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Valeriia G. Scherbak, Olena M. Nifatova
Kyiv National University of Technologies and Design, Ukraine

MANAGING ENERGY EFFICIENCY AND ENERGY SAVING BASED ON THE UNIVERSITY ENERGY INNOVATION KNOWLEDGE HUB

This paper offers an argument for the need to providing further research on improving energy efficiency and searching for modern management methods based on the university energy innovation knowledge hub. The findings have revealed that the specific energy consumption in the Ukrainian economy is unjustifiably higher than that of other European countries and countries with transitive economies. It is noted that economic losses are becoming increasingly apparent in the context of high cost of imported energy resources, low level of energy security, incompetitiveness of industries and significant environmental wastes. The research methodology entails the principle of studying and summarizing factual data on enhancing energy management and quality management systems, as well as the university documentation. To attain the research agenda, the following methods have been employed: the system and structural analysis techniques, management theory, methods of diagnostics and identification, graph theory as well as energy balance methods. The study presents a mechanism of energy efficiency and energy saving management based on the university energy innovation knowledge hub. The findings demonstrate that such a mechanism is able to overcome the rejection by economic actors of innovation technologies in general and energy efficient technologies in particular. The proposed mechanism of energy efficiency and energy saving management based on the university energy innovation hub challenges the implementation of specific economic measures that should include such elements as incentives (motivators) for energy saving, energy market infrastructure and energy efficient technology, energy projects funding sources and tools. The conclusions resume that in modern realia, higher education institutions should promote a shift from a formally declared energy saving policy towards a University energy efficiency economy pattern as an energy autonomy driver, building a strategy for combining indicative and market functions in ensuring energy efficiency.

Keywords: *energy innovation knowledge hub; energy efficiency; university; energy autonomy.*

Валерія Г. Щербак, Олена М. Ніфатова
Київський національний університет технологій та дизайну, Україна

УПРАВЛІННЯ ЕНЕРГОЕФЕКТИВНІСТЮ ТА ЕНЕРГОЗБЕРЕЖЕННЯМ НА БАЗІ УНІВЕРСИТЕТСЬКОГО ЕНЕРГО-ІННОВАЦІЙНОГО ХАБА ЗНАНЬ

Статтю присвячено доцільності здійснення подальших наукових розвідок з питань підвищення енергоефективності та пошуку сучасних методів управління нею на базі створення університетського енерго-інноваційного хаба знань. Визначено, що питоме споживання енергії українською економікою є невиправдано вищим проти показників інших країн Європи та країн із перехідною економікою. Наголошується, що економічні втрати стають все більш очевидними в умовах високої вартості імпортованих енергоресурсів, низького рівня енергетичної безпеки, неконкурентоспроможності галузей промисловості та відчутних екологічних збитків. Доведено, що необхідність підвищення енергоефективності є нагальною потребою як з економічної, так і з екологічної позицій. В основу методології дослідження покладено принцип вивчення та узагальнення фактичного матеріалу з проблем удосконалення систем енергетичного менеджменту та менеджменту якості, а також документація університету. Для виконання поставлених завдань використано методи системного та структурного аналізу, теорії управління, методи діагностики та ідентифікації, теорія графів, а також методи енергетичних балансів. Запропоновано

механізм управління енергоефективністю та енергозбереженням на базі університетського енерго-інноваційного хаба знань. Доведено, що такий механізм здатний подолати неприйняття економічними агентами інноваційних технологій загалом та енергоефективних технологій зокрема. Запропонований механізм управління енергоефективністю та енергозбереженням на базі університетського енерго-інноваційного хаба знань вимагає впровадження саме економічних заходів, що включають такі складові, як стимул (фактор мотивації) енергозбереження, інфраструктура ринку енергоресурсів та енергоефективних технологій, джерела та механізми фінансування енергоефективних проєктів. У висновках резюмується, що на сучасному етапі розвитку для закладів вищої освіти доцільним вбачається перехід від формально задекларованої політики енергозбереження до економіки енергоефективності як фактора енергоавтономії вишу, вибудовуючи на цій основі стратегію поєднання індикативних та ринкових функцій у реалізації енергоефективних заходів.

