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BUILDING A NETWORK OF ENERGY KNOWLEDGE HUB CENTRES TO FORECAST THE PRIORITY DEVELOPMENT OF ENERGY EFFICIENCY AND ENERGY SAVING PROGRAMMES IN HIGHER EDUCATION INSTITUTIONS

This article attempts to verify the relevance of building a network of energy knowledge hub centres to tackle the priority objective in enhancing energy efficiency and energy saving management in higher education institutions. It is emphasized that the issues of careful and wise use of fuels and energy resources challenge more government efforts, active use of advanced projects to manage energy saving and energy efficiency through the integrated use of different energy sources. The study argues that to identify the potential for energy saving, setting regulatory indicators of energy consumption, determining the key energy saving measures and target objects in the public sector where energy saving programs are planned to be implemented, there is a need to conduct energy surveys with further developing of energy passports for buildings. In the frameworks of this study, the following research methods were used: abstract and logical analysis – to interpret the essence of energy saving concepts for universities; systemic approach – to identify the specifics of energy saving projects implementation in universities; in-depth analysis and synthesis – to forecast the university development priority area of the "Energy efficiency and energy saving"; system, structural, comparative and statistical analyses – to assess the energy consumption in universities; economic and statistical methods – to evaluate the level and the dynamics of the energy sources use before and after the implementation of project activities; graph-based and analytical methods – to facilitate visual representation and schematic presentation of forecasts for further development of energy efficiency and energy saving systems. The study offers a mechanism to shape a network of energy knowledge hub centres to forecast a priority development area of energy efficiency and energy saving programs in higher education institutions along with providing an overview on the process of energy saving based on energy knowledge hub centres by carrying out the following tasks: project identification, scanning, energy audit, implementation of an action plan, and monitoring. It has been verified that to enhance the energy supply system in the university buildings, the following objectives should be attained: using the energy knowledge hub to forecast the university energy efficiency and energy saving programme, implementing an automated individual heating station with weather regulation and installing new radiator heaters.

Keywords: *energy hub; energy efficiency; energy saving; university.*

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ФОРМУВАННЯ МЕРЕЖІ ЦЕНТРІВ ЕНЕРГОХАБА ЗНАНЬ ДЛЯ ПРОГНОЗУВАННЯ ПРІОРИТЕТНОГО НАПРЯМУ РОЗВИТКУ ПРОГРАМ ЕНЕРГОЕФЕКТИВНОСТІ ТА ЕНЕРГОЗБЕРЕЖЕННЯ В ЗАКЛАДАХ ВИЩОЇ ОСВІТИ

У цій статті порушується питання щодо доцільності створення мережі центрів енергохаба знань для комплексного вирішення пріоритетних завдань управління енергоефективністю та енергозбереженням у закладах вищої освіти. Наголошується, що проблеми економного та дбайливого використання паливно-енергетичних ресурсів потребують інтенсифікації зусиль з боку держави, інтенсивного використання передових проєктів із управління процесами енергозбереження та енергоефективності шляхом комплексного використання різних джерел енергії. Обґрунтовано, що для виявлення потенціалу енергозбереження, встановлення нормативних показників енергоспоживання, визначення основних енергозберігаючих заходів та об'єктів бюджетної сфери, на яких насамперед планується впроваджувати програми економії енергоресурсів, варто здійснювати

енергетичні обстеження з подальшим розробленням енергопаспортів будівель. У рамках дослідження використано такі наукові методи: абстрактно-логічний аналіз – для вивчення сутності понять енергозбереження для університетів; системний підхід – для визначення особливостей реалізації процесів енергозбереження університетів; методи деталізації та синтезу – для прогнозування пріоритетного напряму розвитку університетів «Енергоефективність та енергозбереження»; системно-структурний, порівняльний, статистичний аналізи – для оцінювання енергоспоживання університетів; економіко-статистичні методи – для аналізу рівня та динаміки показників використання енергоносіїв до та після впровадження проєктних заходів; графічно-аналітичний методи – для наочного зображення та схематичного представлення прогнозів щодо подальшого розвитку систем енергоефективності та енергозбереження. Запропоновано механізм формування мережі центрів енергохаба знань для прогнозування пріоритетного напряму розвитку програм енергоефективності та енергозбереження в закладах вищої освіти. Описано процес енергозбереження на базі центрів енергохаба знань, що проваджується за такими напрямами: ідентифікація проєкту, сканування, енергоаудит, реалізація заходів, моніторинг. Доведено, що для вдосконалення системи енергопостачання будівлі університету доцільним є: використання енергохаба знань для прогнозування напряму розвитку університету «Енергоефективність та енергозбереження», впровадження автоматизованого індивідуального теплового пункту з погодним регулюванням, встановлення нових радіаторів опалення.

