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FORMATION AND IMPLEMENTATION OF A SUSTAINABLE ENERGY AND CLIMATE ACTION PLAN AS THE BASIS FOR THE ENERGY MANAGEMENT SYSTEM IN PUBLIC ADMINISTRATION

The article provides a comprehensive analysis of the process of formation and implementation of the Sustainable Energy and Climate Action Plan (SECAP) as a key instrument of the public energy management system at the local self-government level. Using the example of the Zhytomyr City Territorial Hromada, the institutional, organizational, and procedural mechanisms that ensured the integration of sustainability principles into the main areas of municipal governance are examined. The research methodology, based on a systems approach and content analysis of official documents, allowed for the reconstruction of the full life cycle of the SECAP—from strategic planning and the development of target indicators to the establishment of a monitoring system involving key stakeholders.

Special attention is given to a critical analysis of the challenges associated with plan implementation under conditions of full-scale Russian aggression. It is demonstrated that wartime conditions not only highlighted issues of energy security and independence but also served as a catalyst for the accelerated transformation of local energy policy. The article identifies specific adaptive mechanisms employed by the community to overcome crisis phenomena, particularly regarding the diversification of energy supply sources and urgent modernization of critical infrastructure. A set of practical recommendations is provided

for adapting this experience to other Ukrainian hromadas facing similar security and sustainability challenges.

Keywords: *energy management, SECAP, sustainable development, public administration, territorial hromada, climate adaptation, energy security, wartime conditions.*

General statement of the problem. In the current context of increasing climate challenges, rising energy costs, and growing concerns regarding energy security, the development of public administration systems in the energy sector becomes particularly relevant. Public administration serves as the framework in which national and local energy policies are formed and implemented, with local self-government bodies acting as key actors in applying energy management tools aimed at ensuring the sustainable development of territorial communities.

An important component of the local public energy management system is the Sustainable Energy and Climate Action Plan (SECAP), which ensures the integration of energy, climate, and management decisions into strategic planning processes and the implementation of municipal policy. However, the practice of SECAP implementation in Ukraine reveals a number of managerial challenges, including insufficient institutional capacity of public authorities, limited intersectoral cooperation, shortages of financial and human resources, and underdeveloped mechanisms for monitoring and evaluating the effectiveness of energy management measures.

These processes are further complicated by the conditions of full-scale military aggression against Ukraine, which have significantly affected the functioning of critical energy infrastructure and highlighted the need for the rapid review of management decisions in the energy sector. Under these conditions, public administration and energy management must transform into adaptive systems capable of ensuring energy resilience, security, and continuity of territorial community development. This underlines the need for further research aimed at summarizing SECAP implementation practices and developing effective management mechanisms within the public energy management system.

Analysis of Recent Research and Publications. The issues of energy management, improving energy efficiency, and rational use of fuel and energy resources in modern conditions have been studied by both domestic and international researchers. In particular, the works of N.E. Krasnostanova, S.A. Yaromich, and O.V. Yatsenko justify the feasibility of implementing energy management systems in Ukrainian enterprises as a tool to reduce energy costs and improve operational efficiency [28]. The authors emphasize the formation of corporate energy strategies and their interconnection with national energy security.

Theoretical and methodological aspects of energy management development, as well as the definition of priorities for the 21st century, are addressed in the works of O.V. Kyrylenko, S.P. Denysiuk, and I.V. Blinov, where the necessity of a comprehensive approach to energy consumption management, the integration of innovative technologies, and the adaptation of national policy to modern European trends is emphasized [29]. The researchers underline the role of state regulation and scientific-technical progress in ensuring sustainable development of the energy sector.

A separate group of publications focuses on the analysis of European Union legislative initiatives and their implementation in Ukraine. For instance, V. Vasyliiev conducted a comparative analysis of public energy management mechanisms in Ukraine and Poland, identifying key factors affecting the effectiveness of energy policy implementation [30]. At the same time, despite extensive scholarly work, several questions regarding the practical implementation of energy management systems amid the transformation of public administration remain insufficiently studied, highlighting the relevance of further research in this field.

Analysis of recent research and publications. The aim of the article is a comprehensive study of the formation and implementation process of the Sustainable Energy and Climate Action Plan as the main instrument of the energy management system in public administration of the Zhytomyr City Territorial Hromada, as well as an assessment of its role in ensuring sustainable territorial development, enhancing energy security, and adapting local energy policy to modern crisis challenges. To achieve this aim, the study analyzes the theoretical

and methodological foundations of public administration and energy management at the local level, examines institutional and organizational prerequisites for SECAP development, identifies key stages of its implementation, and explores mechanisms for interaction with the community's main stakeholders. Special attention is paid to assessing the impact of wartime conditions on SECAP implementation and the functioning of the public energy management system, as well as summarizing the practical experience of Zhytomyr City Territorial Hromada in order to develop recommendations for adapting energy management tools for other Ukrainian hromadas.