Ключові слова: *енергоінноваційний хаб знань; енергоефективність; університет; енергоавтономія.*

Валерия Г. Щербак, Елена М. Нифатова
Киевский национальный университет технологий и дизайна, Украина

УПРАВЛЕНИЕ ЭНЕРГОЭФФЕКТИВНОСТЬЮ И ЭНЕРГОСБЕРЕЖЕНИЕМ НА БАЗЕ УНИВЕРСИТЕТСКОГО ЭНЕРГО-ИННОВАЦИОННОГО ХАБА ЗНАНИЙ

Статья посвящена целесообразности осуществления дальнейших научных исследований по вопросам повышения энергоэффективности и поиска современных методов управления нею на базе создания университетского энерго-инновационного хаба знаний. Определено, что удельное потребление энергии украинской экономикой является неоправданно высоким по сравнению с показателями других стран Европы и стран с переходной экономикой. Отмечается, что экономические потери становятся все более очевидными в условиях высокой стоимости импортируемых энергоресурсов, низкого уровня энергетической безопасности, неконкурентоспособности отраслей промышленности и ощутимого экологического ущерба. Доказано, что необходимость повышения энергоэффективности является насущной потребностью как с экономической, так и экологической позиций. В основу методологии исследования положен принцип изучения и обобщения фактического материала по проблемам усовершенствования систем энергетического менеджмента и менеджмента качества, а также документация университета. Для выполнения поставленных задач использованы методы системного и структурного анализа, теории управления, методы диагностики и идентификации, теория графов, а также методы энергетических балансов. Предложен механизм управления энергоэффективностью и энергосбережением на базе университетского энергоинновационного хаба знаний. Доказано, что такой механизм способен преодолеть неприятие экономическими агентами инновационных технологий и энергоэффективных технологий в частности. Предложенный механизм управления энергоэффективностью и энергосбережением на базе университетского энергоинновационного хаба знаний требует внедрения именно экономических мер, включающих такие составляющие, как стимул (фактор мотивации) энергосбережения, инфраструктура рынка энергоресурсов и энергоэффективных технологий, источники и механизмы финансирования энергоэффективных проектов. В заключении резюмируется, что на современном этапе развития для учреждений высшего образования целесообразным усматривается переход от формально задекларированной политики энергосбережения к экономике энергоэффективности как фактора энергоавтономии вуза, выстраивая на этой основе стратегию сочетания индикативных и рыночных функций в реализации энергоэффективных мероприятий.

Ключевые слова: *энергоинновационный хаб знаний; энергоэффективность; университет; энергоавтономия.*

Introduction. Transformation of the energy sector of Ukraine must be based on a radical change in approaches to the implementation of energy efficiency policy (I. Gryshchenko, V. Shcherbak, O. Shevchenko [1]). The existing energy saving potential requires a new professional assessment, as it can be considered as an additional source of energy supply of the economy (J. di Stefano [2]). This is especially relevant for Ukraine, given the priority strategic task of integration into the European economy and community. However, today the energy intensity of Ukrainian GDP is 2 times higher than the world average. As a consequence this makes Ukrainian economy unattractive for investments, and products are not competitive, and living standards are low. The task of improving the overall energy efficiency has to be solved in the context of decentralization. It should be noted that this is a new path of development for Ukraine and it is impossible to protect the community from mistakes and challenges on this path in advance. Under these conditions, the influence of institutional structure on energy factors of economic development is shifting: there is a need to find new managerial approaches and tools for economic development, instead of the existing use of energy resources it is necessary to offer an effective mechanism for their management (V. Kaplun, V. Shcherbak [3]). Reducing the specific consumption of energy resources should be a key priority for the Government of Ukraine.