Ключові слова: *енергохаб знань; енергоефективність; енергозбереження; університет.*

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ФОРМИРОВАНИЕ СЕТИ ЦЕНТРОВ ЭНЕРГОХАБА ЗНАНИЙ ДЛЯ ПРОГНОЗИРОВАНИЯ ПРИОРИТЕТНОГО НАПРАВЛЕНИЯ РАЗВИТИЯ ПРОГРАММ ЭНЕРГОЭФФЕКТИВНОСТИ И ЭНЕРГОСБЕРЕЖЕНИЯ В ЗАВЕДЕНИЯХ ВЫСШЕГО ОБРАЗОВАНИЯ

В этой статье поднимается вопрос о целесообразности создания сети центров энергохаба знаний для комплексного решения приоритетных задач управления энергоэффективностью и энергосбережением в заведениях высшего образования. Отмечается, что проблемы экономного и бережного использования топливно-энергетических ресурсов требуют интенсификации усилий со стороны государства, интенсивного использования передовых проектов управления процессами энергосбережения и энергоэффективности путём комплексного использования различных источников энергии. Обосновано, что для выявления потенциала энергосбережения, установления нормативных показателей энергопотребления, определения основных энергосберегающих мероприятий и объектов бюджетной сферы, на которых в первую очередь планируется внедрять программы экономии энергоресурсов, следует проводить энергетические обследования с последующей разработкой энергопаспортов зданий. В рамках исследования использованы следующие научные методы: абстрактно-логический анализ – для изучения сущности понятий энергосбережения для университетов; системный подход – для определения особенностей реализации процессов энергосбережения университетов; методы детализации и синтеза – для прогнозирования приоритетного направления развития университетов «Энергоэффективность и энергосбережение»; системно-структурный, сравнительный, статистический анализ – для оценки энергопотребления университетов; экономико-статистические методы – для анализа уровня и динамики показателей использования энергоносителей до и после внедрения проектных мероприятий; графически-аналитический

метод – для наглядного изображения и схематического представления прогнозов относительно дальнейшего развития систем энергоэффективности и энергосбережения. Предложен механизм формирования сети центров энергохаба знаний для прогнозирования приоритетного направления развития программ энергоэффективности и энергосбережения в высших учебных заведениях. Описан процесс энергосбережения на базе центров энергохаба знаний, проводимый по следующим направлениям: идентификация проекта, сканирование, энергоаудит, реализация мероприятий, мониторинг. Доказано, что для совершенствования системы энергоснабжения здания университета целесообразно: использование энергохаба знаний для прогнозирования направления развития университета «Энергоэффективность и энергосбережение», внедрение автоматизированного индивидуального теплового пункта с погодным регулированием, установка новых радиаторов отопления.

Ключевые слова: *энергохаб знаний; энергоэффективность; энергосбережение; университет.*

Introduction. Formation and strengthening of market economy, market relations in Ukraine involves the study and use of effective modern tools, in particular, in the implementation of the state energy efficiency program (N. Kuznetsov [1]). Cognition of regularities of energy efficiency is conditioned by practical needs of society and global practice (L. Ganushchak-Efimenko, V. Shcherbak, O. Nifatova [2]).