The scientific novelty of the study lies in a comprehensive approach to analyzing SECAP implementation as a public administration tool at the local level, including the consideration of institutional, organizational, and procedural aspects, as well as evaluating the impact of crisis factors, particularly wartime aggression, on the effectiveness of the energy management system. The study allows not only for the reconstruction of the full SECAP implementation cycle but also for proposing practical mechanisms for adapting and improving energy management policies that can be applied in other Ukrainian hromadas facing similar sustainability and security challenges.

The conclusions of the analysis emphasize that effective SECAP implementation in public administration is a key factor in improving energy efficiency and energy security at the local level, as well as promoting the integration of sustainable development principles into the strategic planning of the community. The results allow for the evidence-based formation of management decisions and practical recommendations for improving the energy management system and enhancing the resilience of local self-government under current economic and security challenges.

Presentation of the Main Material of the Study. Contemporary global challenges, such as climate change, economic decarbonization, and ensuring energy security, require active measures at all levels of governance. Local self-government plays a particularly important role, as it is at the community level that specific energy efficiency projects are implemented, renewable energy sources are introduced, and infrastructures are adapted to climate change.

The purpose of this article is a comprehensive analysis of public administration mechanisms aimed at sustainable energy development, using the Zhytomyr City Territorial Hromada as an example, which developed an ambitious Action Plan until 2050 [22]. The article addresses the following tasks: to analyze the regulatory framework and strategic orientations of the plan; to investigate the organizational model of its implementation; to assess the monitoring system and public engagement; to identify factors that facilitate or hinder implementation, and to formulate practical conclusions.

The development and implementation of the Sustainable Energy and Climate Action Plan (SECAP) at the territorial hromada level is based on a complex multi-level system of legislative acts, methodological recommendations, and data management tools. This system integrates Ukraine's international commitments, national strategic policy, sectoral regulation, and local programmatic documents, creating a comprehensive legal and technical foundation for local action.

The foundation consists of international agreements ratified by Ukraine: the UN Framework Convention on Climate Change (1996) [1] and the Paris Agreement [3]. The Paris Agreement, through the updated Nationally Determined Contribution (NDC), establishes the obligation of the state and, accordingly, territorial hromadas to achieve clear, measurable greenhouse gas emission reduction targets.

At the national level, long-term priorities and direct requirements for communities are established through key strategic documents: the Energy Strategy of Ukraine until 2035 («Security, Energy Efficiency, Competitiveness») [8], the Low-Carbon Development Strategy until 2050 [9], and the Strategy for Environmental Safety and Climate Change Adaptation until 2030 [10]. Among the latest programmatic documents, the National Energy and Climate Plan (NECP) until 2030 [19] plays a central role, integrating energy and climate goals and directly influencing the content of local SECAPs. It is complemented by the National Action Plan for Energy Efficiency until 2030 [14]. Sectoral legislation includes the laws «On Alternative Energy Sources» [2], «On Energy Efficiency» [5], «On the Energy Efficiency Fund» [6], as well as the Law «On Local Self-Government in Ukraine» [31], which serves as the legal basis for the powers of communities in the energy and climate sector.

The immediate basis for developing a specific community SECAP is its own strategic and operational documents. In Zhytomyr, these include the Integrated Development Concept of Zhytomyr City until 2030 [21], which defines overall sustainable development goals, within which energy and climate policy is implemented, as well as the Municipal Target Program «Municipal Energy Plan of Zhytomyr City Territorial Hromada for 2021–2024» [20], which served as a transitional operational document and laid the foundation for a full SECAP.

Practical implementation is impossible without a high-quality methodological and informational basis. The main guiding document is the Methodology for Developing Local Energy Plans [16]. Standardized reporting and monitoring, requiring data digitization (SCADA, automated commercial energy accounting systems), also play a critical role. Data management policies and Business Intelligence tools allow for the development of standards for data collection, processing, and analytics, converting raw information into substantiated management decisions.

The modern regulatory framework of SECAP is a dynamic, multi-level, and integrated system stretching from global climate agreements to specific local programs. Its core today is the National Energy and Climate Plan until 2030 [19], which harmonizes state and community efforts. Successful implementation depends on the community's ability to align its own strategies (Development Concept) with NECP requirements, transform operational plans (Municipal Energy Plan) into a full SECAP, and implement modern systems for data collection, analysis, and monitoring. The combination of regulatory discipline, quality methodology, and effective data management turns legal requirements into real energy and climate results at the local level.