Given the significant heritage of foreign and Ukrainian scientists in the field of energy conservation and energy efficiency, it is necessary to point out the lack of works is practical nature of the use of energy resources (J. Liu, Q. Yao, Y. Hu [4]). For the implementation of energy efficiency policy it is necessary to increase significantly the number of practical works on the study of the use of energy resources by end users. The Ukrainian higher educational institutions should be studied as structures from the point of view of the received possibilities of management of economic development and first of all through conditions and possibilities of use of power resources. This direction of researches will allow to generalize practices of use by the higher educational institutions of own newest possibilities and to substantiate scientifically directions of development of power efficiency which are economically and socially justified by power autonomy (K. Shaposhnikova, V. Shimov [5]). Relevance of the formulated above questions leads to theoretical and practical importance of research of possibility of energy efficiency and energy saving management on the basis of university energy-innovation Hub of knowledge at the critical stage of economic development.

The development of strategies and programs in this area requires a stronger institutional framework at the national and local levels [6]. Increased cooperation with municipalities and other local stakeholders will help: identify problems, quantify potential, obtain better data, develop measures and monitor results [7].

Ukraine can focus on realizing its biomass potential, in particular biogas and energy-intensive waste resources. More attention should be paid to the effective formation, reporting and implementation of energy policy measures. Systematization of conceptual approaches to forming the efficiency of energy resource factors to increase energy autonomy of the university allows to trace the evolution of the structure and mechanisms of management, to determine promising areas of management efficiency of energy resource factors (V. Shcherbak, L. Hanushchak-Yefimenko, O. Nifatova, P. Dudko, N. Savchuk, I. Solonenchuk [8]). Budget sector and service sector consume about 18% of thermal energy of centralized supply.

Conceptual approach to the formation of energy efficiency and energy conservation management strategy on the basis of university energy innovation Hub of knowledge through the introduction of the concept of smart as an element of economic development management in

modern conditions in practice allows the university to minimize barriers to implement strategies and develop its own smart-specialties through an innovative push (N. Kuznetsov [9]). The limited attention of authorities to improving the energy efficiency of public sector buildings (schools, hospitals, administrative premises) has led to the fact that this category of consumers over the past decade has used consistently high amounts of heat for their needs (more than 30% of which is lost), which, in addition, can be qualified as an inefficient use of budgetary funds [10]. In the sphere of services also mainly use (rent, purchase) buildings of old years of development with a low level of energy efficiency. And if in case of buying out the owners of such buildings implement certain measures on saving of thermal energy, in case of renting the technical condition of buildings, as a rule, is not maintained. Such situation is aggravated by the fact that the service sector is a dynamically developing sector of economy with constantly increasing share in the GDP structure. Consequently, in the near future we can expect a significant increase in the used space and a significant increase in the volume of heat consumption.

The purpose of the study is to propose a methodology for energy efficiency and energy conservation management on the basis of university energy-innovation knowledge Hub. The study was conducted in 2021 on the basis of the Kyiv National University of Technologies and Design.

Matherials and methods. In methodological terms, the principle of studying and summarizing the factual material such as: monographs, textbooks, periodicals, publications on the improvement of energy management and quality management systems, as well as the documentation of the university was used.

The main methods of research are methods of system and structural analysis, management theory, methods of diagnostics and identification, graph theory, methods of energy balances.

Results and discussion. In the near future it is planned to equip all university buildings with heat meters (metering and control facilities) by introducing appropriate costs in heat supply tariffs or special budget programs, which will save heat and budget funds significantly. For this purpose it is necessary to carry out serious energy saving measures in universities. The important directions at the first stage will be promotion of energy audit and development of energy passports of buildings, as well as popularization of careful attitude to FER and stimulation of energy saving.

