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ORGANIZATION OF THE ENERGY MANAGEMENT SYSTEM ON THE BASIS OF THE UNIVERSITY KNOWLEDGE HUB

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BACKGROUND AND OBJECTIVES. Energy efficiency and energy saving are the priority direction of science, technology and engineering development in Ukraine. The policy of energy saving, carried out all over the world, is directed to all branches and scientific researches in all spheres. The big consumer of energy resources is the higher school. Updating of normative-legal and technical base aimed at design and operation of buildings with low energy consumption and high energy efficiency class shows the necessity of short-term solution of the problem. At the same time, there is a lack of a systemic view of energy efficiency, which does not allow evaluating the level of energy costs throughout the life cycle of higher education institutions, which shows the need to find effective solutions to the problem.

METHODS. Multiple regression equation was used to assess the influence of factors on electricity consumption and energy efficiency of Kyiv National University of Technologies and Design, statistical analysis of the obtained data was performed.

FINDINGS. As a result it was found out that the data of electricity consumption do not obey the law of normal distribution, so it is difficult to build an accurate prediction of electricity consumption. The use of HAB knowledge on energy efficiency allowed a more qualitative analysis and highlighted the main factors affecting electricity consumption. The university has unregulated central heating, individual air conditioning systems, and central and individual lighting. In this regard, we selected the following main factors: average outdoor air temperature, average duration of daylight hours, heating period, average number of people working per day, during the month to conduct energy monitoring and energy audit of university buildings.

CONCLUSION. Implementation of suggested scheme of structural organization of typical system of automatic accounting of university energy consumption on the basis of university HUB of energy efficiency knowledge: server, allowing to collect, store and process data; routers by means of various wire and wireless communication technologies; hubs, installed on the objects of energy consumption; workstations, which are personal computers with installed software of used HUB will allow to optimize energy consumption.

KEYWORDS: HAB of knowledge on energy efficiency; university; energy consumption; energy audit.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
17	1	1

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ОРГАНІЗАЦІЯ СИСТЕМИ ЕНЕРГОМЕНЕДЖМЕНТУ НА БАЗІ УНІВЕРСИТЕТСЬКОГО ХАБ ЗНАНЬ

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ПОСТАНОВКА ПРОБЛЕМИ ТА ЗАВДАННЯ. Енергоефективність та енергозбереження є пріоритетним напрямком розвитку науки, технологій і техніки в Україні. Проведена в усьому світі політика енергозбереження спрямована на всі галузі і наукові дослідження в усіх сферах. Значним споживачем енергоресурсів є заклади вищої освіти. Актуалізація нормативно-правової та технічної бази, спрямованих на проектування і експлуатацію будівель з низьким рівнем енергоспоживання і високим класом енергоефективності свідчить про необхідність короткострокового вирішення проблеми. При цьому має місце відсутність системного погляду на енергоефективність, що не дозволяє оцінити рівень витрат енергоресурсів на всьому протязі життєвого циклу закладів вищої освіти, що показує необхідність пошуку ефективних шляхів вирішення проблеми.

МЕТОДИ. Для оцінки впливу факторів на електроспоживання та енергоефективності Київського національного університету технологій та дизайну було використано метод множинної регресії, проведений статистичний аналіз отриманих даних.

РЕЗУЛЬТАТИ. В результаті вдалося з'ясувати, що дані електроспоживання не підкоряються закону нормального розподілу, тому побудувати точний прогноз електроспоживання важко. Використання ХАБ знань з енергоефективності дозволило провести більш якісний аналіз і виділити основні фактори, що впливають на електроспоживання. Університет має нерегульоване центральне опалення, системи індивідуального кондиціонування, а також центрального та індивідуального освітлення. У зв'язку з цим для проведення енергетичного моніторингу і енергоаудиту будівель університету було обрано такі основні фактори: середня температура повітря на вулиці, середня тривалість світлового дня, опалювальний період, середня кількість осіб, які працюють в день, протягом місяця.

ВИСНОВКИ. Впровадження запропонованої схеми структурної організації типової системи автоматичного обліку енергоспоживання університету на базі університетського ХАБ знань з енергоефективності: серверу, що дозволяє збирати, зберігати і обробляти дані; маршрутизатори за допомогою різних провідних і бездротових технологій зв'язку; концентратори, встановлені на об'єктах енергоспоживання; робочі станції, які являють собою персональні комп'ютери з встановленим програмним забезпеченням використовуваного ХАБ дозволить оптимізувати енергоспоживання і підвищити енергоефективність університету.