The study of the formation, content, and prospects of the Sustainable Energy and Climate Action Plan of Zhytomyr City Territorial Hromada is based on a combination of general scientific and specialized public administration methods. The methodological basis of the work combines the analysis of regulatory and strategic documents of local self-government bodies with the interpretation of the socio-economic and political-administrative context of their implementation.

The empirical base of the study consists of official public and internal documents of the Zhytomyr City Council and its executive bodies. These include the approved SECAP as the key object of analysis, City Council session decisions regarding its adoption, amendments, and financing, as well as materials from relevant structural subdivisions of the City Council in the field of energy management, housing and utilities, and economic development. A separate group of sources consists of reports on SECAP implementation, analytical notes, presentation materials, and statistical data on energy consumption of municipal enterprises and city infrastructure.

Of particular importance to the study are factual data on the dynamics of consumption of primary energy carriers, particularly natural gas and electricity by municipal enterprises of Zhytomyr during 2010–2020 (Fig. 1).

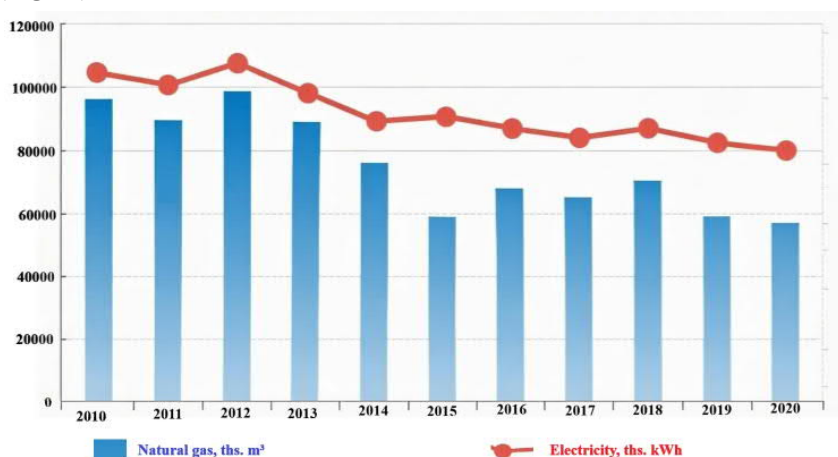


Fig. 1. Dynamics of the consumption of primary energy carriers by Zhytomyr Heating and Utilities Company (KPT «ZhKTE») in 2010–2020.

Source: developed by the author based on analytical materials of Zhytomyr City Council [20,21,22,23].

These indicators allow assessing the baseline conditions for the formation of the Sustainable Energy and Climate Action Plan (SECAP), verifying the realism of its defined target benchmarks, and tracking

existing trends that inform managerial interventions. Such data serve as an objective foundation for analyzing declared political priorities and the practical mechanisms for their implementation.

Methodologically, the study relies on a systems approach, which enables consideration of the SECAP not as a collection of individual projects but as a holistic instrument of public governance for the community's energy development. Within this framework, the analysis covers the structure of the plan, the interconnection between defined goals, objectives, implementation tools, and monitoring mechanisms, as well as the degree of alignment between strategic and operational levels of management.

For an in-depth study of the SECAP content, elements of content analysis were employed to identify key priorities of the community's energy and climate policy, determine dominant intervention areas (building energy efficiency, renewable energy development, heat supply modernization, transportation), and the types of instruments used by local authorities. Special attention was given to the formulation of goals and indicators, their quantitative content, and correspondence with the available community resources.

Institutional analysis focused on examining the organizational and managerial mechanisms for SECAP implementation. In this context, the study considered the distribution of powers among executive bodies of the City Council, existing interdepartmental coordination mechanisms, reporting and evaluation procedures, and potential institutional constraints that could affect plan effectiveness.

The results of the analysis are interpreted in two interconnected contexts. First, the SECAP is viewed as an element of the implementation of European and national approaches to climate and energy policy, particularly within the framework of the «Covenant of Mayors» initiative [24] and relevant national legislation. Second, an assessment is made of the alignment of SECAP goals and measures with the actual socio-economic conditions of Zhytomyr City Territorial Hromada, its infrastructure status, and level of energy dependence.

Thus, the applied methodology provides a comprehensive analysis of the SECAP as a public governance tool, allowing identification of

its strengths, problem areas, and potential for replicating Zhytomyr's experience in other Ukrainian territorial communities.

The transition to sustainable energy requires local authorities to perform new functions that combine regulatory, coordination, and incentivizing roles. Conceptually, this process is based on the principles of the European Green Deal and the «Covenant of Mayors for Climate and Energy» initiative [24], which Zhytomyr joined. A key task is transforming the local energy sector toward energy efficiency, development of local renewable sources, and infrastructure adaptation. Effective public governance in this field involves not only planning but also creating institutional conditions, mobilizing financing, and establishing partnerships.

