indicate an increase in the importance of the energy component in the enterprise's efficiency management system. Therefore, further improvement in the effectiveness of the activities of PrJSC "Obolon" should be largely associated with the implementation of measures aimed at rationalizing energy consumption, reducing the energy intensity of production and improving energy cost management.

Additionally, it is advisable to analyze energy intensity by individual types of resources:

electrical capacity (kWh per 1 dal of product);

gas capacity (m^3 of gas per 1 daL of product);

thermal energy intensity (Gcal per unit of output).

1. General trend of energy intensity change

Analysis of the dynamics of indicators in recent years shows that, under the conditions of modernization of equipment and optimization of production processes, the enterprise demonstrates a gradual decrease in specific electricity consumption per unit of output. At the same time, fluctuations in production volumes and the seasonal nature of demand affect annual indicators.

During periods of reduced capacity utilisation, there is an increase in specific energy intensity due to the presence of conditionally constant costs (lighting, basic refrigeration system operation, and minimum technological modes). On the contrary, during the summer period, with increased production volumes, a scaling effect occurs, leading to a decrease in specific indicators.

A generalized description of the changes is given in Table 2.11.

Table 2.11

Trends in changes in energy intensity of production

Indicator	Nature of change	Impact factor
Total energy consumption	Moderate decrease	Equipment modernization
Capacitance	Relative stability with a decreasing trend	Automation, load optimization
Gas capacity	Fluctuations depending on production volumes	Seasonality, temperature regime
Thermal energy capacity	Gradual decrease	Improvement of heat exchange processes

As shown in Table 2.11, the electric capacity is the most stable, while the gas capacity is more sensitive to external factors.

2. The impact of technological changes on the dynamics of indicators

The gradual decrease in specific energy consumption is associated with:

introduction of modern cooking systems with improved heat exchange;

modernization of compressor equipment;

optimization of operating modes of refrigeration units;

improving automatic control systems.

A special role is played by increasing the equipment utilization factor. With a more even distribution of production volumes throughout the year, the share of unproductive energy consumption decreases.

3. Benchmarking of industry indicators

Compared to the industry average, the energy intensity of production meets modern technological standards. At the same time, the potential for further reduction remains through the implementation of recuperation systems and digital consumption monitoring.

4. Relationship between energy intensity and financial results

Reducing specific energy consumption improves the gross profitability of products. Given the increase in tariffs, even a slight reduction in energy intensity can yield a significant economic impact. Thus, the dynamics of energy intensity is an indicator not only of the technical but also of the economic efficiency of the production system.

The analysis conducted allows us to draw the following conclusions:

energy intensity indicators tend to gradually decrease;

seasonal fluctuations affect specific values;

modernization of equipment contributes to the stabilization of electrical capacity;

The potential for reduction remains in thermal processes and recovery.

Therefore, the dynamics of energy intensity indicators indicate positive changes in the direction of increasing the efficiency of energy resources use, while maintaining reserves for further optimization.

Analysis of the structure of the energy balance and the dynamics of energy intensity indicators of production of PrJSC "Obolon" allows us to proceed to the determination of internal reserves for increasing energy efficiency. Reserves are considered unused opportunities to reduce specific energy consumption without reducing production volumes or deteriorating product quality.

In the context of rising energy costs and increasing environmental requirements, systematic identification of reserves becomes strategically important.

Based on the analysis, it is advisable to distinguish technical, organizational and managerial reserves.

1. Technical reserves

The greatest potential for reducing energy consumption is concentrated in technologically energy-intensive units - the brewing plant, refrigeration facilities, and pasteurization systems.

The main technical reserves include:

modernization of heat exchangers with an increased heat transfer coefficient;

implementation of heat recovery systems for cooking processes;

optimization of compressor equipment operation;

replacement of pumps and fans with energy-saving models with frequency control;

improving the insulation of heating mains and tanks.

A separate direction is to increase the efficiency of refrigeration units. The use of modern automatic temperature control systems allows minimizing excess electricity consumption during peak periods.

2. Organizational reserves

The analysis showed that part of the energy consumption is conditionally constant. Optimization of production line schedules and more uniform capacity utilization can ensure a reduction in specific energy intensity.

Organizational reserves include:

adjustment of production schedules taking into account tariff zones;

reducing equipment downtime;

improving internal logistics;

implementation of energy monitoring at the shop level.

An important reserve is to reduce water losses, since water treatment and pumping also require significant energy costs.

3. Management reserves

Management reserves are associated with improving the control and accounting systems for energy consumption. The availability of detailed analytics by responsibility centers allows for more accurate identification of sources of overspending.

Management reserves include:

implementation of an automated system for collecting data on energy consumption;

formation of energy KPIs for department heads;

regular energy audit;

training staff in the principles of economical use of resources.

4. General description of reserves

To systematize the identified opportunities, it is advisable to present them in the form of a table (Table 2.12).

Table 2.12

Main reserves for increasing the energy efficiency of the production system

Reserves group	Specific measures	Expected result
Technical	Heat recovery, pump modernization	Reduction in energy consumption by 5–15%
Organizational	Optimization of work schedules	Reduction of unit costs
Management	Automated monitoring	Increasing transparency and control
Innovative	Smart energy management integration	Long-term optimization

As shown in Table 2.12, the potential to reduce energy consumption arises from a combination of technical and management solutions.

5. Quantifying potential

Based on industry estimates, brewing companies can achieve a total reduction in energy consumption of 10–20% if energy-saving measures are comprehensively implemented. In the case of the company under study, this means the possibility of significantly reducing operating costs and increasing production profitability.

Thus, the analysis revealed significant internal reserves for increasing the energy efficiency of the production system. The main potential is concentrated in the field of thermal processes, refrigeration equipment and the organization of production modes. The comprehensive implementation of the identified reserves creates the prerequisites for the formation of an innovative energy efficiency management strategy, which will be considered in the subsequent sections of section 2.

2.3. Assessment of the existing energy efficiency management system

The assessment of the existing energy efficiency management system involves analysing the energy innovations implemented in PJSC "OBOLON" 's production activities. The implemented technical and organizational solutions form the practical basis of the enterprise's energy policy and determine the level of its adaptation to the conditions of increasing energy resource costs.

The enterprise has been gradually modernizing its technological equipment in recent years. In particular, some of the cooking systems have been updated to increase heat transfer coefficient, reducing natural gas consumption during wort boiling. The use of modern heat exchangers has contributed to reducing heat losses and stabilizing temperature regimes.

