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CONCEPTUAL FOUNDATIONS OF ENERGY MANAGEMENT: MICRO- AND MACRO-LEVEL APPROACH

Khomiuk N.L.
d.e.s., as.prof.
ORCID: 0000-0002-3277-8840
Yushchyshyna L. O.
c.e.s., as.prof.
ORCID: 0000-0001-8926-7577
Hulchak O. M.
ORCID: 0009-0003-0691-4583
Lesya Ukrainka Volyn National University,
Lutsk, Vynnychenko 28, 43021

Abstract. *The article examines the conceptual foundations of energy management, taking into account both micro- and macro-level approaches. The relevance of the issue is determined in the context of the global energy crisis and the war in Ukraine, which has led to the destruction of energy infrastructure and increased risks of energy dependence. Scientific approaches to the interpretation of the concept of "energy management" are analyzed, as well as its evolution from local energy-saving programs to comprehensive management systems in accordance with the national standard DSTU ISO 50001:2020 (ISO 50001:2018, IDT). The importance of integrating microeconomic measures (energy audit, equipment modernization, certification, investments in renewable energy sources) with macroeconomic instruments (state strategies, standards, incentives, infrastructure development) is substantiated. It is shown that the systemic combination of these levels ensures a synergistic effect, increases the energy efficiency of enterprises, and contributes to the implementation of state policies on energy security and environmental sustainability. It is concluded that the adaptation of international experience and the introduction of modern energy management systems are necessary for the restoration of energy infrastructure, strengthening economic resilience, and fostering innovative development of Ukraine in wartime and post-war conditions.*

Key words*: energy management; energy efficiency; energy security; sustainable development; microeconomic approach; macroeconomic approach; renewable energy.*

Introduction.

The modern transformations of the global economy are increasingly driven by the challenges of energy security and the necessity of transitioning to sustainable development models. In the context of the global energy crisis, intensifying climate risks, and growing dependence on imported energy resources, countries are compelled to establish effective energy management mechanisms that combine state policy, business strategies, and innovative technologies. One of such mechanisms is energy management, which is considered a multi-level system of organizational, technical, economic, and managerial measures aimed at optimizing the use of energy resources.

The relevance of energy management research is particularly increasing under the conditions of the war in Ukraine, which has caused significant destruction of energy infrastructure, exacerbated the risks of energy dependence, and posed urgent challenges for the state and businesses in ensuring the continuity of energy supply. Under these circumstances, effective energy management becomes not only an instrument of resource optimization but also a means of maintaining business resilience, preserving critical infrastructure, and safeguarding national security.

Scientific literature demonstrates growing attention to the conceptual foundations of energy management, its historical evolution, and modern approaches at both micro- and macro-levels. At the same time, further elaboration is required regarding the integration of these approaches, which allows energy management to be considered not only as a tool for resource saving but also as a strategic factor in the development of enterprises and the state under wartime and post-war challenges.

The purpose of this article is to substantiate the conceptual foundations of energy management, taking into account micro- and macro-level approaches, and to analyze international experience and the possibilities of its adaptation to the Ukrainian context in order to enhance economic efficiency, energy security, and environmental sustainability.

Main Text.

The concept of energy management gradually emerged in the second half of the 20th century as a continuation of the ideas of energy saving and energy efficiency. Earlier forms of this idea manifested during the oil crises of the 1970s, when many countries paid increased attention to the limited availability of energy resources and the need for their rational use. Over time, energy management was recognized as both a scientific discipline and a practical methodology, which led to the development of energy audit methods and certification procedures.

Energy management has become one of the key components of sustainable economic development and ensuring energy security. As Brych and Tkach (2023) emphasize, effective management of energy resources contributes to the stabilization and development of the national economy, reducing dependence on imported energy,

and diversifying energy sources [1]. At the same time, the implementation of an integrated approach is critically important: Azhaman et al. (2023) demonstrate that establishing an energy-saving system requires the introduction of energy management, which ensures comprehensive optimization of different types of energy [2].

