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IMPLEMENTATION OF AN ENERGY EFFICIENT DRIVING SYSTEM BASED ON THE CONSUMPTION OF ENERGY CARRIERS AS A WAY TO INCREASE ENERGY CONSERVATION IN HIGHER EDUCATION INSTITUTIONS

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Abstract. *The problem of energy conservation is a priority direction in the development of energy security of Ukraine. The importance of solving the energy conservation and energy efficiency problem in Ukraine increases by the fact that today there is no single possible recipe for eliminating losses of electrical energy on all elements of the power supply and power consumption system, that is to say, both in the processes of generation and transportation, and in the localization of its sources of electrical energy and its consumers structure.*

Increasing the efficiency of the energy industry and, first of all, energy, raw and financial resources minimization problems is one of the priority directions of our state. The solution to this problem is determined by the development of a complex of energy conservation measures, which is the realization of legal, organizational, research and production, power engineering and economic measures that contribute to the effective use of electricity and fuel energy resources.

By example of the National University of Life and Environmental Sciences of Ukraine considered the fundamental issues of planning and management of energy conservation measures by using the features of various methods in the direction of reducing electrical energy losses, increasing its energy efficiency and quality.

Keywords: *energy efficiency, energy conservation, energy carrier, saving, measure, housing and communal area, technology, modernization.*

I. INTRODUCTION

Obviously that in order to overcome the crisis in the energy industry, to provide the country's energy independence, it is necessary to form a new energy culture in all areas of life and to educate a new energy awareness generation.

To develop energy awareness among young people only by real examples of energy conservation and improving energy efficiency around. The university should become a basic innovation platform, which experience will help to educate a new generation of young professionals in the future, for whom a thrifty attitude to the consumption of energy resources will be the basis of professional and social activities.

The current experience of implementing energy conservation technologies in educational institutions of Ukraine witnesses that the problem of budget objects in general and educational institutions in particular is the irrational use of energy resources, the lack of necessary investments in the modernization of energy infrastructure.

II. LITERATURE ANALYSIS

Today, Ukraine is faced a number of significant problems with the energy supply of the communal industry.

In the recent past, the main factors of low energy efficiency of urban housing and communal heat supply, especially in small cities and towns were cheapness of energy resources and water, insufficient attention to stimulation of energy efficiency issues, as well as low qualification of service personnel.

Currently, Ukrainian industry and the domestic area are extremely energy intensive, they depend to a large extent on energy sources, first at all oil and gas, which are obtained from abroad. So, according to the International Energy Agency, in 2017, to generate $1 of GDP, Ukraine produced an amount of energy equal to 0.27 kg of oil equivalent. At the same time, Ukraine has a huge potential for energy conservation and energy efficiency [1].

Until recently, the problems of energy conservation, energy resources and water were basically was not solving at all, although funds were transferred from the budget to finance energy conservation [1, 2].

A high increase in tariffs for energy resources and energy carriers has changed a lot the attitude of the management of operating companies and its staff to the realization of their direct duties, although there are still many unresolved problems [1, 2].

The priority areas are the reduction of heat losses in heating systems by improving the thermophysical characteristics of building constructions, the introduction of heat shields for radiators, and finally, the development and implementation of automated accounting systems and regulation of coolant consumption at heating points. Payments for the consumption of thermal energy significantly decreased when heat and water meters were installed [3].

The level of reduction of heat consumption in heating systems depends on many factors, the main of which are heat losses through the enclosing surfaces, which determinate with the thermophysical characteristics of the surfaces, the type and characteristics of heat energy accounting devices, as well as the heat consumption regulation system.

The system of accounting and regulation of heat carrier costs for water supply in the residential area, which is implemented in an individual heating point, should ensure the regulation of heat carrier costs depending on the ambient air temperature and limit heat consumption at night time of the day and on weekends (holidays).

Installation of ways of accounting and regulation of heat energy consumption, creation of a centralized information and measurement system with further dispatching of it makes it possible to carry through full operational control by heat flows, which allows to reduce the volume of heat energy consumption by an average of 30% - 35% [3, 4].