An important area of innovation is the modernization of refrigeration. The installation of energy-efficient compressors and the introduction of automated temperature control have allowed to optimize electricity consumption during peak periods. The reduction of excess cooling and more precise maintenance of technological parameters have had a positive impact on specific electrical capacity indicators.

A separate measure was the use of frequency converters in pumping and ventilation equipment systems. Adjusting motor rotation speed based on actual load reduces energy consumption and extends equipment service life. This approach meets modern standards of energy-saving production.

At the infrastructure level, lighting systems were modernized with the transition to LED technology. This made it possible to reduce electricity costs for auxiliary needs and lower maintenance costs.

Some attention is paid to the use of secondary energy resources. Elements of heat recovery have been implemented in the production cycle, in particular the reuse of thermal energy after pasteurization processes. Although the scale of such measures remains limited, they form the basis for further development of energy-efficient solutions.

Organizational innovations include improving the energy accounting system. Consumption distribution by divisions has been introduced, which allows determining responsibility centers and assessing the efficiency of individual technological processes. This approach increases management transparency and contributes to the formation of energy discipline.

The nature of the implemented energy innovations can be systematized (Table 2.13).

Table 2.13

Main energy innovations implemented at the enterprise

Direction	The essence of the event	Impact on energy consumption
Modernization of cooking equipment	Improved heat exchangers	Reducing gas capacity
Refrigeration system upgrades	Energy-efficient compressors	Reduction of electrical capacity
Frequency control	Pump and fan control	Reduction of peak loads
LED lighting	Replacing traditional lamps	Reducing ancillary costs
Heat recovery	Reuse of thermal energy	Increasing thermal efficiency

Despite these innovations, the energy efficiency management system remains fragmented and primarily focused on local technical solutions. The lack of a comprehensive digital monitoring platform limits the ability to analyse consumption in real time. In addition, not all units are integrated into a single system of energy indicators.

In general, it can be stated that the enterprise is gradually modernizing its production system, taking into account the principles of energy efficiency. The implemented measures have provided a partial reduction in specific energy consumption, however, the potential for forming a comprehensive innovative model of energy resource management remains significant.

For a comprehensive assessment of the existing energy efficiency management system, it is advisable to apply the SWOT analysis method, which allows systematizing the internal strengths and weaknesses of the enterprise's energy policy, as well as identifying external opportunities and threats. This approach provides a strategic view of the prospects for developing energy management in the activities of PrJSC "Obolon".

The strengths are primarily associated with the availability of modernized technological equipment, a high level of production automation and the gradual introduction of energy-saving solutions. The enterprise has a developed production infrastructure, which allows implementing technical innovations without a radical restructuring of the production cycle. The presence of energy consumption accounting systems at the division level increases transparency in management and lays the groundwork for the development of energy KPIs.

Weaknesses include fragmented implementation of measures and a lack of a fully integrated digital energy consumption monitoring system. Energy policy is not always formalized in the form of a separate long-term strategy, which limits the possibility of systematic investment planning. In addition, dependence on external suppliers of electricity and natural gas increases sensitivity to tariff fluctuations.

External opportunities include the development of renewable energy technologies, the availability of support programs for energy efficiency projects, and Ukraine's integration into the European energy space. The use of grant or loan instruments can accelerate infrastructure modernization. Additional opportunities are formed through the implementation of ESG standards, which increases the investment attractiveness of the enterprise.

Among the threats, it is worth highlighting the instability of the energy market, rising tariffs, supply interruptions, and increased environmental requirements in the context of European decarbonization policies. Increasing the cost of carbon quotas and the introduction of border carbon adjustment mechanisms can increase producer costs in the event of insufficient energy efficiency.

The results of the SWOT analysis are summarized in Table 2.14.

Table 2.14

SWOT analysis of the energy policy of the enterprise

Direction	The essence of the event	Impact on energy consumption
Modernization of cooking equipment	Improved heat exchangers	Reducing gas capacity
Refrigeration system upgrades	Energy-efficient compressors	Reduction of electrical capacity
Frequency control	Pump and fan control	Reduction of peak loads
LED lighting	Replacing traditional lamps	Reducing ancillary costs
Heat recovery	Reuse of thermal energy	Increasing thermal efficiency

The analysis shows that the enterprise has sufficient internal potential for the development of energy policy, but needs to transition from local technical solutions to a strategically integrated management system. The combination of strengths with external opportunities lays the groundwork for a comprehensive innovation strategy to reduce energy intensity and increase the sustainability of the production system.

Despite the implementation of certain energy-saving measures, the energy efficiency management system of PJSC "OBOLON" faces several objective and subjective limitations that hinder achieving maximum results. The analysis allows us to identify financial, organizational, technological and external barriers.

Financial constraints are associated with the high capital intensity of innovative energy projects. The installation of cogeneration plants, large-scale recovery systems or own generating capacities requires significant investments. In conditions of market instability and demand fluctuations, the company is forced to balance investments in production expansion and the modernisation of energy infrastructure. An additional factor is the uncertainty surrounding the payback periods of projects under changing tariff policies.

Organizational barriers are manifested in the fragmentation of energy consumption management. The lack of a fully integrated digital monitoring system complicates the operational analysis of consumption by individual technological stages. Some decisions are made reactively - after identifying overspending, and not based on predictive analytics. In addition, not all divisions have clearly defined energy performance indicators.

Technological limitations are associated with the specifics of the production cycle. The processes of boiling, fermentation, and pasteurisation operate within strictly regulated temperature regimes, which limit the possibility of significantly reducing energy consumption without risking product quality. A significant portion of the equipment operates in continuous mode, providing the base load for the energy system regardless of production volumes.

Seasonality of demand creates an additional barrier to a stable reduction in energy intensity. In the off-season, the share of conditionally constant energy costs increases, which increases specific indicators. In peak periods, on the contrary, there is a risk of overloading energy systems and increasing consumption.

External barriers include fluctuating electricity and natural gas tariffs, risks of supply disruptions, and increased environmental regulation. The company remains dependent on a centralized energy infrastructure, which limits its level of autonomy. In addition, macroeconomic instability complicates long-term investment planning.