The energy management system is part of the overall enterprise management system and includes organizational structure, management functions, distribution of duties and responsibilities, as well as procedures, processes, and resources aimed at developing, implementing, and achieving energy-saving goals. At the enterprise level, this makes it possible to reduce energy costs and increase production efficiency [1]. Thus, energy management at both the macro- and micro-levels is interconnected: it enhances business competitiveness while ensuring sustainable economic development and environmental resilience of the state [2].

In the scientific literature, various definitions of energy management are provided. In particular, Sharma et al. (2022) define it as the process of monitoring, planning, optimizing, and saving energy in order to create an energy-efficient system [3]. Domestic researchers also emphasize the multifactor nature of this concept. According to Dziadykevych et al. (2010), energy management is a managerial and technical activity of enterprise personnel aimed at the rational use of energy, taking into account social, technical, economic, and environmental aspects [4]. Similarly, Shashko et al. (2017) stress that energy management is “a tool for achieving efficient use of energy resources”, which includes a set of organizational, technical, informational, analytical, and regulatory measures for the optimal production and rational consumption of fuel and energy resources [5]. Sapozhnikov (2015) considers energy management to be a branch of management science that encompasses the development and implementation of energy-saving measures at all stages of energy production and consumption [6].

Studies of global experience confirm that a comprehensive approach is the key element in this process: analyzing international practice, Azhaman et al. (2023) identified advanced technologies and mechanisms of energy management and defined energy efficiency as “a key aspect for business and society” [7]. Therefore, considering the variety of sources, energy management can be regarded as a systemic activity aimed

at coordinating technical, organizational, and economic measures to save energy and ensure sustainable energy consumption.

Based on international experience, the analysis of the global development of energy management systems conducted by Azhaman et al. (2023) demonstrates a gradual evolution from local programs to comprehensive approaches. The researchers highlighted that the study of world experience revealed "advanced practices, technologies, and tools in the field of energy management", as well as assessed economic incentive mechanisms for energy efficiency [2].

In Ukraine, the ideas of energy management began to be gradually implemented with the country's independence. In particular, during the 1990s–2000s, the concept of "energy saving" appeared in legislation, followed later by regulations on the establishment of energy management systems at enterprises. Over the next 10–15 years, depending on the field of application, a number of definitions were developed in Ukraine, each reflecting different aspects of the concept of energy management.

Only in recent years have attempts been made to generalize international experience for national conditions [2]. Considering the absence of a unified historical and scientific source, it can be stated that the concept of "energy management" developed sporadically over several decades, driven by increasing attention to energy efficiency and the creation of international energy management standards.

Thus, in 2011, as a response to the global need to improve energy efficiency, reduce greenhouse gas emissions, and cut energy costs, the International Standard ISO 50001 was published. Its development was initiated by the International Organization for Standardization (ISO) to provide a universal methodology for creating, implementing, and improving energy management systems (EnMS), and to formalize energy management within organizations. To align the standard with the unified High-Level Structure (HLS), which ISO applies to all management system standards (including ISO 9001 and ISO 14001), a three-year transition took place from ISO 50001:2011 to ISO 50001:2018. The new edition, published in August 2018, clarified terms and definitions, introduced more specific requirements for data analysis on energy consumption, risk-based thinking, and integration of energy management into

strategic organizational planning [7]. Since August 2021, only ISO 50001:2018 has remained valid, fully replacing the 2011 version.

In Ukraine, this international standard was adopted as a national standard under the code DSTU ISO 50001:2020 (ISO 50001:2018, IDT), which represents the official translation and confirmation of the international edition. Therefore, since 2020, the current version of the standard applicable to Ukrainian organizations has been fully aligned with international requirements [8].