The beginning of the introduction in world practice of a new direction of construction of structures with increased requirements to the level of energy exploitation efficiency appeared after the world energy crisis of 1974. It was a response to the criticism of experts of the International Energy Agency (IEA) of the UN that modern buildings have significant reserves for improving their thermal efficiency. At the same time, the scientific community showed their criticism in front of this decision due to the insufficient research of this issue,

the specifics of the formation of the thermal regime, and the inability of designers to optimize heat and mass flows in the areas and in the house [3, 4]. In the same report, IEA experts formulated the main idea of energy saving – energy resources can be used more efficiently by applying measures that are technically feasible, economically justified, and also acceptable from an ecological and social points of view, that is, they cause minimal changes in the usual way of human life.

As we know, Ukraine belongs to the countries with small energy reserves [3, 4]. At the same time, prices on the world market of energy resources are growing rapidly, and their reserves are running out. The process cannot be stopped, but it can be slowed down due to the introduction of energy efficient technologies in all areas, and first of all, in the housing and communal area, as one of the most energy intensive. Therefore, the main reason for the introduction of energy conservation technologies in the housing and communal area of the Ukrainian economy is the high cost of thermal energy [3, 4]. For example, the city of Kyiv today uses more than 2 billion m^3 of gas in the housing and communal economy during the year , and Ukraine at all uses more than 30 billion m^3 of gas per year [5]. The potential for gas savings in housing and communal economy is at least 30% (Fig. 1).

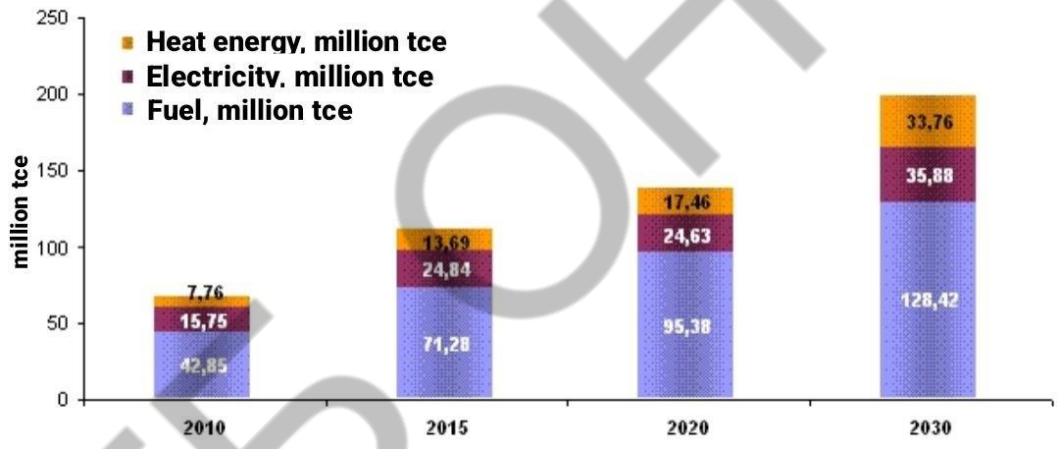

Fig 1. Energy conservation potential due to the technical (technological) factor [6]

So, about 90% of the existing communal and household fund, which is exploited at the moment, does not meet the heat efficiency requirements adopted in our state. Specific energy consumption of buildings in Ukraine in 2 - 2.5 times more than in developed countries located in similar climatic conditions. Due to this, increasing the energy efficiency of communal and household buildings is an urgent problem, and in order to solve the issues of optimizing the thermal regime of the building, improving its energy qualities, a thorough research of outside climatic and internal engineering and technical influences is necessary.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The development of the Comprehensive scientific and technical program of energy efficiency management at the National University of Life and Environmental Sciences of Ukraine for 2021-2025 (CSTP) aimed to introduce systemic energy management based on the results obtained and the experience gained in last years. The exploitation of experience gained during the period of realization of measures for the modernization of construction and engineering networks at the National University of

Life and Environmental Sciences of Ukraine during 2016-2020 allowed to focus attention on the introduction of modern fundamentals of energy management and optimal control of the university's energy carriers and water expenses in the conditions of constant increase in tariffs.