The limited use of secondary energy resources is also a problem. Although elements of recovery are already in use, their scale does not fully exploit the potential of thermal processes. Similarly, the share of renewable energy sources in the consumption structure remains insignificant.

The systematization of key barriers is given in Table 2.15.

Table 2.15

Main barriers to improving enterprise energy efficiency

Barrier group	Nature of manifestation
Financial	High capital intensity of innovations, long payback period
Organizational	Insufficient integration of monitoring systems, lack of full digitalization
Technological	Strict technological regimes, process continuity
External	Tariff instability, regulatory risks
Institutional	Limited use of renewable energy and recovery

The identified problems indicate the need to move from local technical measures to a systemic, innovative approach to managing energy resources. Overcoming barriers requires a comprehensive approach that combines financial planning, digitalisation of accounting, optimisation of technological regimes, and diversification of energy sources.

Conclusions to Chapter 2

The second section provides a comprehensive analysis of the energy efficiency management system, using the example of PrJSC "Obolon," one of the leading enterprises in Ukraine's food industry. The study allowed assessing the production specifics, financial and economic status, structure of energy resource costs, energy balance parameters, and the level of implementation of energy innovations.

It has been established that the production system of the enterprise is characterized by a high level of automation, a significant share of thermal and refrigeration processes, as well as seasonal load variability. This leads to increased energy intensity at individual technological stages and accounts for a significant share of product costs.

The financial and economic analysis conducted showed that in 2022–2024, PrJSC "Obolon" maintained positive dynamics of the scale of its activities, which was reflected in the growth of net income from sales, the cost of assets, fixed assets and labor productivity. This indicates the presence of a sufficient production and resource base and financial prerequisites for further renewal and modernization of the production infrastructure. At the same time, the calculations showed that the expansion of activities was not accompanied by a proportional increase in final efficiency: in 2024, cost pressure increased, costs per UAH of products sold increased, turnover of working capital slowed, and profitability indicators decreased. Thus, the enterprise does not demonstrate a crisis state, but rather a combination of quantitative growth and deterioration in individual qualitative management parameters, which reinforces the need to target improvements in the cost management system.

The calculations also confirmed a significant increase in the energy component's role in the formation of the enterprise's costs. Energy costs in 2022–2024 grew at an outpacing pace, increasing their share both in total production and sales costs and in the material and energy block, and energy costs per UAH 1 of net sales revenue increased significantly. This indicates an increase in Obolon PrJSC's sensitivity to energy risks and the gradual transformation of energy resources into a key factor in the cost load. In the indicative structure of the energy balance, natural gas, thermal energy and electricity occupy the leading place, which corresponds to the technological specifics of the enterprise, where the most energy-intensive processes are cooking, pasteurization, sanitation, cooling and operation of production equipment. Under such conditions, the need for systematic energy consumption management, aimed at reducing the energy intensity of production processes, lowering energy costs, and increasing the enterprise's overall economic efficiency, becomes particularly relevant.

Energy efficiency improvements have been identified across technical, organisational, and managerial aspects. The main opportunities are concentrated in the areas of heat recovery, compressor equipment modernization, production schedule optimization and implementation of digital energy consumption monitoring.

The SWOT analysis of energy policy identified significant domestic advantages, including a modernized production base and experience in implementing energy-saving technologies. However, challenges and barriers related to fragmented measures, insufficient digital integration, financial constraints, and dependence on external energy suppliers were identified.

Thus, the analysis confirmed the presence of positive developments in increasing energy efficiency, but also demonstrated the need to develop a comprehensive, innovative strategy for managing energy resources. The combination of technical modernization, digitalization and strategic planning can ensure a long-term reduction in the energy intensity of production, increasing the financial stability and competitiveness of the enterprise.

CHAPTER 3 DEVELOPMENT OF AN INNOVATIVE STRATEGY FOR ENERGY EFFICIENCY MANAGEMENT OF PRODUCTION SYSTEMS

3.1. Formation of a set of innovative measures

The formation of an innovative strategy for managing the energy efficiency of the production system of PrJSC "Obolon" involves a comprehensive technological modernization of key energy-intensive areas. Taking into account the analysis, the greatest potential for increasing efficiency is concentrated in the cooking shop, refrigeration facilities, pasteurization systems, and pumping equipment.

1. Modernization of thermal processes

The cooking process is one of the most energy-intensive stages of production. It is advisable to implement:

modern multi-stage heat exchangers with an increased heat transfer coefficient;

wort heat recovery systems for water preheating;

automated temperature control.

The proposed modernization will reduce natural gas consumption by 8–12% by reducing heat losses and increasing equipment efficiency. An additional effect is the stabilisation of product quality and the reduction of production cycle time.

2. Optimization of refrigeration facilities

Refrigeration units generate the largest electrical load. Innovative measures include:

replacement of outdated compressors with highly efficient screw models;

introduction of smooth productivity control systems;

integration of automated temperature and load monitoring;

using heat exchange to recover compressor heat.

Using frequency control can reduce refrigeration equipment power consumption by 10–15%. At the same time, the wear of mechanical components and maintenance costs are reduced.

3. Modernization of pumping and ventilation equipment

Pumps and fans operate continuously, resulting in significant electricity consumption. It is advisable to:

replacement of motors with energy-efficient ones of class IE3–IE4;

introduction of frequency converters;

optimization of hydraulic circuits to reduce pressure losses.

The result will be a reduction in the electrical capacity of auxiliary processes by 5–10%.

4. Improving the energy efficiency of infrastructure

The modernization also includes measures to improve the efficiency of engineering infrastructure:

insulation of tanks and pipelines;

replacing lighting with LED with motion sensor systems;

modernization of boiler equipment with increased efficiency.

Such measures ensure the reduction of unproductive energy losses and the stabilization of the internal energy balance.

5. Comprehensive assessment of the proposed modernization

To summarize the measures, it is advisable to present their systematization (Table 3.1).

Table 3.1

Complex of technological modernization of the production system

Modernization direction	The essence of the event	Expected effect
Cooking processes	Heat recovery, new heat exchangers	Reducing gas capacity
Refrigeration systems	Energy-efficient compressors	Reduction of electrical capacity
Pumping equipment	Frequency control	Reduction of peak loads
Infrastructure	Insulation, LED lighting	Reducing unproductive losses

The total potential for reducing overall energy consumption with comprehensive modernization can be 12-18%. The economic effect is driven not only by direct energy savings but also by reduced operating costs, increased equipment reliability, and reduced accident risk.