Analysis of the Sustainable Energy and Climate Action Plan of Zhytomyr [23] reveals a clear and systematic hierarchy of goals that ensures linkage between strategic vision and practical implementation. The long-term vision to 2050 is formulated as achieving climate neutrality and a full transition to 100% renewable energy in the community's overall energy balance. This transformational trajectory is reinforced by specific quantitative benchmarks: an 80% reduction in CO₂ emissions and a significant increase in «green» energy generation compared to the 2010 baseline.

Ambitious long-term goals are detailed in a system of intermediate targets to 2030, making the strategy manageable. The most critical interim target is a 38.7% reduction in greenhouse gas emissions. However, the target framework is not limited to mitigation alone. It comprehensively includes adaptation objectives, critical for enhancing city resilience, such as development of cycling infrastructure, reduction of sealed surfaces to mitigate urban heat, and intensified waste management.

The formulation of adaptation goals is informed by scientifically grounded climate change projections. Expected warming will affect all sectors of community life, including building energy consumption, public health, and infrastructure condition. Effective planning requires understanding the nature of anticipated climatic changes. As shown in Fig. 2, the most intensive temperature increases are expected in summer and winter, particularly by the end of the 21st century. This trend will drive higher energy needs for cooling during hot periods and may

alter heating regimes in winter. Accounting for these projected trends is essential for developing a sustainable and economically balanced development strategy.

A socially oriented block of goals addresses energy poverty. This involves both direct support to vulnerable groups and structural measures for energy modernization of the housing stock to reduce utility costs.

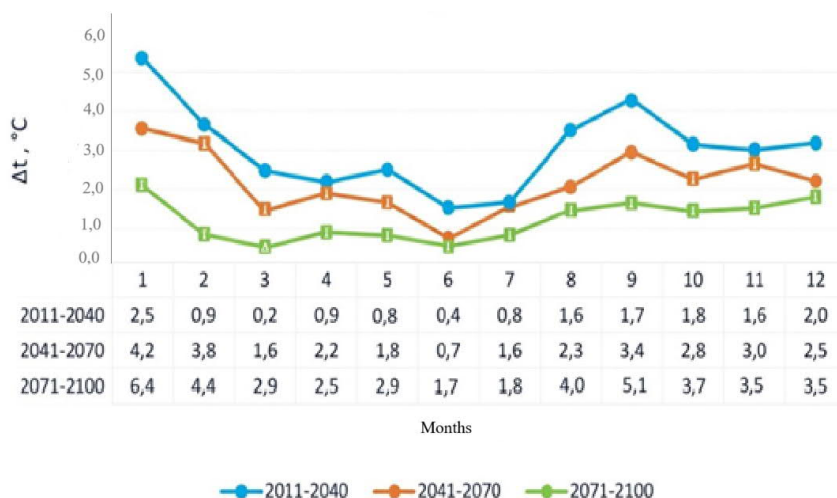


Fig. 2. Modeling of temperature regime dynamics: projected deviations of average monthly temperatures (°C) over three thirty-year periods under a realistic high-emission scenario (RCP 8.5) compared with the climate norm of 1981–2010.

Source: developed by the author based on analytical materials of Zhytomyr City Council [20,21,22,23].

The SECAP's goal hierarchy demonstrates a comprehensive understanding of sustainable development, systematically integrating environmental (emission reduction, adaptation), social (combating energy poverty), and economic (transition to renewables, energy efficiency) aspects. This approach transforms the document from a mere list of measures into a coherent strategic framework that responds to global challenges (climate change) and local needs (energy independence, quality of life). Incorporating climate projections (Fig. 2) ensures

scientific substantiation of planned adaptation measures and allows the community to prepare for real future challenges.

Effective implementation of complex cross-sectoral strategies such as the SECAP requires not only the existence of a plan but also the establishment of a specialized institutional mechanism capable of overcoming traditional fragmentation across municipal governance areas. In response, Zhytomyr City Territorial Hromada formed a permanent specialized working group [23,22]. Its creation represents a shift from isolated departmental actions to a systemic, coordinated policy in energy and climate.

The working group is chaired by the First Deputy Mayor, providing necessary administrative leverage and a direct link to senior community leadership. Members include heads of key City Council structural units responsible for economic development, budget planning, transport systems, municipal services, education, healthcare, ecology, and urban planning. This composition ensures horizontal coordination, integrating energy policy into the overall socio-economic development strategy.