КЛЮЧОВІ СЛОВА: ХАБ знань з енергоефективності; університет; енергоспоживання; енергоаудит.

INTRODUCTION.

One of the priority directions of development of Kyiv National University of Technologies and Design (KNUTD) is to reduce energy intensity and optimize the use of energy resources. Therefore, the issue of improving energy efficiency and energy conservation of the university is quite relevant at the moment, and energy management is the financial tool that will allow the university to save money through a competent policy of energy resources use ((Shaposhnikova et al., 2016; Vieira et al., 2020).

Achieving real improvements in energy efficiency must be based not only on technical solutions, but first and foremost on perfect management (García et al., 2020; Nayak et al., 2021). The process of creating an energy management system in Ukrainian universities, despite its relevance has not been properly developed (Werth et al., 2021; Di Stefano, 2000; Xing et al., 2019). The unified technical policy on all issues of operation, maintenance and repair of power equipment of the university is carried out by the department of the chief power engineer (Abu-Rayash et al., 2020; Wang et al., 2021). This department ensures and is responsible for the uninterrupted and reliable energy supply to all university departments (Liu et al., 2019).

Energy management functions related to the optimization of equipment operation modes in order to improve energy efficiency and minimize energy costs are generally not properly performed in practice (Zhong et al., 2020; Shcherbak et al., 2019; Shcherbak et al., 2021). Creation and implementation of decent energy management service within the university will certainly give additional impetus to the process of energy efficiency improvement within Kyiv National University of Technologies and Design (Gryshchenko et al., 2017).

The Energy Management Service should be a permanent university body for effective management of energy use and control over the implementation of energy-saving projects and programs. Its creation will allow to concentrate in one place all managerial functions directed on energy saving and increase of energy efficiency. In the structure of the university, this service should report to the top management – the Representative of the Management for Energy Management (Hanushchak-Yefimenko et al., 2018). This would give it the status of a cross-functional, rather than a highly specialized unit with horizontal and vertical links with other units. One of the options for creating such a unit is to organize the energy management system on the basis of the university Knowledge Hub.

The purpose of this article is to substantiate the necessity and expediency of the organization of energy management system on the basis of university hub of knowledge. The research was conducted on the basis of Kyiv National University of Technologies and Design in 2020.

MATHERIALS AND METHODS.

To assess the impact of each factor on electricity consumption and energy efficiency it is necessary to use a multiple regression equation. The linear equation of multiple regression has the following form (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_m X_m + \varepsilon, \quad (1)$$

where β_0 – free term;

β_n – values of coefficients of influence of each specific factor on the final result;

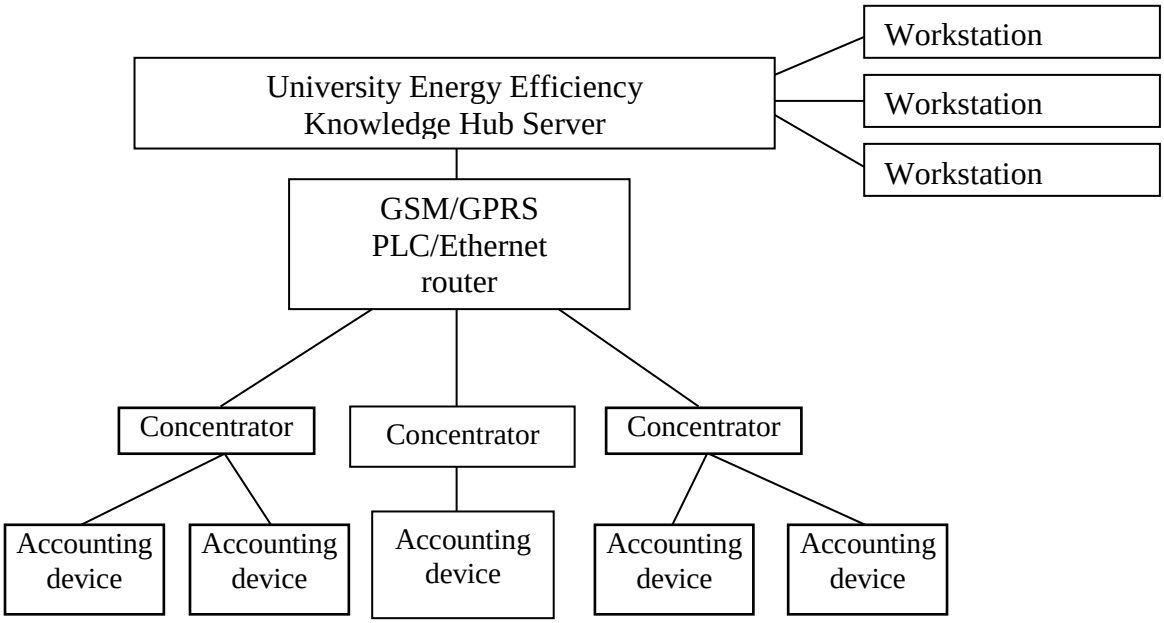
X_n – quantitative value of the factor.