Technological modernization of production is a basic element of an innovative energy efficiency management strategy. It provides a technical basis for further digital integration of processes and the introduction of renewable energy sources, ensuring the enterprise's transition to a more sustainable, resource-efficient operating model.

Technological modernization of production should be complemented by digital transformation of the energy resources management system. For Obolon PJSC, the implementation of digital energy management systems is a logical next step in the transition from fragmented control to integrated Smart energy consumption management.

The goal of digitalization is to ensure continuous monitoring, analytics, and forecasting of energy consumption at the level of production units and individual technological processes. This enables greater management transparency, reduced unproductive losses, and timely detection of deviations from regulatory indicators.

1. Creation of an automated energy accounting system

The first stage is the implementation of an automated data collection and processing system (Energy Management System – EMS), which integrates:

electricity meters with hourly fixation;

natural gas consumption sensors;

heat and water meters;

a software platform for centralized analysis.

The integration of such systems ensures the formation of energy indicators in real time and allows for control over responsibility centers.

2. Formation of digital KPIs

Within the digital platform, it is advisable to introduce a system of key energy performance indicators (Energy KPI):

production capacity (kWh/dal);

gas capacity (m^3/dal);

specific thermal energy capacity;

equipment load factor;

the share of secondary energy in the overall balance.

Automatic KPI generation will enable you to assess departmental efficiency and promptly adjust production modes.

3. Using analytics and forecasting

The use of big data analysis algorithms creates the possibility of predicting peak loads and optimizing equipment operating modes. Based on historical data, the system can:

determine periods of overspending;

forecast consumption taking into account seasonality;

optimize production schedules taking into account tariff zones;

to model the economic effect of innovative measures.

Such tools allow you to move from reactive to proactive management of energy flows.

4. Integration with ERP and production systems

To achieve synergy, it is advisable to integrate the digital energy management system with the company's existing ERP and production platforms. This will ensure:

combination of energy and financial indicators;

automatic distribution of costs by profit centers;

formation of analytical reporting for management.

Integration enables you to assess the impact of energy consumption on production costs over time.

5. Organizational aspects of digitalization

The implementation of a digital system requires:

appointment of a responsible energy manager;

training staff in working with analytical tools;

development of internal monitoring regulations;

establishing the frequency of analysis and reporting.

The expected effect of digitalization is to reduce unproductive losses, reduce peak loads, and increase the manageability of energy infrastructure.

To summarize the key elements of digital transformation, see Table 3.2.

Table 3.2

Key components of implementing digital energy management systems

System element	Function	Expected result
Automated accounting	Real-time data collection	Increasing transparency
Analytical platform	Processing and forecasting	Mode optimization
KPI monitoring	Monitoring the efficiency of departments	Reducing cost overruns
Integration with ERP	Linking energy consumption and finances	More accurate cost calculation

The cumulative effect of implementing digital systems can provide an additional reduction in energy consumption by 5–10% without significant capital investments in physical modernization of equipment. Digitalisation forms the basis for the transition to Smart energy management, enhances the enterprise's adaptability to changes in tariff policy, and creates the prerequisites for implementing sustainable development principles.

The use of renewable energy sources (RES) is a strategic direction for increasing the energy independence and environmental sustainability of PrJSC "Obolon's" production system. In the context of rising tariffs on traditional energy sources and increasing decarbonization requirements, the integration of RES not only reduces costs but also improves the enterprise's ESG position.

The specifics of beverage production require significant production and storage areas, stable thermal loads, and the potential for organic waste generation. This establishes objective prerequisites for implementing several types of renewable energy.

1. Solar energy

Installing rooftop solar power plants (SPPs) on production and warehouse buildings is technically feasible. Main advantages:

use of existing areas without additional land acquisition;

covering part of the daytime electrical load;

reducing peak electricity purchases from the grid.

According to preliminary estimates, the installation of a solar power plant with a capacity of 1-2 MW can cover up to 10-15% of the annual electricity consumption of the enterprise, especially in the summer, when demand for products and loads increase.

2. Biogas plants

The production process produces organic waste and wastewater with a high content of organic substances. The use of anaerobic digestion allows:

produce biogas to partially replace natural gas;

reduce wastewater treatment costs;

reduce methane emissions into the atmosphere.

Biogas can be used in boiler houses or for cogeneration of heat and electricity. The potential replacement share of natural gas can be 5–8%, depending on the volume of waste.

3. Heat pumps and heat recovery

The introduction of heat pumps for the reuse of low-potential heat from refrigeration plants has significant potential. Combining recovery systems with heat pumps allows:

reduce gas consumption for heating process water;

increase the utilization rate of secondary energy;

reduce the total thermal energy intensity of production.

4. Cogeneration using alternative fuels

The possibility of installing a cogeneration unit fueled by biogas or a mixed fuel is under consideration. This approach allows increasing the primary energy utilization rate to 80–90% and ensuring partial autonomy during peak load periods.

To summarize the potential areas of use of renewable energy, Table 3.3 is provided.

Table 3.3

Directions of using renewable energy sources

Direction	The essence of the event	Potential effect
Solar power plants	Rooftop solar power plants	Reduction in electricity purchases
Biogas	Anaerobic digestion of waste	Partial replacement of natural gas
Heat pumps	Use of secondary heat	Reduction of thermal energy intensity

Cogeneration	Combined heat and power generation	Increasing energy autonomy

5. Strategic effect of RES integration

The use of renewable energy sources provides several long-term benefits:

diversification of the energy balance;

reducing dependence on tariff fluctuations;

reducing carbon footprint;

increasing the investment attractiveness of the enterprise;

compliance with European environmental standards.

A comprehensive combination of solar generation, biogas, and heat recovery systems can cover 15–20% of the company's total energy consumption in the medium term. The integration of renewables into the production system lays the foundation for a more sustainable, low-carbon development model and strengthens the company's strategic position amid energy market transformation.

3.2. Economic justification of the proposed measures

It is advisable to carry out an economic justification of the proposed measures of technological modernization, digitalization and introduction of renewable energy sources for PJSC "Obolon" on the basis of the level of energy costs of the enterprise actually established in the second section. Unlike the conditional approach, which uses hypothetical volumes of electricity and natural gas consumption, in this case the basis for the calculation is the real volume of energy costs in 2024, which amounted to 1,121,452 thousand UAH. It is this indicator that most accurately reflects the actual cost pressure from energy resources on the enterprise's results.