A notable feature is the inclusion of direct operational actors—directors of major municipal enterprises such as Zhytomyr Heating and Utilities and Zhytomyr Water Utility – ensuring vertical integration, creating a direct link between strategic planning at the City Council level and operational enterprise activities. This structure allows alignment of investment programs with SECAP goals and rapid resolution of technical and resource issues.

The organizational architecture of this coordination mechanism is illustrated in Fig. 3.

The working group's functional responsibilities go beyond ordinary consultation. Its key tasks include:

1. Organizational and technical support: coordinating schedules, monitoring project implementation stages.
2. Problem identification and resolution: operational analysis of barriers arising during implementation and finding interdepartmental solutions.
3. Analytical and advisory activities: preparing recommendations to optimize measures, adjusting plans due to changing external conditions, and improving financing mechanisms.

HEAD OF THE WORKING GROUP		
First Deputy Mayor for the Activities of the Executive Bodies of the Zhytomyr City Council		
COORDINATOR OF THE WORKING GROUP		
Head of the Department of Infrastructure Projects, Energy Efficiency and Projections, Department of Energy Resources, Zhytomyr City Council		
MEMBERS OF THE WORKING GROUP		
Director of the Department of Economic Development, Zhytomyr City Council	Deputy Head of the Department of Housing and Communal Services, Zhytomyr City Council	Head of the Department for Youth and Sports, Zhytomyr City Council
Director of the Department of Budget and Finance, Zhytomyr City Council	Head of the Department of Communal Services, Zhytomyr City Council	Head of the Department of Culture, Zhytomyr City Council
Deputy Director of the Department of Urban Development and Land Resources, Zhytomyr City Council	Head of the Department of Transport and Communications, Zhytomyr City Council	Head of the Department of Health Care, Zhytomyr City Council
First Deputy Director of the Department of Education, Zhytomyr City Council	Deputy Head of the Department of Architecture and Urban Planning, Zhytomyr City Council	Head of the Department of Municipal Development, Zhytomyr City Council
Head of the Strategic Development Service of the Municipal Enterprise “Zhytomyr City Information and Technology Center”, Zhytomyr City Council	Head of the Department of Ecology and Natural Resources, Zhytomyr City Council	Director of the Municipal Institution “City Development Agency”, Zhytomyr City Council
Director of the Municipal Enterprise “Zhytomyrvodokanal”, Zhytomyr City Council		

Fig. 3. Structural-functional model of the working group for implementing energy-climate initiatives within local self-government.

Source: developed by the author based on analytical materials of Zhytomyr City Council [20,21,22,23].

Thus, the established coordination structure functions as a central «hub,» transforming SECAP’s strategic provisions from a document into concrete managerial decisions, investment programs, and operational actions. This mechanism is a key institutional tool ensuring resource consolidation, action alignment among stakeholders, and practical implementation of long-term sustainable energy transformation goals.

Successful implementation of the SECAP also requires sustained public consensus, active stakeholder engagement, and systematic communication

by local authorities. In Zhytomyr, stakeholder engagement was established as a core principle of SECAP governance, employing a differentiated approach tailored to various groups, ensuring both political support and practical realization across sectors and sites.

Stakeholders were divided into internal and external groups to adapt interaction tools to their functions, powers, and interests. Internal stakeholders included local authorities, energy managers of public institutions, heads of condominium associations (OSBB), municipal utilities, and local businesses. Local authorities (council deputies and relevant departments) ensured political legitimacy, integration into strategic documents, and budget financing. Communication emphasized economic and social impacts, cost reduction, and energy security, through meetings, analytical presentations, and briefings.

Energy managers implemented energy efficiency measures in schools, hospitals, and kindergartens. Regular training seminars and practical workshops in energy monitoring, data analysis, and modernization proposals enhanced their capacity, transitioning from ad hoc solutions to data-driven energy management.

Heads of Condominium Association (COA) and housing organizations acted as intermediaries between the city and residents in housing modernization. Communication combined consultations, detailed explanations of financial mechanisms, and demonstration of pilot project results, reducing mistrust and stimulating participation in efficiency programs.

Local businesses were engaged as potential partners in innovative solutions and investment attraction. Information events demonstrated participation in energy service projects, use of modern technologies, and access to financial support programs, fostering public-private sector synergy.

External stakeholders included state authorities, international financial institutions, donor organizations, NGOs, and expert communities. Interaction with central authorities ensured SECAP alignment with national energy and climate policy and access to support programs. International financial institutions and donors financed capital-intensive projects, providing technical assistance, grants, and loans. Communication involved preparation

of high-quality investment proposals, participation in competitions, and transparent reporting.

A multi-level communication approach maintained dialogue and trust. Public discussions, working group meetings, educational events, and information campaigns fostered energy-efficient behavior. Transparency in financing and participation criteria enhanced trust and participation in housing modernization programs.