The most obvious priority energy saving measures will be to increase the thermal protection of windows and balcony doors, thermal insulation of exterior walls, and insulation of roofs and basements, which will save up to 30% of heat. Another direction of energy saving will be the wide implementation of individual heating substations, the advantage of which is, among other things, the possibility to regulate the air temperature in the premises and the exclusion of the forced "overheating" in the warm periods. Thanks to the implementation of these measures, heat savings can reach 10-30%. In addition, on the basis of the university's energy hub we can consider the feasibility of partial technical rehabilitation of district heating systems in low-density residential areas by closing low-power boilers with extensive networks and the transfer of social facilities and budget organizations to autonomous or individual heat supply. Electric heating can be used as an alternative to district heating.

An important slowing factor in the implementation of energy saving measures for universities is the limited own funds. Limited use of financial instruments for implementation of energy efficiency measures in Ukraine is explained by a high level of investment risk, as well as the practice of reducing the costs of budget organizations in the periods following the implementation of energy efficiency projects by the amount of annual savings of fuel and energy resources, which makes it impossible to recover the funds invested in the implementation of energy efficiency measures and reduces the attractiveness of energy saving services in the public sector. The success of this area will depend on the ability to attract loans or funds from private investors under public-

private partnerships. In the future most higher education institutions will actively work in this direction, adapting the provisions of the legislation on public-private partnership to local conditions.

The main risk factors that may hinder implementation of energy saving measures in the sphere of heat supply of university buildings include: imperfect tariff policy that does not stimulate energy saving measures; uncertainty regarding budgetary support of energy saving in the future; high risks inherent to the budget sphere; low level of local management qualification, insufficient level of culture of energy resources saving.

University buildings were built mainly before 1990, their traditional architectural and construction systems (large-panel, large-block, prefabricated reinforced concrete frame, etc.) by their parameters do not meet modern requirements for energy efficiency, are characterized by low energy-saving properties, most of them need major repairs. Lack of effective measures to improve energy efficiency of university buildings led to the fact that this category of consumers used for their needs stably high volumes of heat energy (more than 30% of which is lost), without creating comfortable thermal conditions in the buildings. That is, there is a typical example of inefficient use of budgetary funds for heating of buildings of budgetary / municipal sector [1, 3, 8].

Specific values of consumption of energy resources are the most important target indicators of effective use of energy for higher education institutions. They are called to provide a connection of university energy passports with regional and municipal programs in the field of energy saving and increase of energy efficiency [10].

Consequently, the optimization of thermal energy consumption in university buildings contains a significant potential to reduce energy consumption and save budgetary funds, which makes the solution of the problem of improving the energy efficiency of the buildings highly relevant. Let's consider the initial data for the specified time intervals, for comparison including here 2018 and 2019 (tab. 1).

Table 1

Levels of electricity consumption in December and November 2018–2020

Period	Power consumption level, kW × h	Number of inhabitants, pers.	Average monthly ambient temperature, ^{0}C
November 2018	719,1	318	6,3
December 2018	866,71	325	-0,2
November 2019	1004,51	347	1,6
December 2019	911,77	311	-2,1
November 2020	1190,13	348	4,6
December 2020	1236,44	348	1,8

This is due to the different length of heating networks, heat losses due to wear of heat pipes, hydraulic modes of operation of heating networks, the conditions for regulating the parameters of the coolant. Therefore, for social facilities of the university it is important to conduct energy surveys to develop programs to rationalize the structure and future development of heat management, calculation of hydraulic regimes in heating networks and subsequent adjustment of heating networks, development and implementation of energy saving measures.

The graph of thermal energy consumption, built after processing the data obtained during the monitoring of measurements of thermal energy consumption for heating of KNUTD buildings, is shown in Fig. 1. A significant increase in heat consumption is caused by the inclusion of the ventilation load. The power consumption of electric energy by 5 kW also increases.