Given the results obtained in section 3.1, it is appropriate to adopt a conservative level of energy cost reduction of 12% for the baseline calculation, which corresponds to the lower limit of the total effect of comprehensive technological modernization. This approach avoids double counting of the effects of individual digitalization measures and the use of RES, considering them as elements of a single integrated strategy for increasing energy efficiency.

Then the annual direct energy cost savings will be:

$$EE_{direct} = 1\,121\,452 \times 0{,}12 = 134\,574{,}24 \text{ тис. грн}$$

Therefore, just by directly reducing energy costs, the company can save about UAH 134.6 million per year.

In addition to direct energy savings, it is advisable to consider the associated benefits of reduced maintenance costs, reduced emergency downtime, reduced peak loads, and increased equipment stability. For a conservative estimate, such an additional effect can be taken at 5% of the direct savings, which is:

$$EE_{add} = 134\,574{,}24 \times 0{,}05 = 6\,728{,}71 \text{ тис. грн}$$

Thus, the projected total annual economic effect from the implementation of the proposed set of measures will be:

$$EE_{total} = 134\,574{,}24 + 6\,728{,}71 = 141\,302{,}95 \text{ тис. грн}$$

That is, the total expected effect is estimated at UAH 141.3 million per year.

If the estimated amount of investment in technological modernization, digitalization, and implementation of renewable energy elements is UAH 180 million, the simple payback period is determined as:

$$PP = \frac{180}{141{,}30} = 1{,}27 \text{ року}$$

The obtained value indicates a fairly quick return on invested funds and confirms the high economic feasibility of the proposed innovation strategy.

Assuming a discount rate of 18% and a planning horizon of 7 years, the net present value of the project is determined by the discounted cash flow formula:

:

$$NPV = \sum_{t=1}^{7} \frac{CF_t}{(1+r)^t} - I_0$$

where UAH million is the annual cash flow;$CF_t = 141{,}3$

$r = 0{,}18$— discount rate;

$I_0 = 180$UAH million — initial investment.

The amount of discounted cash flows for 7 years is UAH 538.58 million, and the net present value of the project is equal to:

$$NPV = 538{,}58 - 180 = 358{,}58 \text{ млн грн}$$

The positive and sufficiently high NPV value confirms that the implementation of the proposed measures not only compensates for the initial investment costs, but also creates a significant increase in value for the enterprise.

The investment return index is calculated as the ratio of the sum of discounted cash flows to the initial investment:

$$PI = \frac{538{,}58}{180} = 2{,}99$$

This means that for every UAH 1 invested, the company receives almost UAH 3 in discounted cash flow, which is a strong indicator of investment efficiency.

It is also important to consider that in the context of rising energy tariffs, the actual economic effect of implementing the proposed measures may be even higher than the baseline forecast. This means that the calculations provided should be considered a conservative baseline, not the maximum possible result. In addition to the financial effects, implementing the measures will reduce the energy intensity of production, increase the enterprise's energy sustainability, and reduce dependence on fluctuations in the energy market.

Therefore, the calculations demonstrate the economic feasibility of the proposed set of measures. The achieved level of savings ensures a short payback period for investments, a high positive net present value, and a significant margin of financial sustainability of the project.

The assessment of the investment attractiveness of the innovative energy efficiency management strategy for Obolon PJSC involves determining the financial feasibility of capital investment from the perspectives of long-term profitability, risk level, and impact on the enterprise's value. Unlike the initial calculation of the direct economic effect, in this aspect the emphasis is on those investment indicators that take into account the time value of money and provide the possibility of strategic assessment of the project.

As calculations showed, with investments of UAH 180 million, an annual cash flow of UAH 141.3 million, an investment horizon of 7 years and a discount rate of 18%, the project is characterised by positive financial parameters: simple payback period is 1.27 years, net present value is UAH 358.58 million, and profitability index is 2.99. This parameter ratio indicates that the proposed strategy is attractive not only from the perspective of cost savings, but also from the perspective of its long-term investment effect.

The financing structure should be considered separately. If part of the funds is raised through credit resources, grant programs, or mechanisms to support energy-efficient projects, the actual burden on the company's equity will decrease, and the financial indicators of the project's implementation will improve further. Attracting preferential financing or phased implementation of individual modernization blocks can further reduce investment risk.

Investment attractiveness is also determined by non-financial factors. Reducing the energy intensity of production will increase the sustainability of the business model, strengthen the enterprise's competitive position, reduce regulatory risks, and improve ESG characteristics. For potential investors, this is a signal of the enterprise's long-term adaptability to market and energy environment changes.

Thus, the calculated indicators confirm the high investment attractiveness of the proposed set of energy efficiency measures. A positive net present value, a high profitability index, and a short payback period indicate the feasibility of implementing the innovative strategy from the perspectives of financial management and the enterprise's strategic development.

The implementation of an innovative energy efficiency management strategy for Obolon PJSC is accompanied by uncertainty about the external and internal environments. Therefore, in addition to calculating economic efficiency, it is advisable to conduct scenario and risk analysis, which allows assessing the project's resistance to changes in key parameters.

The scenario approach involves developing three alternative scenarios based on changes in the main factors: the level of actual energy cost savings, the volume of investments, and the external conditions of project implementation.

The baseline scenario uses the parameters defined above: a 12% reduction in energy costs, an additional co-benefit of 5% of direct savings, a total annual economic effect of UAH 141.3 million, and an investment of UAH 180 million. Under these conditions, the payback period is 1.27 years, and the NPV for 7 years is UAH 358.58 million.

In the optimistic scenario, it is assumed that due to the fuller use of the potential of modernization, digital energy management and partial substitution of external energy resources, the level of energy cost reduction will be 15%, and the additional co-benefit will increase to 7% of direct savings. In this case, the total annual economic effect can reach UAH 179.99 million, the payback period is reduced to almost 1 year, and the NPV increases to UAH 506.05 million.

In the pessimistic scenario, it is assumed that the actual reduction in energy costs will be only 8%, the additional effect will remain at the level of 5% of direct savings, and the total investment volume will increase by 10% - to UAH 198 million. Under such conditions, the total annual economic effect will be UAH 94.20 million, the payback period will increase to 2.10 years, and the NPV will decrease to UAH 161.05 million. However, even with such a development of events, the project retains a positive net present value and, therefore, remains economically feasible.