A monitoring, evaluation, and reporting system aligns with the Covenant of Mayors and the Global Protocol for Cities, enabling strategic management and adaptation. Monitoring includes energy consumption in municipal sectors, transport, and services, adjusted for external factors such as weather. Climate parameter monitoring informs adaptation measures and efficiency evaluation (Fig. 4).

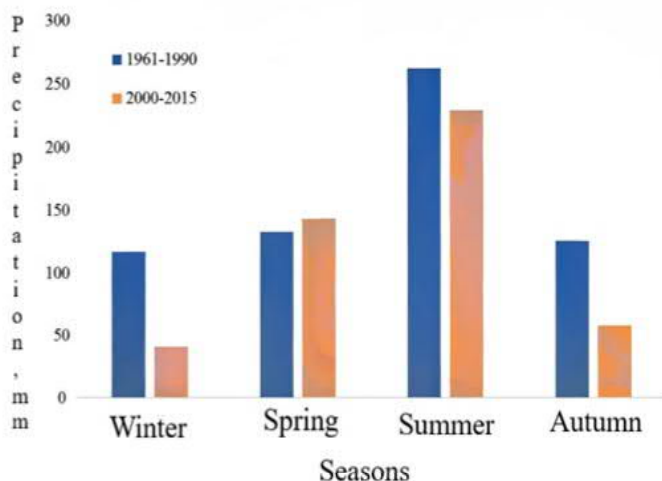


Fig. 4. Seasonal precipitation dynamics (mm) for 1961–1990 and 2000–2015.

Source: developed by the author based on analytical materials of Zhytomyr City Council [23].

Seasonal patterns, particularly summer peaks, affect drainage systems and green infrastructure planning. Comparing periods reveals

potential shifts, critical for adaptation planning in the context of climate change.

A Monitoring Cadastre of Emissions (MCE) tracks greenhouse gas dynamics by sector, updated every 2–4 years, providing an objective basis for evaluating policy impacts. Reporting occurs in two stages: interim reports every 2 years and full updates every 4 years, creating a continuous improvement cycle: planning → implementation → monitoring → evaluation → adjustment. The City Council's Department of Economic Development is responsible, integrating climate policy into overall governance.

The initial phase of energy transformation prioritized reducing energy consumption in key municipal enterprises and facilities, driven by both immediate budget savings and high impact potential.

The largest project was street lighting modernization, replacing 16,000 old lamps with 18,000 LED lights, increasing coverage while reducing energy consumption by ~50% (Fig. 5).

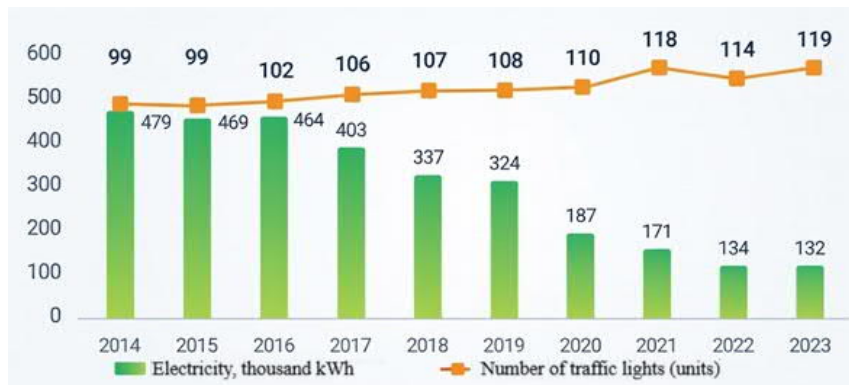


Fig. 5. Dynamics of street lighting network development and electricity consumption of streetlight objects in Zhytomyr, 2014–2023.

Source: developed by the author based on analytical materials of Zhytomyr City Council [20,22].

In addition to street lighting, similar measures were implemented in administrative buildings, schools, kindergartens, and hospitals. Replacing lighting fixtures, installing motion and presence sensors, and optimizing

equipment operating schedules enabled significant cumulative energy savings. These initiatives not only produced economic benefits but also served a demonstrative and educational function, showing residents and businesses the tangible results of energy saving and fostering a culture of resource-efficient behavior. Thus, the lighting modernization program became a catalyst for further changes, initiating a systematic approach to managing energy consumption at the municipal level and creating a financial resource for investment in subsequent, more complex projects.

Thanks to a World Bank loan, 10 km of main pipelines were replaced, significantly reducing water losses and the associated energy costs for water pumping. As a result, electricity consumption by the water utility decreased by 27%, helping the community comply with consumption limits during crisis-related outages.