RESULTS AND DISCUSSION

The main functions of the energy management service of the university on the basis of the university Knowledge Hub:

- providing extended and continuous control over energy consumption and efficiency of fuel and energy resources use;
- formation of technical, economic and personnel policy of rational energy consumption;
- developing annual plans to implement the energy saving program;
- organization of targeted energy monitoring and assessment of the actual economic effect from implementing energy-saving projects and measures;
- coordination of activities to develop and implement energy-saving measures;
- forming proposals to the university's investment program;
- organization of information exchange, training and cooperation in the field of efficient energy use;
- analysis and coordination of the university energy technological services in terms of reducing irrational energy consumption;
- development of terms of reference for pre-project work on energy saving projects;
- development of technical specifications for investment projects on modernization or design of new energy saving equipment and technologies, organization of work on holding tenders by potential contractors;
- technical support of the energy saving projects being implemented;
- preparation and approval within the university of the technical part of agreements and contracts for the purchase of energy saving technologies, equipment and materials;
- collection, analysis and systematization of information about new energy saving technologies and equipment used in related organizations;
- organization of work to increase the level of information support of the university's energy consumption.

Let's consider a simplified scheme of structural organization of a typical system of automatic energy consumption accounting. The basis of system is the server, allowing to collect, store and process the data. To this server hubs are connected through routers by means of different wired and wireless communication technologies, installed at objects and uniting data collectors into groups. Also connected to the server are workstations, which are personal computers with installed software from the university's Energy Efficiency Knowledge Hub. In universities that use only one workstation, the same station can be the server (Figure 1).



Source: Kaplun et al., 2016.

Fig. 1. **Simplified diagram of the structural organization of the university Knowledge Hub**

Most of the existing automatic energy accounting systems are organized according to the given structure (Zhong et al., 2020). The main tasks of the university energy management service on the basis of the university Knowledge Hub should include:

- Assessment of the results of departments and divisions on rational energy consumption and energy conservation based on the analysis of the actual consumption of fuel and energy resources.
- Development, expertise, timing of implementation and control of energy saving projects aimed at solving current and strategic tasks of energy saving.
- Develop methods to assess the actual efficiency of the implemented energy saving measures.
- Develop, coordinate and implement mechanisms to stimulate efficiency of fuel and energy resources use.

- To control the implementation of the program of rational energy consumption and energy saving.
- Implementation of targeted energy monitoring.

The number of staff in the university's energy efficiency hub will depend on the volume of energy costs, the number and characteristics of university facilities, and their current level of energy efficiency. In any case, the specialists of these units should not combine the functions of energy managers with other job responsibilities. We suggest including several energy managers and energy auditors in this service.

Energy manager – a specialist whose activity is aimed at ensuring the implementation of the energy policy of the university. Organization of activities aimed at the continuity of energy management, ensuring communication functions between all objects of energy management, planning and control of activities aimed at the maximum efficiency of energy management (Kaplun et al., 2016).

Energy auditor – a specialist in conducting energy audits of consumers of fuel and energy resources in order to establish indicators of efficiency of fuel and energy resources use and to develop economically sound measures to reduce the consumption of fuel and energy resources (Kaplun et al., 2016).

Within the university Energy Efficiency Hub of Knowledge, the main requirements for an energy manager should be:

- the presence of higher professional education;
- knowledge of the methodology of energy management evaluation and training of employees in this area;
- knowledge of the methodology for rewarding university employees who save energy;
- ability to analyze energy flows in detail;
- ability to communicate with the administration and all staff;
- ability to conduct economic analysis of energy saving measures;
- the ability to develop energy-saving measures;
- know the basic technologies of the given organization;
- the ability to work with new information technologies.

The functions of the university energy manager will include:

- organizing the work of the energy management service;
- supervise the energy audit;
- conducting an analysis of energy consumption, taking into account the evaluation of energy saving measures;
- preparation of proposals for the improvement of the production process, equipment, maintenance and operation of the equipment;
- determination of energy consumers' efficiency;
- control over investments in energy saving measures.