CSTP is a component in the realization of the strategic direction of the NUBiP of Ukraine within the area of the realization of the Development Program of the NUBiP of Ukraine "HOLOSIIVSKA INITIATIVE - 2025" regarding the reduction of expenditures on energy consumption through the implementation of organizational, technical and technological measures and material stimulation of energy conservation and energy efficiency improvement at the expense of the internal potential of the University.

Energy consumption by the buildings of the University depends to a considerable measure on the functional purpose of buildings and structures of primary and secondary educational and production purposes, which are used to provide the educational process.

CSTP is a conceptual document for the practical realization of the energy conservation policy, aimed at the implementation of the international standard ISO 50001:2018 "Energy management systems. Requirements and guidance for exploitation" at the university, which defines the requirements for the development, implementation, operation and improvement of the energy management system. ISO 50001 is based on the continuous improvement model of the management system, which is also used to develop other known standards such as ISO 9001 or ISO 14001. The mechanism simplifies the integration of energy efficiency measures during quality control, as well as monitoring energy and water consumption.

To ensure the implementation of ISO 50001:2018, it is necessary to ensure a number of requirements, in particular:

- the need to develop internal policies related to more efficient explotation of energy carriers during the educational process, scientific research, etc.;
- adjustment of goals and objectives according to the developed policy;
- implementation of continuous monitoring of energy and water consumption and application of this data for more effective decision-making according to energy efficiency management;
- analysis of monthly and seasonal results of energy consumption and forecasting of expenses for future periods;
- reviewing and adjusting the plan of energy efficiency management measures in according to current goals.

Based on the above provisions, the implementation of CSTP involves the step-by-step realization of measures with the development of project documentation and the corresponding technical and economic justification, namely:

- formation of an effective vertical of the university's energy consumption management, creation of an energy management service;
- attracting scientific, industrial and innovative resources to the realization of energy conservattion projects, creating demonstration zones of high energy efficiency and spreading experience in energy conservation issues;
- organization of internal consulting and information resources for the dissemination of experience on energy conservation issues among scientific and pedagogical workers, students and employees.

The realization of CSTP involves the analysis of the existing state, constant monitoring and forecasting of the development of energy consumption systems in the area of the current regulatory framework, the development of scientific and methodological support for the main, most effective areas of energy conservation activities, aimed at the realization of the energy conservation policy in university conditions.

The area of energy efficiency management and economical consumption of energy sources goes beyond purely technical issues of fuel and energy resources use and should be consistent with the principles and model of university development, positively influence on the structure of expenditures on energy supply, social and cultural aspects of energy explotation of scientific and pedagogical workers, employees and students.

IV. RESULTS

Obviously that in order to overcome the crisis in the energy area, to achieve energy independence of the country, it is necessary to bring up a modern energy conservation culture in all areas of being. Energy awareness among young people can be developed only by real examples of energy efficiency improvement.

The university, as a business subject, should be a basic innovative platform for the dissemination of experience and best energy conservation practices for the education and preparation of the modern generation of young professionals, for whom a thrifty attitude to the consumption of energy resources will be the basis of professional and social activities.

Productive use of energy resources is impossible without maintaining certain strategic principles for the development of the university's energy economy. A significant increase in energy tariffs in 2013, and after that as a result of military aggression in 2022, which made significant problems in the budgeting of expenses for the university's energy supply. The university immediately started the work with the development of project and estimate documentation and execute thermal modernization of buildings of educational buildings and student dormitories by attracting grant investments. Currently, the thermal modernization of 10 educational buildings and partially 5 student dormitories has already been completed.

For several years in a row, the National University of Life and Environmental Sciences of Ukraine has been developing and implementing organizational and technical and technological measures to reduce levels of energy consumption and is creating a new environment for making effective management decisions to stimulate energy conservation at the expense of the university's internal potential.

First at all, program documents were developed for the implementation of the energy consumption management system based on real-time data analysis, energy audits and energy inspections of university buildings were performed according to current regulatory documents (Fig. 1). In the future the available data were used to determine the forecast indicators of technical and economic justifications for future projects.