It is important to know the regularities of instrumental provision of energy efficiency in the preparation of appropriate regional and national programs aimed at improving the environmental and energy security of the relevant enterprise, region and country as a whole, forecasting the development of individual areas of economic activity and inter-branch complexes, taking into account the unsolved problems of environmental threats and energy conservation (S. Yermilov, Yu. Yashchenko, V. Grigorovsky, V. Geyets, V. Lir [3]). The main of them are specialization, consistency, complexity, relative autonomy, sustainable development, social orientation and European integration of Ukraine (O. Klimchuk [4]). On definition of instrumental support of realization of the state program of energy efficiency on the target markets the general scientific laws applied also for the enterprises, small settlements and regions influence: quality management, modeling of business processes, steady development, green economy, territorial division of labor, coordination of interests, the scientific organization of management, regionalization and globalization (J. Dziadikevich, O. Sohatska, I. Lubezna [5]).

The first steps to improve energy efficiency in Ukraine began to be implemented since the mid-2000s. (A. Khalatov [6]), with almost every year one of the main priorities was to solve the problems of improving energy efficiency of industry and housing and communal services, ways of solving these problems, developing appropriate government programs, defined a set of measures that contributed to their implementation.

Improving the efficiency of energy resources use (energy efficiency) is a direction to address issues related to climate change, economic development and energy security.

To summarize theoretically the main provisions for the formation of a network of energy-Hab knowledge centers, the interdependence of the concepts of energy efficiency and energy conservation, economic and energy potentials at different management levels, the construction of quality management systems in executors and participants of the energy efficiency program of universities were used to forecast the priority direction of "energy efficiency and energy conservation (I. Gryshchenko, V. Shcherbak, O. Shevchenko [7]). The probability of achieving successful results in energy saving policy measures is the highest when there is an effective system of energy saving management. Energy efficiency management is a combination of legislative, regulatory framework and funding mechanisms, institutional organization and coordination mechanisms, which are aimed to

support the implementation of energy saving strategies, policies and programs. The legal and regulatory framework should provide: direction for the development of energy saving policies; a legislative framework of rules and regulations, such as building codes, minimum energy requirements; responsibility for developing programs; and mechanisms for financing energy saving measures. International cooperation and assistance are important as elements of overall energy efficiency management and promote stakeholder participation. It is necessary to involve government, scientific, and private organizations in the process of energy saving. Cooperation with the private sector makes it possible, along with public funding, to attract private investment for the development and implementation of energy saving policies and programs.

Paying tribute to the achievements of scientists in these areas of research (V. Shcherbak, L. Ganushchak-Yefimenko, O. Nifatova, P. Dudko, N. Savchuk, I. Solonenchuk [8]), it should be noted, that in-depth study requires substantiation of theoretical foundations of formation of instruments of state energy efficiency programs implementation; conceptual approach to building the mechanism of energy efficiency programs implementation; study of economic environment on availability of state energy efficiency program implementation; identification of objects and determination of state energy efficiency program implementation instruments; methods of state energy efficiency program implementation.

The rate of reduction of energy intensity in the absence of a coordinated state policy on energy efficiency can dramatically slow down. This could lead to even more dynamic growth in domestic demand for energy resources.

The empirical and factual bases of the study are the scientific results of Ukrainian authors on the problems of sustainable development, energy conservation and energy efficiency, investment support of the Ukrainian economy, state regulation of investment activity, marketing concepts, improvement of logistics systems and quality management (V. Shcherbak, I. Gryshchenko, L. Hanushchak-Yefimenko, O. Nifatova, V. Tkachuk, T. Kostiuk, V. Hotra [9]). The problem of reliable energy supply can be solved by increasing the efficiency of the use of fuel and energy resources [10].

The purpose of the study is to propose a mechanism for the formation of a network of energy-Hab knowledge centers of the priority direction of "energy efficiency and energy conservation" of universities. The study was conducted in 2021 on the basis of Kyiv National University of Technologies and Design (KNUTD).

Results and discussion. Energy efficiency are measures aimed at reducing the consumption of fuel and energy resources. Especially relevant for universities are the following measures: reconstruction of individual heating points with automatic regulation of heat supply; installation of heat shields behind the radiators, flushing, hydraulic adjustment of heating systems, installation of thermal valves on heating radiators; replacement of mercury lamps and fixtures with sodium or LED for street lighting and LED for indoor lighting; automatic regulation of electric lighting by using sensors of room lighting and e

The organization must have an energy passport, compiled by the results of energy audits [7]. The report of energy auditor [7] must contain the recommended measures, for each measure the approximate required investments, payback period, etc. First of all the head of the organization should pay attention to effective actions with short payback periods.