At the core of Zhytomyr community's energy transformation strategy is an ambitious course toward the development of decentralized generation, which simultaneously addresses energy independence, resource efficiency, and carbon footprint reduction. This direction is based on the comprehensive use of local, renewable, and alternative energy resources.

Bioenergy became the first breakthrough area, thanks to the implementation of an innovative wood chip combined heat and power (CHP) plant with financial and technical support from the Swiss Confederation [27]. This facility, with an electrical capacity of 1.1 MW, allowed the generation of «green» electricity while significantly reducing the consumption of imported natural gas. The success of this pilot project created an imperative for further development: currently, the construction of another biomass CHP plant is planned with financing from the European Bank for Reconstruction and Development (EBRD) – the projected capacity is 2 MW of electricity and 10 MW of thermal energy. The cumulative effect of switching to alternative fuel is impressive: over ten years, the community's natural gas consumption has been nearly halved – from 100 million m³ to 48–49 million m³ – substantially improving the city's economic and energy resilience.

Gas-fired cogeneration has become a strategic solution to ensure the resilience of critical infrastructure during wartime blackouts. With support

from USAID [25], modular gas-piston units (GPU) were installed at existing city boiler plants. Their key advantage is the ability to operate in a completely isolated mode from centralized grids, providing electricity for boiler circulation pumps, control systems, and lighting. Economic efficiency is also significant: the cost of electricity produced by these units is three times lower than the market price. The completion of the planned six modular GPUs will fully supply electricity to the entire heat generation enterprise, covering 4.5 MW of demand.

Solar energy is developing as a means of diversification and meeting peak loads, particularly in municipal infrastructure facilities. The pilot project was the main sewage pumping station, equipped with solar panels with a capacity of 0.4 MW. The positive experience supports project scaling: it is planned to install solar power plants at 12 municipal water utility facilities with a total capacity of 2.6 MW. This measure will allow these critical facilities to fully cover their own energy needs in summer, reducing grid load and operational costs.

Energy-from-waste (RDF fuel) represents a long-term strategic vector, based on the community's existing infrastructure – a waste processing plant capable of producing high-calorific fuel from solid household waste. This creates a unique precondition for developing a waste-to-energy project that could potentially close the «energy-waste» loop, transforming the problem of waste disposal into a stable energy source for municipal needs.

The implementation of such a large portfolio of projects became possible through a combination of diverse financing sources and strong partnerships. The financial architecture for the construction of the biomass CHP included the community's own funds for preparatory work, EBRD loan resources, and, at the preparation stage, grant assistance from Switzerland [27]. The gas-piston units project was implemented with USAID support, and funds from the Slovenian government were used to develop solar energy. Another area is public-private partnership: a memorandum was signed with a private company for the installation of a large 25 MW GPU connected to the city's electrical network. Thus, the financing model is hybrid, allowing risk distribution and optimal use of instruments for each type of project.

The practical implementation of these innovative projects revealed several systemic challenges and barriers. Key issues included a shortage of qualified personnel capable of operating and maintaining modern high-tech equipment. Another significant limitation was the dependence on imported components and equipment, complicating supply chains and increasing project costs. There was also an urgent need for parallel modernization of outdated internal electrical networks at facilities, as new generating capacities often require an adequate level of grid readiness. Successfully overcoming these barriers critically depended on effective coordination among all key players: the city council (providing political support and budgetary decisions), the management of municipal utilities (responsible for technical implementation), and the executive authorities (providing overall management and communication with partners). This experience underscores that technological innovations in energy are accompanied by equally important institutional and managerial changes.

The full-scale Russian invasion in February 2022 fundamentally reshaped the context of implementing Zhytomyr community's Sustainable Energy and Climate Action Plan (SECAP). Long-term goals, designed over decades for emission reductions and gradual «greening» of the energy balance, were quickly transformed into urgent operational tasks for physical survival and energy resilience. The 2023–2024 energy crisis, caused by systematic attacks on Ukraine's energy infrastructure, with cumulative electricity outage durations reaching up to 22% of annual time in some periods, became a severe practical test (stress-test) for the community's strategy. The sustainable energy management system, which had been steadily built over previous years, was forced to operate under extreme deficit and instability conditions.

Policy and infrastructure adaptation to the new realities proceeded simultaneously along two interrelated directions, forming a dual-response model:

- The primary task was to minimize energy consumption without halting the city's vital activities. This prompted the acceleration and radicalization of existing programs.
- Full-scale replacement of outdoor lighting with LEDs was completed, reducing electricity consumption in this sector by 50%

without compromising service quality, freeing valuable kilowatts for other needs.

The involvement of international financing (World Bank, EBRD [26]) for replacing worn-out water utility and «Zhytomyrteplokomunenergo» networks not only improved service reliability but also significantly reduced technical losses and energy intensity of these systems.