During the period of 2014-2020, a comprehensive system of energy management formed in the university, based on the Education and research institute of Energetics, Automatics and Energy saving, the Center for Energy Efficiency was created, which became a kind of specialist unit for the engineering services and heads of structural

divisions for monitoring energy and water consumption, regulating the regimes of heating stations, technical and economic justifications of the proposed measures, etc.

The mission of the first stage was to determine the generally corresponded to existing and perspective potential for energy conservation, to develop and justify priority and perspective measures to increase energy efficiency.

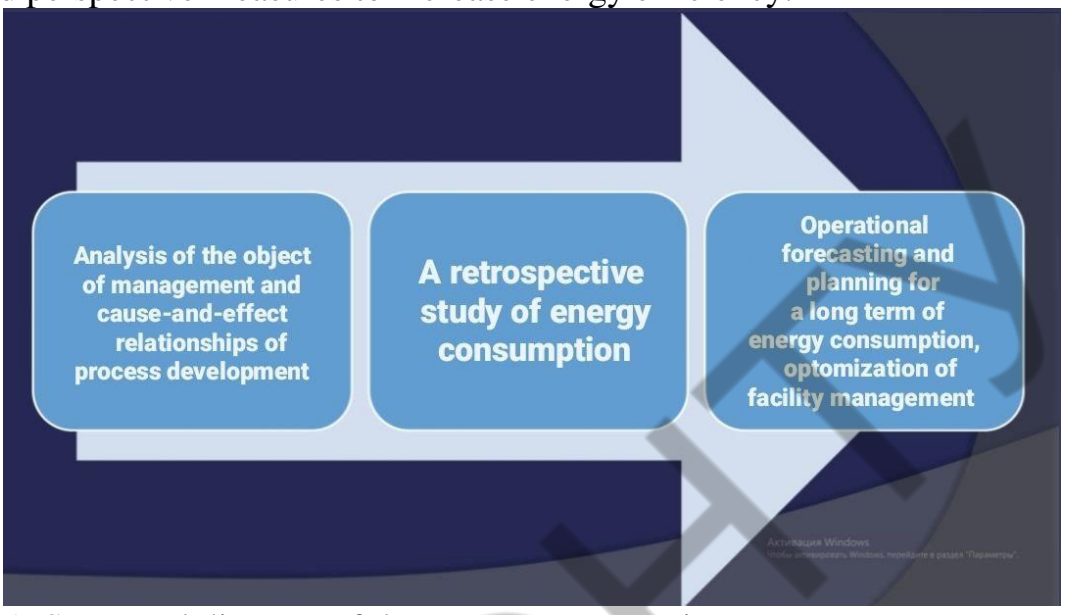

Fig. 1. Structural diagram of the energy consumption management system

The first steps related to the installation of modern accounting units for energy carriers and water in all buildings, modern heating points with weather dependent regulation of the supply of the heating medium were installed, which made it possible to identify cases of irrational exploitation of energy carriers and adaptively manage energy and water consumption (depends to the season, the academic period, on weekends and holidays, time of day, etc.) (Fig. 2).