KNUTD is a large economic energy-consuming complex consisting of 45 buildings. For its proper functioning a lot of resources and, first of all, energy resources are necessary. For this reason the problem of energy saving is one of the major problems sharply facing the collective of establishment in modern economic conditions. After all the sums of money which the university should pay for the consumed resources: thermal energy, electric energy, water, natural gas, amount

to millions grivnas annually. Therefore KNUTD should develop on the basis of entrepreneurship, innovativeness and increase of energy efficiency.

Complex of buildings KNUTD was built before 1966 and does not meet modern requirements for thermal protection of buildings. Analyzing the above-stated schedule, it is possible to draw the following conclusions:

- since 2006, in the main building in a number of rooms the windows were replaced and double-glazed windows were installed, which allowed to decrease the specific energy consumption by 4%;

- within the limits of actions for energy saving before the heating period 2019–2020 all thermal points of the main building of KNUTD were automated, that, certainly, affected the subsequent power consumption of a building, having reduced it on 5% (according to research [7] potential of energy saving as a result of automation of heating systems of buildings can make on the average for a year 20%). The small value of the decrease can be explained by the fact that no work was carried out to reduce heat losses in the building structures;

- the attic was examined with a Fluke Ti20 thermal imaging camera and the defects of the attic insulation were found;

- a 2% to 3% reduction of specific energy consumption in building #4 was mainly due to a reduction of heat losses caused by the replacement of the wooden windows by double-pane windows.

To estimate the costs of consumed energy resources (electrical energy, heat energy, tap water) an analysis was made. Fig. 1 shows the dynamics of energy resources consumption (electricity, heat energy) from 2017 to 2021, in tons of fuel equivalent.

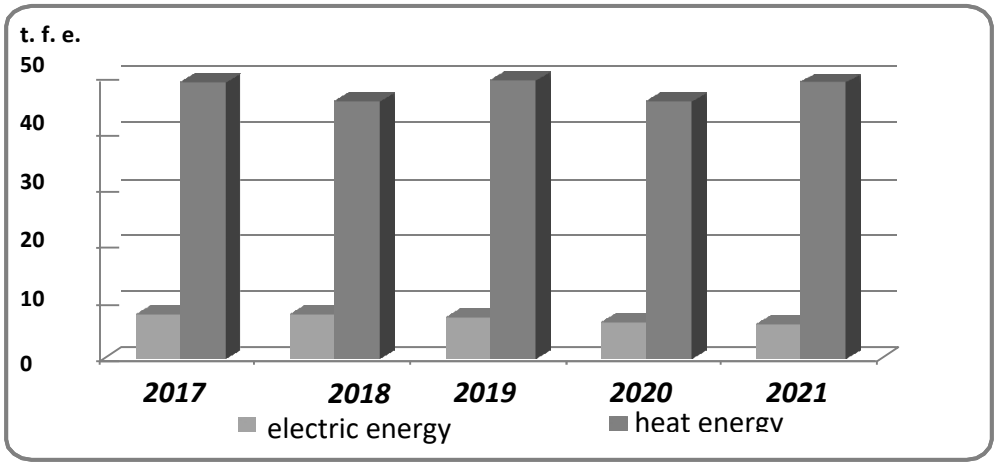

Fig. 1. **Consumption of energy resources KNUTD**

The information on a share of expenses on various kinds of power resources is presented in the Table 1.

Table 1

Summary data on energy consumption KNUTD

Indicator	Units	2017	2018	2019	2020	2021
Electricity	thousand kWh	21.82	22.46	20.72	18.27	17.46
	tce.	7.52	7.74	7.14	6.29	6.01
Heat energy	Gcal	329.40	307.30	332.20	307.86	328.74
	tce.	48.95	45.66	49.36	45.75	48.85
Water consumption	thou. m³	0.159	0.156	0.168	0.129	0.245
Water discharge	thousand m³	0.651	0.565	0.339	0.276	0.425

The conducted analysis shows that payment for electric power accounts for 7.7%; payment for heat power accounts for 91.4%; payment for water supply and sewage services accounts for 0.9%. Heat consumption accounts for a significant share of expenditures. This is due to the fact that thermal power is the main share in the structure of consumed energy resources in terms of the unified energy equivalent (one ton of fuel equivalent). Besides, the cost structure is affected by the high growth of energy tariffs. During the period under consideration the tariff for cold water and heat energy increased more than 1.4 times, and for electricity and wastewater disposal almost by a quarter.