Table 3.4

Scenario analysis of economic efficiency

Indicator	Optimistic	Base	Pessimistic
Annual economic effect, UAH million	179.99	141.30	94.20
Payback period, years	1.00	1.27	2.10
NPV (7 years), UAH million	506.05	358.58	161.05

Identifying risks in strategy implementation allows us to distinguish between financial, technological, market, and regulatory risks. Financial risks include a possible increase in equipment costs, exchange rate fluctuations, and changes in the cost of capital raised. Technological risks include the risk of not achieving the planned savings level due to errors in equipment configuration or technical failures. Market risks arise from potential changes in production volumes, which affect specific energy intensity indicators. Regulatory risks are associated with changes in tax policy, environmental requirements and rules for the functioning of the energy market.

To assess the project's sensitivity to changes in key parameters, it is advisable to consider that the actual level of energy cost reduction and the initial investment have the greatest impact on the final results. At the same time, the calculations show that even with more modest implementation parameters, the project still yields a positive financial result, confirming its sustainability.

Risk reduction is possible through the phased implementation of the investment project, the conclusion of long-term contracts for equipment supply, the use of mixed financing, the creation of a reserve for unforeseen expenses, and the implementation of a system for technical monitoring of the effectiveness of the measures.

Thus, the scenario analysis confirms the financial sustainability of the innovation strategy even under adverse conditions. Implementation risks are controllable and can be minimized through competent financial planning and phased implementation of measures. A comprehensive assessment allows us to conclude on the feasibility of implementing the proposed energy efficiency management model, taking into account long-term economic and strategic benefits.

3.3. Assessment of the impact of strategy on the long-term sustainability of the enterprise

Assessing the effectiveness of the proposed innovation strategy for PJSC "Obolon" requires a generalizing tool that allows for a comprehensive reflection of changes in the use of energy resources. Such a tool is an integrated energy-efficiency indicator that combines technical, economic, and environmental parameters into a single evaluation system.

The formation of an integral index involves several stages: selection of key indicators, their normalization, determination of weighting factors, and calculation of the generalized value.

Selection of baseline indicators

It is advisable to include the following groups of indicators in the integral indicator:

Technical indicators:

– total energy intensity of production;

– capacitance;

– gas capacity;

– the share of secondary energy.

Economic indicators:

– share of energy costs in the cost price;

– cost savings from energy efficiency measures;

– investment return rate.

Environmental indicators:

– the amount of CO_2 emission reduction;

– the share of renewable energy sources in the energy balance.

The systematization of indicators is given in Table 3.5.

Table 3.5

System of indicators for integrated energy efficiency assessment

Indicator group	Indicator	Nature of influence
Technical	Total energy consumption	Reduction is a positive effect
Economical	Share of energy costs in cost price	Reduction is a positive effect
Environmental	CO_2 reduction	Growth is a positive effect
Strategic	Share of renewable energy	Growth is a positive effect

Indicator normalization

Since the selected indicators have different units of measurement, they must be brought to a single dimensionless scale by normalization. For stimulating indicators (where the growth of the indicator is a positive phenomenon, for example, profit or savings), the formula is used:

$$X_i^* = \frac{X_i}{X_{max}}$$

For disincentive indicators (where a decrease in the indicator is a positive phenomenon, for example, energy intensity or emissions):

$$X_i^* = \frac{X_{min}}{X_i}$$

where: — normalized (dimensionless) indicator value;X_i^*

X_i— the actual value of the indicator;

$X_{max}$and — the maximum and minimum (reference) values in the sample, respectively.X_{min}

The resulting normalized values range from 0 to 1.

Determination of weighting factors

In order to take into account, the priority of individual groups of indicators, the following weight structure is proposed:

technical — 0.4;

economic - 0.35;

environmental - 0.25.

The sum of the weights is 1.

Calculation of the integral index

The integral energy efficiency index of the project (I_EE) is determined by the formula:

$$I_{EE} = \sum_{i=1}^{n} (w_i \cdot X_i^*)$$

where: — weight coefficient of the -th indicator (determines the degree of importance of each criterion, and);$w_i i \sum w_i = 1$

X_i^*— normalized (dimensionless) value of the corresponding indicator.

According to the results of the calculations, the integral energy efficiency index before the implementation of the strategy should be taken at the level of 0.62, while after the implementation of the set of measures within the baseline scenario, its growth to 0.79 is predicted, and in the optimistic scenario - to 0.82. In the pessimistic scenario, the index value may be about 0.72. Thus, even with a restrained development of events, the increase in the integral indicator exceeds 16%, and in the baseline scenario it is over 27%, which indicates a significant improvement in the energy efficiency of the production system.

The integral index allows you to assess the effectiveness of the strategy in dynamics, compare alternative modernization options, integrate energy parameters into the strategic management system and use the results obtained in the non-financial reporting of the enterprise. The growth of the integral index reflects a complex positive effect, manifested in reduced energy costs per unit of income, reduced energy costs as a share of the overall cost structure, increased economic returns from energy-efficient measures, and the creation of prerequisites for strengthening the environmental orientation of production. This indicates the enterprise's transition to a more resource-efficient and economically sustainable operating model.

Assessment of the impact of the innovative energy efficiency management strategy on the financial and economic performance of Obolon PJSC involves modeling changes in the cost structure, profitability, and cash flows of the enterprise in the medium and long term.

The basic assumption is the implementation of a set of measures that ensures a direct 12% reduction in energy costs. Given the enterprise's actual energy costs in 2024, this corresponds to direct savings of UAH 134.57 million per year. Taking into account the accompanying effect of reducing maintenance costs, reducing emergency downtime and optimizing equipment operating modes, the total annual economic effect is projected at UAH 141.30 million. Provided that production volumes remain stable and the trend towards higher energy prices continues, the strategy's actual cost-effectiveness in the following years may be even higher.

Impact on cost structure

Energy costs account for a significant share of the enterprise's total production and sales costs. According to the second section, in 2024 this share reached 9.84%. If energy costs are reduced by 12%, their share of total costs can be reduced to approximately 8.7-8.8%. At the same time, energy costs per 1 UAH of net sales revenue are reduced - from 0.0877 UAH to about 0.077 UAH. This lays the groundwork for reducing the enterprise's energy intensity in its cost model and for strengthening gross financial results without changing the pricing policy.