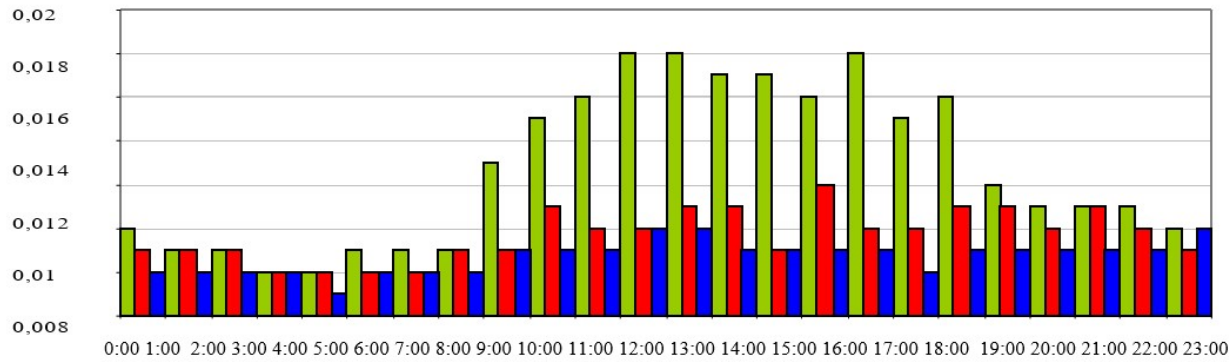

Fig. 1. **Schedule of hourly heat consumption**

Regulation of heat consumption when the outside air temperature changes is made at the heat supply source by changing the temperature of supply water. It should be noted that the temperature at the radiators of heating in the premises of KNUTD buildings surveyed ranged from 30 to 53°C (the temperature in the supply pipeline was 61.4°C), while in some rooms the required temperature of 18°C was not provided.

Periodically over the years, at the beginning and end of the heating period, the temperature in some rooms of KNUTD buildings exceeded the values required by sanitary and hygienic standards. The reason for this phenomenon ("overheating") is a discrepancy between the actual outdoor temperature and the temperature for heat supply predicted by the heat supplier. In the near future, all buildings of the university will be equipped with heat meters (metering and regulation means). This will make it possible to significantly save heat (and, accordingly, budgetary funds) by introducing appropriate expenses into heat supply tariffs or special programs. But for this purpose universities will have to carry out serious energy saving measures. Consequently, development of special energy saving programs, including modernization of heat systems and thermal renovation of all university buildings will become more and more widespread in university development plans. All of the above measures will make it possible to obtain significant savings in the fall and spring period, when overheating is widespread due to the features of centralized quality control of heat loads at heat supply sources.

Budgetary institutions have the right to conclude energy service contracts, the subject of which is implementation by the executor of measures aimed at energy saving and improvement of energy efficiency of energy resources. Energy efficiency measures aimed at reducing the consumption of fuel and energy resources. The following measures are especially important in the public sector: installation of individual heating substations with automatic regulation of heat supply; hydraulic adjustment of heating systems; installation of thermostatic valves on heating radiators; replacement of mercury lamps and lamps with sodium or LED lamps for street lighting and LED lamps for indoor lighting; automatic regulation of electric lighting by using sensors of lighting and motion; installation of a frequency-controlled electric drive in the system of dimmer switches. The organization must have an energy passport drawn up based on the results of an energy survey of the facility. In the report of the energy auditor it is necessary to give the recommended measures and for each measure to indicate the approximate required investments, payback period, etc. First of all, the head of the organization should pay attention to effective measures with a short payback period, which are of the greatest interest to the energy service company and the investor. In practice, the following models of public-private partnership are used:

- entrusting the investor with the implementation of all elements of the project (organization of financing, design, construction and operation);

- charging the investor with implementation of all project elements, except for its participation at the facility exploitation stage;

- the investor to be solely responsible for the operation phase of the facility.

Carried out works on energy audit of pilot buildings of KNUTD have shown that for effective development of university it is necessary to involve considerable investments. At the present time at production of capital repairs with long payback periods support from the state is necessary.

The degree of energy efficiency of an individual building is determined by comparing it with reference values and is indicated in the energy certificate of the building. Improvement of energy efficiency of existing buildings is possible through the implementation of the following measures: modernization with the installation of building automation systems, setting comfortable heating and cooling temperatures, equipping the ventilation system with heat recovery means, reducing heat loss on the outer surfaces of the building, replacement of windows. A noticeable reduction in energy consumption can be achieved by modernizing automation systems in older and less energy efficient buildings.