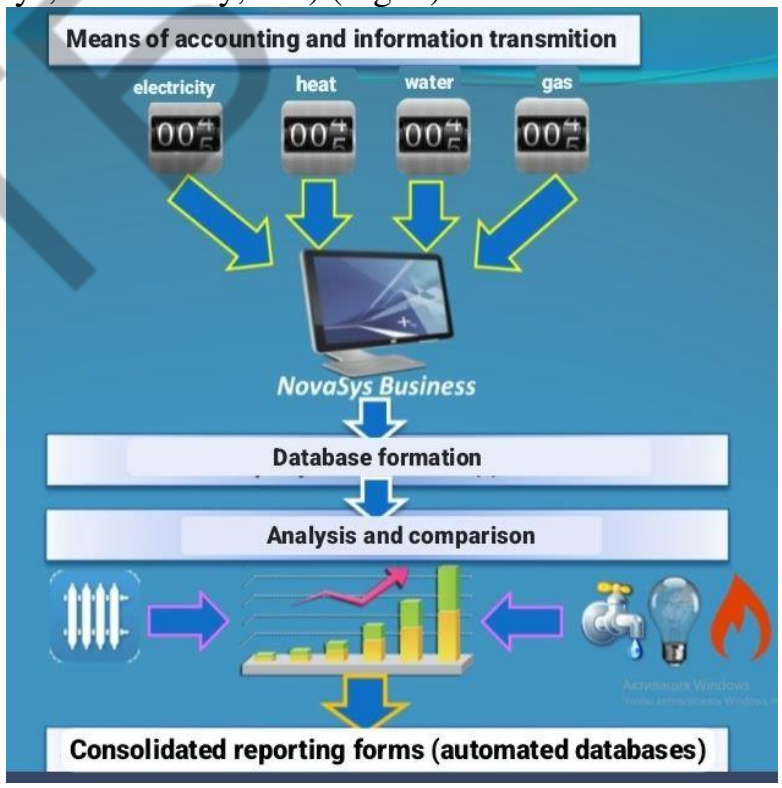

Fig. 2. Structural scheme of energy consumption

According to the order of the rector, in 2015, the university began a phased reconstruction of the heating stations of the educational buildings with the use of internal circulation pumps, control valves, hydraulic pressure regulators and heat exchangers, which ensure effective regulation and balancing of thermal power. Object oriented algorithms the regulation were developed by our specialists.

At the same time, constructive cooperation was adjusted with the companies supplying electricity and thermal energy to settle the issues of tariffs in the dormitories use, which led to a significant decrease in the financial costs of the university. In 2017, technical changes were made to the system of commercial accounting and the terms of application of contractual tariffs, which made it possible to reduce the financial burden on the university budget by more than UAH 700,000 per year. Today, boiler units for hot water accounting have already been installed, which make it possible to account only for actually consumed thermal energy. The development of the project of the automated commercial electricity accounting system with the modernization of accounting schemes is at the stage of completion, and the pilot project of software installation for ASKOE NUBiP of Ukraine has been completed.

Incandescent lamps were replaced with energy conservation ones with a reduction of the installed power of lighting devices by 79%, reconstruction of external electrical networks was carried out, pilot projects of an automated lighting control system were implemented in common areas, electric boilers were installed in student dormitories and dining halls; energy inspections of educational buildings were performed.

A method of normalizing energy consumption limits has been implemented, and their use is constantly monitored. In addition, since 2018, PJSC DTEK "Kyiv Electric Networks" compensates the university for expenses for the joint exploitation of external power networks in the amount of about UAH 200,000 per year.

Retrospective data on consumption (Tab. 1) and expenditure on energy and water (Fig. 3) at the university during 2016-2020 are indicative of the evaluation of the Center's performance. They testify that the internal engineering systems of energy consumption, educational buildings, dormitories, etc. still contain significant practical energy saving potential.

Table 1. Costs of energy and water consumption at the university in 2014-2020, thousand UAH

Type of service	**Funds were actually paid at current rates, thousand UAH**						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Heat consumption (heating)	9900	10118	16105	11676	16609	14103	11407
Hot water	2843	3388	6960	6583	4712	6160	4536
Water consumption	1296	2349	3271	3417	3552	4915	4330
Electricity consumption	6100	7496	11585	10299	10757	10954	7881
Gas consumption	1007	1449	2334	1531	1980	1483	863
IN ALL:	**21146**	**24800**	**40256**	**33507**	**37612**	**37616**	**29019**