Comparative analysis of the provided data by years shows that for the five-year period the share of costs for payment of electric energy decreased to 7.7% as compared to 2017 (10.5%). At the same time, the share of costs for heat energy increased by 3.3%. The consumption of cold water and wastewater remained at 1%. This means that development of measures on heat and power saving is a priority in energy and financial saving. Based on the data on settlements with the supplier of electric energy, Fig. 2 shows a graph of monthly electricity consumption of the building.

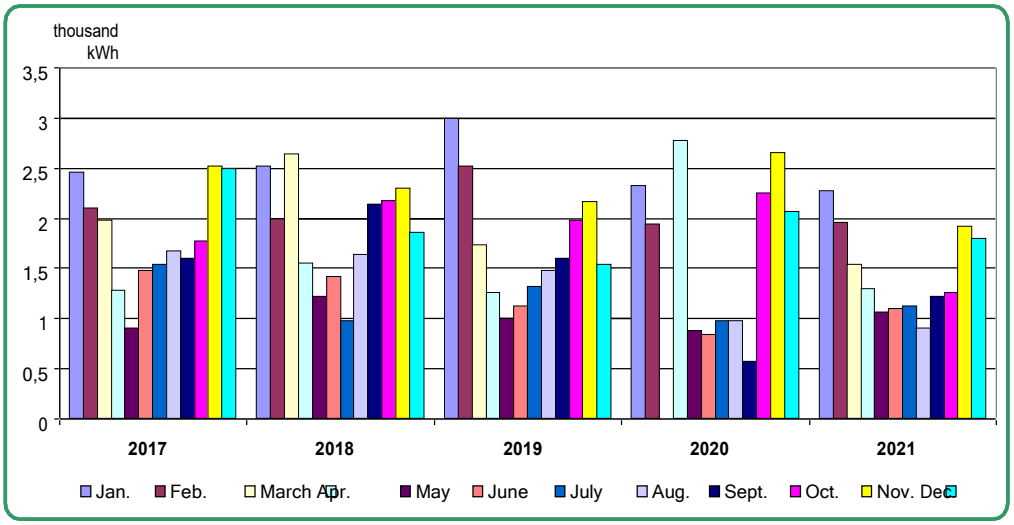

Fig. 2. **Diagram of monthly consumption of electricity KNUTD**

The uneven consumption of electricity is determined by the different daylight hours in different months of the year. Payment of electricity bills in the base year was made on time in accordance with the terms specified in the contract. The power allowed for use is sufficient to meet the internal needs of the premises. LB 18 and LB-40 type fluorescent lamps are mainly used for lighting the building's rooms. Corridors and stairwells are mainly lit with fluorescent lamps. The lighting in the hallways is controlled locally, with switches located at the doors, and the lighting in the hallways is always on during facility hours. The windows in the rooms are moderately soiled and, according to their design features, provide sufficient light levels during daylight hours. Experience with motion detectors has shown that they save 70–80% of the building's electric power used for lighting. Motion detectors are installed in administrative and industrial buildings. It is advisable to install them in rooms where people stay for a short time (corridors, staircases, storage rooms, etc.). Total lighting power, where you want to install motion sensors is 240 watts. Based on experimental data, the operating time of lighting in the presence of a sensor is reduced by 40%.

Heating system of buildings KNUTD – open, dependent with a breakdown on the hot water supply. As heating devices are mainly used metal pipe registers, in some – cast iron and aluminum radiators. The heating system provides thermal energy to the heating system and hot water supply of the premises by supplying heated coolant. Heated water is used as the coolant. On the basis of the

provided data on the calculations with the supplier of thermal energy in Fig. 3 shows a graph of monthly consumption of thermal energy in the building for 2017–2021.