Energy saving measures need to implement a control system for electrical appliances, machinery drives and all automation systems, which is based on the use of the built-in functions of the equipment in the distribution of electricity (energy accounting, diagnostics, energy quality indicators, etc.), and devices which allow to see these parameters with the help of web technologies for subsequent analysis of energy consumption and taking measures to reduce costs and maintain the optimum level of energy consumption. The control system also provides collection of data on energy consumption (water, gas, heat) in real time, assessing the status of circuit breakers, the possibility of remote control of switching devices, consolidation and visualization of information on large or dispersed objects using local or cloud energy monitoring systems. This creates new opportunities to compare energy consumption by objects, evaluate energy consumption by types of loads (lighting, heating, hot water, etc.), compare consumption over identical time periods (days, weeks, months), predict consumption trends and change tariff plans, avoid the risk of sudden power outages due to overlapping consumption peaks. The automatic power supply system installed at the facility creates the necessary conditions for efficient energy saving.

In 2019, KNUTD launched an energy audit and energy passport in order to identify problem areas and develop measures that help reduce consumption of energy resources. Such measures include: increasing thermal protection of buildings, structures, facilities during major repairs, automation of heat consumption by buildings, facilities. organizational and technical measures to optimize the operation of lighting systems, etc. Measures in the field of energy saving in KNUTD are necessary, but their carrying out is complicated by absence of objective calculation of a ratio of the planned reduction of consumption after carrying out the measure to the planned consumption before the measure, the planned effect at the current tariffs, payback period. There is no logical chain of sequence of measures, there is no calculation of the cumulative effect of the implementation of measures aimed at energy conservation.

Thus, the main problems in the way of effective energy efficiency policy of the university remain:

- non-systematic and disorganized policy, unreasonable and fragmented decisions without calculation of the result, lack of institutional and managerial coordination;

- lack of motivation to save energy and improve energy efficiency, insufficient awareness and confidence in the necessity and "safety" of implementing measures in the public sector;

- high cost of implementing measures that make energy efficiency projects economically unjustified;

- lack of qualified specialists and institutions for monitoring of energy efficiency issues (technological, engineering, financial, administrative);

- lack of permanent and assured sources of funding for energy saving and energy efficiency programs in higher education institutions.

Conclusion. Globally, buildings are responsible for a high level of energy consumption (40% of the global total), as well as greenhouse gas emissions that far exceed those of all vehicles combined. There are great and attractive opportunities to reduce the energy consumption of buildings at a lower cost and a higher return than in other sectors. These reductions are fundamental to achieving the goal of energy efficiency and energy conservation management through the university's Energy Innovation Hub of Knowledge. A full solution requires a combination of site-specific measures coupled with widespread awareness of energy use. The problems of university heat supply systems include a high level of moral and physical deterioration of equipment of sources and networks, low efficiency of fuel use, insufficient instrumentation and efficiency of regulation of heat consumption, high cost of fuel supplies to the region for heat supply of consumers. The purpose of this study was to improve the energy management and energy efficiency of KNUTD.

In the course of scientific research work on support of the project on improvement of management of energy efficiency and energy saving on the basis of university energy-innovation Knowledge Hub KNUTD (methods of planning, dispatching, control of activity in this area, including concerning electric and heat supply, water supply and water removal), that is on all stages of life cycle of the project: planning, realization, check, introduction of changes for continuous improvement was conducted. The model of management of energy efficiency of the university should take into account execution of the program of energy efficiency and implementation of state policy in the region, achievement of integral indicators of energy saving in the field of energy efficiency. The basic result includes the first development of the Manual on energy management of KNUTD: policy, structure, the list of processes and their sequence and interaction concerning system of energy management of the university. Besides, scientific result is also the developed technique of an estimation of processes of power management, namely measurement of power efficiency of divisions of higher education institution.

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