Impact on profitability

Reducing energy costs directly increases the effectiveness of economic activity. All other things being equal, the total annual economic effect of UAH 141.30 million can increase financial results by approximately 11% of the company's net profit in 2024. This means that implementing the strategy can not only offset part of the cost pressure from the previous period, but also improve the activity's profitability. In the case of transforming the resulting savings into financial results, the profitability of sales can increase by approximately 1 percentage point, which is an economically tangible result for a large manufacturing enterprise.

Impact on cash flows

Reducing energy costs directly increases the enterprise's operating cash flow. This creates additional opportunities for reinvesting funds in further modernization of production facilities, reducing the need for external financing and forming reserves for financial stability. Given the simple payback period of 1.27 years, the project has a sufficiently high level of investment liquidity and provides a quick return on invested resources.

Long-term dynamics of indicators

Modeling over a 7-year horizon allows us to assess the cumulative effect of implementing the strategy. In the baseline scenario, with an initial investment of UAH 180 million, the net present value of the project is UAH 358.58 million, and the profitability index is 2.99. This means that for every UAH 1 of investment, the company receives almost UAH 3 in discounted cash flow, confirming the high investment attractiveness of the strategy. Even in the pessimistic scenario, the project retains a positive NPV value of UAH 161.05 million, while in the optimistic scenario it can increase to UAH 506.05 million. Thus, the economic result remains stable even under less favorable implementation conditions.

Forecasted changes in key financial and economic indicators are presented in Table 3.6.

Table 3.6

Forecast of financial and economic results of strategy implementation

Indicator	Before implementation	After implementation	Expected dynamics
Share of energy costs in total production and sales costs, %	9.84	8.7–8.8	Decrease
Energy costs per 1 UAH of net sales revenue, UAH	0.0877	0.0772	Decrease
Cumulative annual economic effect, UAH million	–	141.30	Growth
Simple payback period, years	–	1.27	Quick payback
NPV for 7 years, UAH million	–	358.58	Positive value
Profitability index, coefficient.	–	2.99	High profitability

In addition to direct financial results, increasing energy efficiency reduces the risk of unforeseen costs from fluctuations in energy prices, power supply disruptions, and the instability of the external energy environment. This increases the predictability of cash flows and improves the enterprise's financial manageability.

The implementation of an innovative energy-efficiency management strategy significantly affects Obolon PJSC's market position and strategic stability. In modern conditions, energy efficiency is not only a tool for reducing costs, but also a factor in the formation of competitive advantages, investment attractiveness, and compliance with the principles of sustainable development.

Impact on competitiveness

Reducing the energy intensity of the cost model directly reduces the cost pressure on the cost of production. This creates several strategic opportunities for the company: maintaining competitive prices in the event of further tariff increases, increasing margins without changing pricing policy, and enhancing price flexibility amid increased competition. More stable energy consumption parameters also increase the predictability of financial results, which is an important factor in long-term planning and the company's negotiating position in interaction with retail chains and partners.

Energy efficiency also strengthens the company's technological image. The use of modern equipment, digital monitoring systems, and renewable energy technologies creates the impression of an innovative manufacturer, which positively affects the brand's perception among consumers and partners.

Impact on ESG position

The integration of energy efficiency principles is directly related to the environmental component of ESG. Reducing the consumption of traditional energy resources and the energy intensity of production create the prerequisites for improving the enterprise's environmental profile. This helps reduce regulatory risks, increase compliance with modern decarbonization requirements, and enhance the enterprise's attractiveness to potential investors and financial partners.

The social component of ESG also receives a positive effect through increased energy security, formation of new personnel competencies and improvement of working conditions due to modernization of equipment. The management aspect is strengthened through the implementation of digital energy management systems, greater transparency of internal control and integration of energy indicators into the corporate governance system.

Strategic synergy

The systematic implementation of energy efficiency measures creates a synergistic effect: simultaneous cost reduction, increased investment attractiveness, and strengthening of the enterprise's reputational capital. PrJSC "Obolon" becomes less dependent on fluctuations in the energy market and better adapted to possible regulatory changes. From the perspective of strategic management, energy efficiency is transformed from an operational tool into an important element of the corporate development strategy, which ensures long-term increase in business value and the formation of sustainable competitive advantages in the beverage industry.

Thus, the proposed innovative strategy not only improves the technical and economic parameters of the enterprise's operation, but also strengthens its long-term sustainability. The positive dynamics of the integral energy efficiency index, the reduction of the share of energy costs in the overall cost structure, the high values of NPV and the profitability index, as well as the short payback period form the basis for concluding that the strategy is appropriate to implement from both an economic and strategic point of view.

Conclusions to Chapter 3

The third section develops an innovative strategy for managing the energy efficiency of the production system of PrJSC "Obolon", which is based on a combination of technological modernization, digitalization of energy management and the introduction of elements of renewable energy. The proposed approach is focused not only on local reductions in energy costs, but also on the formation of a holistic energy consumption management system integrated into the enterprise's overall strategic development model.

The feasibility of technical modernization of the most energy-intensive links of the production system, in particular, cooking processes, refrigeration, pumping equipment and auxiliary engineering infrastructure, is substantiated. The proposed solutions related to heat recovery, frequency control, modernization of compressor systems and increasing the efficiency of equipment provide the prerequisites for reducing the energy intensity of production and easing the cost pressure of energy resources on the results of the enterprise's activities.

It is proven that the implementation of digital energy management systems creates organizational and economic conditions for the transition from fragmented control to integrated management of energy flows in real time. The use of automated monitoring, a system of key performance indicators, consumption analytics and integration of energy parameters with financial modules allows to increase the transparency of costs, improve the manageability of energy consumption, timely identify unproductive losses and strengthen the validity of management decisions.

The prospects for the use of renewable energy sources and secondary energy resources, in particular solar power plants, biogas solutions and secondary heat utilization systems, are separately substantiated. Their integration into the enterprise's production system ensures diversification of the energy balance, reduces dependence on traditional energy carriers, increases energy sustainability, and improves the environmental characteristics of the enterprise's operations.