Conceptual foundations of energy management are presented in the works of such scholars as Burkynskyi and Dudkin (2019), and Vdovychenko (2020), who emphasize the importance of integrating energy aspects into the overall enterprise management strategy and highlight the necessity of implementing the principles of sustainable development in the process of energy consumption [9; 10].

The studies of Capehart, Turner, and Kennedy (2020) propose approaches that focus on the application of the continuous improvement cycle (PDCA – Plan-Do-Check-Act) as the basis of energy management. This allows for the systematic reduction of energy consumption through planning measures, their implementation, monitoring effectiveness, and process correction, as well as underlining the crucial role of top management in implementing energy policy [11].

In our view, the energy management system should go beyond resource savings and be considered as a tool for achieving the enterprise's long-term environmental objectives and its harmonious interaction with the environment [12]. The global development program until 2030 is set out in Transforming our world: the 2030 Agenda for Sustainable Development – a strategic document adopted by the UN General Assembly in 2015 [13]. Special attention in this study is given to Sustainable Development Goal No. 7 – "Ensure access to affordable, reliable, sustainable and modern energy for all" and Goal No. 12 – "Ensure sustainable consumption and production patterns". These goals specifically outline the need to design and implement energy-saving strategies, including through the development of enterprise energy management systems [12].

The development and implementation of energy management measures at both

the macro- and micro-levels are crucial for ensuring economic efficiency, environmental sustainability, and the overall success of business entities. Contemporary research [1–3; 5; 11; 12; 15; 19] emphasizes that effective energy management requires a comprehensive integration of these levels. In particular, strategic support from the state (through standards, incentives, and policies) should be complemented by enterprise-level actions such as equipment modernization, audits, and the implementation of energy management systems.

At the level of individual enterprises (microeconomic level), energy management is carried out through direct managerial actions and technical measures to optimize energy consumption. Its primary goal is to reduce energy costs while ensuring stable production performance. Key components of micro-level energy management include energy auditing and monitoring, optimization of technical equipment, ISO 50001 certification, investments in renewable energy sources (RES), and energy-saving measures (Table 1).

The implementation of these measures results in reduced production costs, increased operational efficiency, and enhanced competitiveness of the enterprise. As emphasized in micro-level approaches, energy is considered a resource, and its management is as necessary as the management of any other production factor.

At the macroeconomic level, energy management encompasses state policy, strategic planning, and regulation of the energy sector. This involves the establishment of legislative standards, government programs, and incentives that ensure the country's energy security and sustainable development (Table 2).

Thus, the macro-level approach establishes the regulatory, financial, and organizational framework for energy management. State policy should align with company activities: energy-saving requirements and support for technological innovations at enterprises contribute to achieving strategic goals such as energy independence and environmental sustainability.

Table 1 – Directions, measures, and results of energy management implementation at the micro level

Directions of energy management	Measures	Implementation results
Energy audit and monitoring	Systematic accounting, regular measurements, and auditing of energy consumption at the enterprise	Identification of inefficient energy expenditures, creation of a database for managerial decision-making, and enhancement of energy consumption transparency at the enterprise.
Optimization of technical equipment	Modernization of equipment, implementation of energy-efficient technologies, and automated energy management systems.	As noted in [14], the implementation of these measures resulted in the following outcomes: a 40% reduction in actual specific electricity consumption per unit of production, a 20% decrease in gas consumption, and a 60% reduction in pollutant emissions into the air.
ISO 50001 certification	Implementation of a formal Energy Management System (EnMS) compliant with DSTU ISO 50001:2020 (ISO 50001:2018, IDT).	The standard provides formal procedures for planning, implementing, and improving energy management within an enterprise. Its implementation results in increased energy efficiency, reduced energy costs, decreased environmental impact, and enhanced competitiveness and reputational appeal of the enterprise.
Investments in renewable energy sources (RES) and energy saving	The establishment of on-site solar or wind power plants, heat pumps, and other renewable energy sources, as well as the implementation of energy-saving programs and environmental awareness initiatives for personnel.	The use of renewable energy sources at the local level allows enterprises to reduce energy dependence and contribute to environmental protection.