This direction shifted from strategic to tactically critical. Conditions of regular full-scale blackouts made creating «islands» of energy independence a priority. The greatest focus was on the rapid installation of modular gas-piston cogeneration units (GPU) with USAID support. Their key advantage is the ability to operate fully autonomously, supplying electricity and heat to key facilities (boiler plants, water pumping stations, hospitals) even during prolonged disconnections from central networks. An additional important effect was economic benefit: the cost of electricity produced by such units was three times lower than the market price.

The wartime necessity to reduce dependence on imported gas gave a new impetus to local resource projects. The construction and operation of wood-chip CHPs, as well as the development of RDF fuel projects from waste, allowed the community to cut natural gas consumption almost in half compared to a decade ago, creating a powerful buffer against price fluctuations and supply interruptions.

Analysis of Zhytomyr community's experience confirms that an effective public energy management system can be established even under extremely difficult conditions; however, its success requires a comprehensive combination of strategic leadership, institutional capacity, and systemic openness to cooperation. The uniqueness of this case lies in the fact that the development and implementation processes of SECAP ran parallel with the challenges of full-scale Russian aggression, which intensified needs and transformed the sustainability strategy into a survival and recovery tool. Under wartime conditions, strategic planning becomes particularly significant: the long-term vision to 2050 must be combined not only with intermediate goals for 2030 but also with operational crisis plans based on detailed sectoral vulnerability analysis of infrastructure.

The creation of a high-level interdepartmental working group proved to be a critically important institutional solution, allowing the fragmentation of local authorities to be overcome and enabling rapid coordination of actions to restore and protect energy infrastructure. Financial resilience of policy under wartime conditions is achieved through even greater diversification of sources: in addition to the community budget, state programs («ENERGODIM») [5], and international grants, access to special recovery and humanitarian aid funds becomes critically important, aimed specifically at overcoming the consequences of war destruction. Transparent local support programs for Condominium Associations (COAs) and households in this context turn from energy-saving tools into means of social stabilization and population support.

Conclusions. Wartime conditions require constant review of priorities, rapid reallocation of resources to the most vulnerable areas, and the search for unconventional, fast solutions to ensure energy independence (e.g., deployment of decentralized renewable generation capacities). Recommendations for other communities aiming to develop energy management during wartime or post-war periods begin with mandatory analysis of new risks and infrastructure vulnerabilities. Implementation should start with projects that simultaneously solve several tasks: ensure energy independence, enhance the resilience of critical facilities (hospitals, resilience centers), and have a short implementation period. At the same time, it is necessary to maintain and develop institutional capacities and public communication, as trust and interaction are the foundation of resilience in crisis situations.

ФОРМУВАННЯ ТА ІМПЛЕМЕНТАЦІЯ ПЛАНУ ДІЙ СТАЛОГО ЕНЕРГЕТИЧНОГО РОЗВИТКУ ТА КЛІМАТУ ЯК ОСНОВА СИСТЕМИ ЕНЕРГОМЕНЕДЖМЕНТУ В ПУБЛІЧНОМУ УПРАВЛІННІ

У статті здійснено комплексний аналіз процесу формування та впровадження Плану дій сталого енергетичного розвитку та клімату (ПДСЕРК) як ключового інструменту системи публічного енергоменеджменту на рівні місцевого самоврядування. На прикла-

ді Житомирської міської територіальної громади досліджено інституційні, організаційні та процедурні механізми, що забезпечили інтеграцію принципів сталості в основні напрями міського управління. Методологія дослідження, що ґрунтується на системному підході та контент-аналізі офіційних документів, дозволила реконструювати повний цикл життєвого циклу ПДСЕРК — від стратегічного планування та розробки цільових показників до побудови моніторингової системи із залученням ключових стейкхолдерів.

Особлива увага приділена критичному аналізу викликів, пов'язаних із реалізацією плану в умовах повномасштабної російської агресії. Доведено, що воєнні умови не лише актуалізували питання енергетичної безпеки та незалежності, але й стали каталізатором прискореної трансформації місцевої енергетичної політики. У статті виокремлено конкретні адаптаційні механізми, застосовані громадою для подолання кризових явищ, зокрема в напрямку диверсифікації джерел енергопостачання та термінової модернізації критичної інфраструктури. Сформовано комплекс практичних рекомендацій щодо адаптації цього досвіду для інших українських громад, які стикаються з аналогічними викликами безпеки та сталості.

Ключові слова: енергоменеджмент, ПДСЕРК, сталий розвиток, публічне управління, територіальна громада, кліматична адаптація, енергетична безпека, воєнні умови, відновлювана енергетика.

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