Requirements to the energy auditor of the university:
- availability of higher profile education;
- basic knowledge of energy management;
- knowledge of standards for conducting audits;
- knowledge of safety requirements when carrying out energy audits;
- have the ability to analyze data on energy consumption;
- ability to analyze energy flows in detail;
- have practical auditing skills;
- be able to develop energy-saving measures;
- have an idea of the main technologies of the organization;
- be able to work with new information technologies.

Functions of the energy auditor of the university:
- conducting an energy survey of the university;
- to audit the energy management system;
- preparation of university energy passport;
- analysis of carrying out corrective and preventive actions;
- instrumental inspection of energy supply systems;
- calculation of standard indicators of consumption of each type of fuel and energy resources;
- development of effective measures to implement the identified energy saving potential;
- development of proposals for the organization of energy management system at the university.

In addition, all those university employees who will be involved in the organization of energy consumption and related to the operation of energy facilities must be aware in advance:
- of the need to comply with the energy policies, procedures, and requirements of the energy management system;
- of their roles, responsibilities, and authority to facilitate compliance with the requirements of the energy management system, and the benefits of energy efficiency improvements;
- any significant energy consumption arising in the performance of work, and any consequences of the actions performed.

One of the main moments of energy management system organization in Kyiv National University of Technologies and Design is the formation of energy policy. Energy policy is an official written declaration of interest in rational spending and saving of fuel and energy resources, environmental protection accompanied by a list of stated goals, action plan for their achievement, provision with necessary resources and clear distribution of delegated rights, duties and responsibilities. The mandatory existence of an energy policy in the university is not always realized by the top management and its staff. There is

usually shared responsibility and accountability for the expenditure of fuel and energy resources and energy supplies. Until responsibility and interest are formalized at the formal level, there is a danger of ignoring energy policy, shifting priorities with a loss of ongoing control over energy use and rationalization.

The university energy policy should:

- define the main objectives in the field of energy use and available at the boundary of the application of energy management system;
- include requirements for energy efficiency and energy saving;
- include obligations for legal and informational support for effective energy use;
- provide an opportunity to make adjustments and revise tasks.

The primary role in the implementation of effective energy management in the university should be given to the management. Its task is to formulate and adopt energy policy of Kyiv National University of Technologies and Design and maintain energy management system in working and self-improving state.

Thus, the direct responsibilities of the University management in ensuring the operability of the University Energy Efficiency Knowledge Hub can include:

- the activities of developing and implementing energy management system documents;
- enforcement of university standards and regulations that are part of the energy management system;
- appointment of a responsible and authorized management representative in the energy management system. Periodic reporting by this person on the effectiveness of energy management and energy efficiency in the university;
- planning of measures and operational management of the energy management system;
- allocation of responsibilities and delegation of management authority.

Equation of four-factor regression was obtained: based on eq. (1)

$$Y = -1341024{,}8002 + 110{,}5904X_1 + 3538{,}9134X_2 - 2518{,}0955X_3 - 8304{,}8214X_4.$$

To assess the quality of the resulting equation, we make calculations for each month of energy consumption KNUTD, calculate the standard deviation. The calculation results are presented in Table 1.

Table 1

Results of calculations of the energy efficiency of KNUTD

Month	Electricity consumption, kWh	Estimated electricity consumption, kWh	Deviation, kWh	Rejection, %
January	186808	189483,69	2829,69	1,46
February	160339	168838,34	8499,24	4,68
March	141634	138348,22	4286,88	3,02

End Table 1

Month	Electricity consumption, kWh	Estimated electricity consumption, kWh	Deviation, kWh	Rejection, %
April	98240	98200,84	49,14	0,04
May	46984	49948,94	2983,94	4,21
June	34941	33419,82	2421,18	6,83
July	22192	22482,19	390,19	1,86
August	43904	39211,83	4682,16	8,89
September	48684	61424,31	2840,31	4,84
October	122034	123444,43	1419,44	1,24
November	183193	168984,64	4218,34	3,01
December	211063	201866,60	9296,39	4,40

The calculations confirm the feasibility of organizing the university's Energy Efficiency Knowledge Hub.

CONCLUSION.

Timely provision and organization of high-quality energy management system of the university on the basis of the Energy Efficiency Hub will allow Kyiv National University of Technologies and Design to: reduce costs, eliminate unproductive costs, improve financial performance and gain a reputation as an organization successful in improving its energy efficiency.

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ABBREVIATIONS

%	Percentage
Eq.	Formula of calculation
Fig.	Figures
HEI	Higher education institution
Hub	Common connection point
KNUTD	Kyiv National University of Technologies and Design

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