Compiled by the author based on [1;5; 6-8; 14; 15; 16; 19].

Table 2 – Directions, measures, and outcomes of energy management implementation at the macro level

Directions of energy management	Measures	Implementation results
National energy strategies and policy	Development of strategic documents (e.g., "Ukraine's Energy Strategy until 2035") and government programs	Ensuring energy security through the diversification of sources and the development of local generation
Regulation and standards	Establishment of energy consumption standards, requirements for construction and reconstruction of facilities, implementation of EnMS in accordance with the standards DSTU ISO 50001:2020 (ISO 50001:2018, IDT) and energy audits.	Ensuring enterprise compliance with national energy standards, improving energy efficiency, and aligning with the national energy policy goals.
Infrastructure readiness and security	Modernization and restoration of energy networks; ensuring stable energy supply; rapid recovery of damaged infrastructure; enhancing the resilience of energy systems in emergencies.	Reducing the risks of accidents and outages; decreasing vulnerability to attacks and emergencies; ensuring uninterrupted operation of critical facilities (hospitals, transportation, industry); increasing public trust in state institutions.
Support for RES and innovation promotion	State programs for subsidizing and preferential financing of renewable energy, tax incentives for energy efficiency projects, and the creation of incentive instruments (energy funds, "green" tariffs).	Increasing the share of renewable energy in the overall energy balance of enterprises, promoting the implementation of innovative technologies and energy efficiency programs, reducing dependence on conventional energy sources, enhancing environmental safety, and strengthening the resilience of enterprises to economic and energy crises.

Compiled by the author based on [1-3; 6-8; 17-20].

Summary and conclusions.

The conceptual foundations of energy management, its historical development, and evolution from local programs to comprehensive systems, as well as key energy management standards DSTU ISO 50001:2020 (ISO 50001:2018, IDT), highlight the importance of integrating international experience in the context of Ukrainian enterprises. Energy management is a multifaceted system that combines macro- and

micro-level approaches. At the macro level, it ensures the implementation of state energy security and environmental stability objectives, stimulates the development of innovative solutions, and enhances economic resilience. At the micro level, energy management systems enable enterprises to optimize resource use, reduce costs, increase production efficiency, and improve competitiveness.

Systematic accounting and monitoring of energy consumption, equipment modernization, system certification, investments in renewable energy sources, and energy-saving programs contribute to improving resource efficiency, reducing pollutant emissions, and enhancing the environmental sustainability of enterprises. Certification formalizes the processes of planning, implementation, and improvement of energy management, ensuring resource savings and minimizing negative environmental impacts.

It has been established that state strategies, regulations, and incentives for renewable energy sources align enterprise activities with national goals, promote diversification of energy sources, and support local generation.

A systematic analysis has shown that the integration of micro- and macro-level approaches creates a synergistic effect: the comprehensive combination of enterprise and state actions promotes sustainable development of the energy sector, increases economic efficiency, and enhances environmental sustainability. Effective energy management serves as a key instrument for implementing economic policy, energy security, and environmental strategy at all levels of governance.

The study revealed the influence of state strategies, standards, and RES incentive programs on the effectiveness of energy management in Ukrainian enterprises under contemporary conditions, including military and economic challenges. Comprehensive integration of energy standards, government programs, and innovative practices ensures not only resource optimization but also strengthens economic resilience and competitiveness of enterprises. Adapting international experience while considering national specifics allows for the development of effective energy management models that provide strategic energy security and support innovative growth.

Thus, the conducted research confirms that the application of modern energy management systems is essential for enhancing the economic and environmental resilience of Ukrainian enterprises. The comprehensive combination of standards, state strategies, and innovative approaches provides a foundation for implementing effective energy management models and advancing renewable energy development.

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