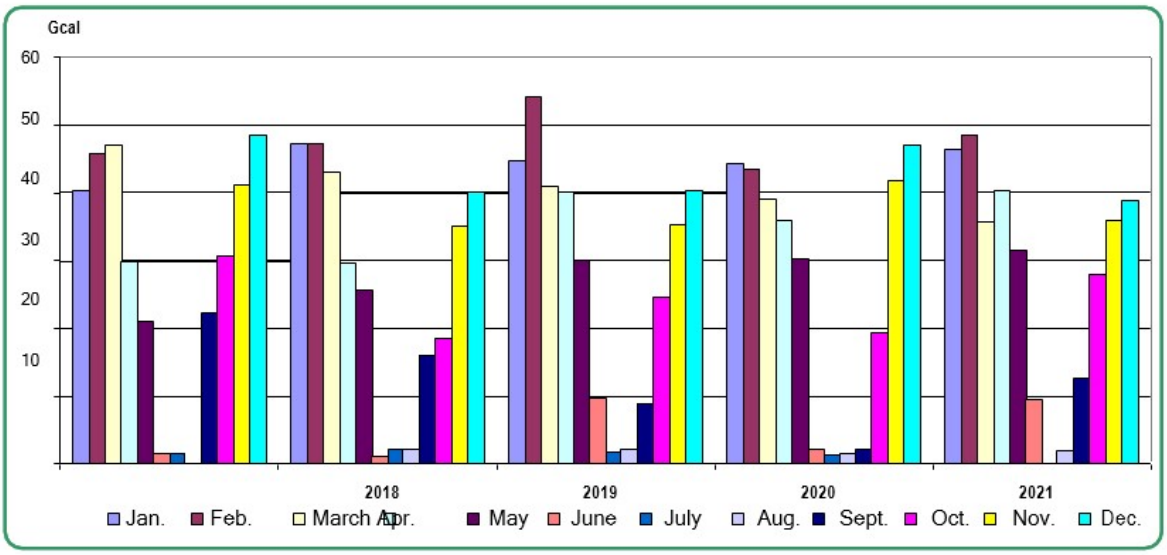

Fig. 3. **Diagram of the monthly consumption of thermal energy**

The heat supply system allows the institution to operate at various ambient temperatures in full. With further modernization of the system, we can recommend the installation of an automated individual heating substation.

A comparative analysis of heat consumption over a five-year period shows that the average annual heat consumption is 320 Gcal, and the small deviations of 3.8-5% in some years are most likely associated with the heating period - colder and longer winters.

The ratio of estimated and actual heat consumption in the base year 2020 is shown in Fig. 4.

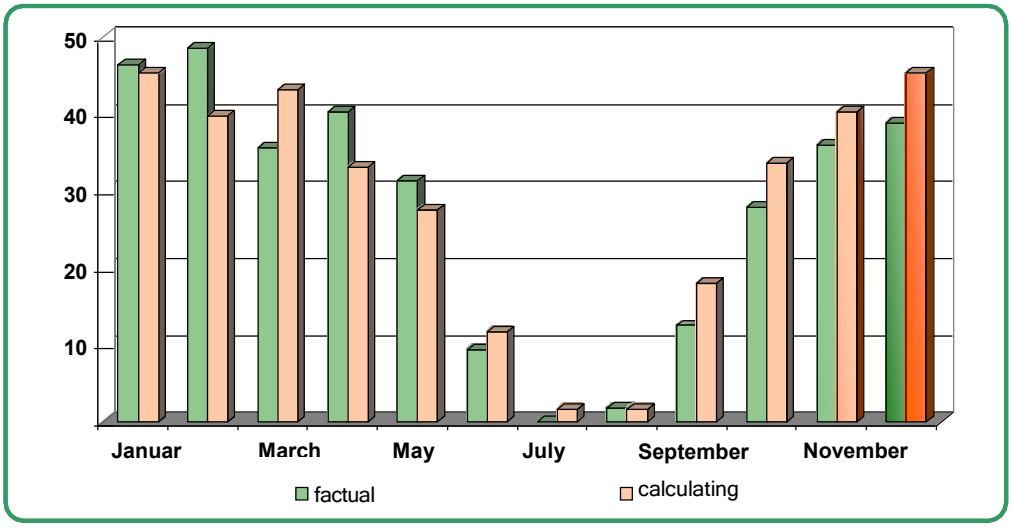

Fig. 4. **Estimated and actual heat consumption in the base year 2020, Gcal**

Thus, the proposed concept of energy efficiency program implementation in universities, based on the integration of principles of consistency (sequencing), compatibility (compatibility) and complementarity (complementarity) allows to substantiate an effective mechanism and select a set of effective energy efficiency tools for energy Hub system of universities.