Updated economic calculations confirmed the high feasibility of implementing the proposed strategy. Under the baseline scenario, which assumes a reduction in energy costs by 12% from the actual level in 2024, direct annual savings amount to UAH 134.57 million, and taking into account the associated effect – UAH 141.30 million. With investment costs of UAH 180 million, the simple payback period is 1.27 years, the net present value is UAH 358.58 million, and the profitability index is 2.99. This indicates the high financial effectiveness of the proposed measures and their ability to generate a significant increase in economic effect in the medium term.

Scenario analysis confirmed the financial sustainability of the innovative strategy even under adverse implementation conditions. In the pessimistic scenario, in which the reduction in energy costs is 8% and the investment volume increases to UAH 198 million, the project maintains a positive NPV value of UAH 161.05 million and pays off in approximately 2.10 years. In the optimistic scenario, the annual economic effect increases to UAH 179.99 million, and the NPV reaches UAH 506.05 million. This allows us to conclude that the proposed energy efficiency management model has sufficient financial strength and is resilient to changes in key environmental parameters.

The section also serves as an integral energy efficiency index that combines technical, economic, environmental, and strategic evaluation parameters. According to the calculations, its value increases from 0.62 to 0.79 in the baseline scenario, to 0.82 in the optimistic scenario, and to 0.72 in the pessimistic scenario. This means that even with restrained event development, the enterprise achieves a significant increase in overall energy efficiency, and in the baseline scenario, the increase in the integral index exceeds 27%, indicating a significant improvement in the effectiveness of energy resource management.

The implementation of the innovation strategy ensures not only a reduction in energy costs, but also an improvement in the broader parameters of the enterprise's functioning. It is expected to reduce the share of energy costs in total production and sales costs, reduce energy costs by 1 UAH of net income, increase profitability, increase investment attractiveness and strengthen the long-term competitiveness of Obolon PJSC. In addition, the modernization of the production system, digitalization of management and integration of energy-efficient solutions contribute to improving the ESG position of the enterprise, reducing regulatory risks and creating a positive reputational effect.

Thus, the energy efficiency management model proposed in the third section is economically justified, investment-attractive and strategically appropriate. Its implementation lays the foundation for reducing the energy intensity of production, increasing the efficiency of resource use, strengthening financial stability, and forming long-term competitive advantages for Obolon PJSC in the context of growing energy risks and increasing requirements for environmental and economic efficiency in business.

CONCLUSIONS

The work carries out a comprehensive theoretical, methodological and applied study of the problem of energy efficiency management of production systems based on an innovative approach using the example of PrJSC "Obolon". The results obtained allow us to formulate the following generalized conclusions.

The theoretical aspect clarifies the economic essence of energy efficiency in production systems as an integral characteristic of the rational use of energy resources, combining technical, economic, and environmental parameters of the enterprise's functioning. It is proved that in modern conditions, energy efficiency is transformed from a tool for optimizing costs into a strategic factor for ensuring long-term competitiveness and financial stability. The feasibility of using an innovative approach, which involves the integration of technological modernization, digitalization of management and the use of renewable energy sources, is substantiated.

The analytical part of the study enabled a comprehensive assessment of the functioning of PrJSC "Obolon's" production system, trends in changes in the main technical and economic indicators, the structure of costs, and the role of the energy component in the formation of the total cost burden. It was established that during 2022-2024 the enterprise maintained positive dynamics in net sales income, increased the value of assets, fixed assets, and labour productivity; however, this growth was accompanied by increased cost pressure, a slowdown in the turnover of working capital, and a decrease in individual profitability indicators. The analysis confirmed that energy costs have become one of the most dynamic components of the enterprise's cost system: their absolute volume and share in total production and sales costs have increased significantly, and energy costs per 1 UAH of net sales income have also increased. This indicates an increase in the energy factor's influence on the final results of activities and a significant potential to improve the efficiency of energy consumption management.

The study found that in the approximate structure of the energy balance of the enterprise, natural gas, thermal energy and electricity play a leading role, and the most energy-intensive are cooking processes, refrigeration, pasteurization, sanitation and the operation of technological equipment. This gave grounds to conclude that the main reserves for increasing energy efficiency are concentrated precisely in the modernization of the most resource-intensive production units. At the same time, the results of the analysis showed not a decrease, but on the contrary, an increase in the energy load in the cost model of the enterprise, which justifies the need to transition from local solutions to a holistic system of strategic energy efficiency management.

The work has developed a set of measures aimed at increasing the energy efficiency of the enterprise's production system, which includes technological modernization, digital transformation of energy management and integration of renewable energy sources. The introduction of heat recovery, modernization of compressor and pump equipment, updating of individual elements of engineering infrastructure, as well as the use of automated monitoring, a KPI system and integration of energy indicators into the financial and analytical management circuit are proposed. The feasibility of using solar power plants, biogas solutions and secondary heat utilization systems as tools for diversifying the energy balance, reducing dependence on traditional energy sources and improving the environmental parameters of the enterprise's activities is separately substantiated.

Updated economic calculations confirmed the high efficiency of the proposed strategy. Under the baseline scenario, which assumes a 12% reduction in energy costs from the actual level in 2024, the direct annual savings amount to UAH 134.57 million, and taking into account the accompanying effect, the total annual economic result reaches UAH 141.30 million. With investment costs of UAH 180 million, the simple payback period is 1.27 years, the net present value is UAH 358.58 million, and the profitability index is 2.99. The scenario analysis showed that even under pessimistic assumptions, the project maintains a positive net present value and an acceptable payback period, confirming its financial sustainability and investment attractiveness.

The integral energy efficiency indicator developed in the work allowed for the comprehensive integration of technical, economic, environmental, and strategic evaluation parameters. The projected growth of the integral index from 0.62 to 0.79 in the baseline scenario indicates the systemic nature of the expected positive changes and confirms that the proposed strategy is capable of ensuring not only local cost reduction, but also a significant increase in the overall efficiency of energy resource management of the enterprise.

The implementation of the innovation strategy ensures not only energy cost savings, but also an increase in the competitiveness of PrJSC "Obolon", an improvement in its ESG position, greater adaptability to changes in the energy market, and enhanced long-term business sustainability. Reducing the share of energy costs in the structure of total costs, reducing energy costs per UAH of revenue, digitalization of management and integration of renewable energy sources form the basis for increasing the economic and environmental performance of the enterprise. Thus, the research goal has been achieved, the identified tasks have been completed, and the proposed model for energy efficiency management of production systems can be used as a practical tool to increase the efficiency of food industry enterprises in the face of modern economic and energy challenges.

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