Justified expediency of ensuring the reliability of power supply systems in energy efficiency program, its characteristics and indicators provides for the use of a range of technical, economic and organizational measures aimed at reducing the damage from the disruption of normal operation of electricity consumers. The list of reliability indicators and minimum acceptable (threshold) values of the main reliability indicators at the level of the regional electric power system was formed, which determines the development of appropriate measures of the energy efficiency program in the system of energy Hub of universities.

Water supply for household needs is centralized. The source of water supply is the city water supply network. The input is located in the basement. The water supply is provided at the expense of the pressure in the external water supply network. The main water consumers are sanitary units. During the inspection no leaks of sanitary equipment were detected. Calculations are made according to the meter readings. The direction of work to save cold water is preventive inspection and repair of sanitary equipment for leaks. Automatic sensor faucets are used to automatically turn on and off the water supply and thermostatically regulate its temperature and allow saving up to 50% of hot and cold water. Actual consumption of hot water for the mixing devices during the year is 180 m^3. The actual consumption of cold water for the mixing devices for the year – 245 m^3. The savings coefficient of automatic sensor faucets is 50%. The annual savings of hot water with the installed automatic sensor faucets will be 90 m3.

From all of the above it can be concluded that the main technical measures to improve energy efficiency at the objects of the budgetary sphere can include:

- insulation of basements, flat roofs, attic ceilings, windows;
- insulation of external walls;
- installation of heat-reflecting screens behind radiators;
- insulation of pipes of the internal distributing of the hot water supply system;
- installation of meters and balancing valves at the input to the building;
- adjustment of the heating system, installation of thermostats on heaters;
- replacement of the scheme with the use of elevator stations to the scheme with the pump and the system of regulation and automation;
- installation of individual heating points with the installation of a device for facade regulation of the building;
- installation of a periodic heating mode of the building;
- re-laying of heating networks.

Conclusion. At the present stage, solving the problem of increasing energy efficiency for higher education institutions is a strategic task that allows them to solve the issues of their financial development.

On the basis of research of existing approaches to definition of essence of economic and energy potential of universities of Ukraine the suggested model of realization of energy efficiency program is described. It was established that the level of technical and economic energy potential of Ukrainian universities is determined by the degree of technical, organizational and economic perfection of material and technical base of the main activities of executors / participants of energy efficiency program implementation, as well as the efficiency of the use of available labor, financial, material, energy (natural) resources. Due to this it was possible to avoid differently oriented goals and make possible the compensatory principle, which in this case is adopted, as purposefully affects the energy efficiency potential of participants in the implementation of the program to form a network of energy-hub knowledge centers forecasting priority area of "energy efficiency and energy conservation" of universities.

This is possible through the formation of a network of energy-hab knowledge centers for forecasting the priority area of development "energy efficiency and energy saving" of universities.

Today it is difficult to assess the efficiency of energy use in the system of higher education institutions. Based on the analysis of the current evaluation of energy efficiency program effectiveness, it is proposed to provide for the development of a matrix of indicators and tools of the program to form a network of energy-Hab knowledge centers forecasting priority development direction "energy efficiency and energy saving" of universities. Integral evaluation of the effectiveness of tools and mechanism for implementing the proposed energy efficiency program will include the definition of indices of achievement of target indicators of the program, the degree of implementation of key projects, implementation of the cost part of the program and evaluation of the activities of the responsible executor and their importance. Allow for effective implementation of the proposed energy efficiency program, which will provide for its rational planning, monitoring, and evaluation of the results obtained. The synergetic effect of the developed energy efficiency program and the project approach will be achieved in case of consistent step-by-step implementation.

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