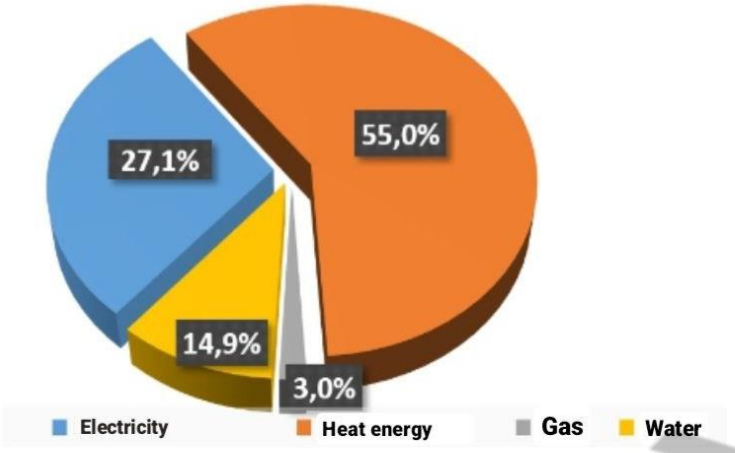

Fig.3. The pie chart of expenses for heat and water supply of the university as of 2020

To assess the scope of the work, we should to conduct a basic analysis of indicators regarding the levels of energy consumption in physical and monetary units. Such retrospective data by year eloquently tells about the successful work of the entire team (Fig. 4-9).

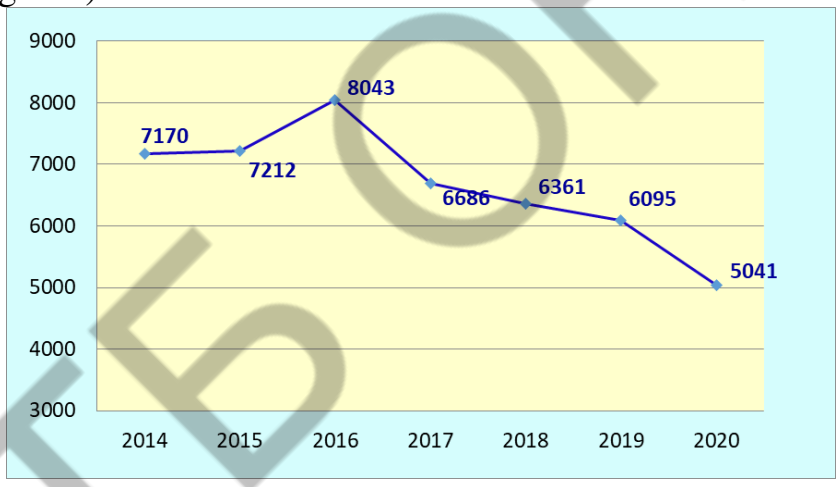

Fig.4. Dynamics of electricity consumption in 2014-2020, thousand kW·h

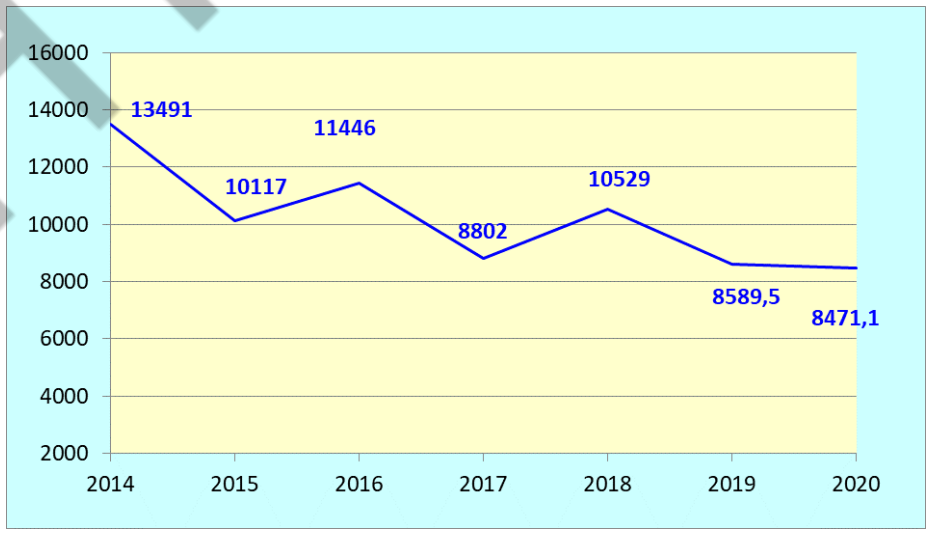

Fig.5. Dynamics of heat consumption in heating systems in 2014-2020, GKal

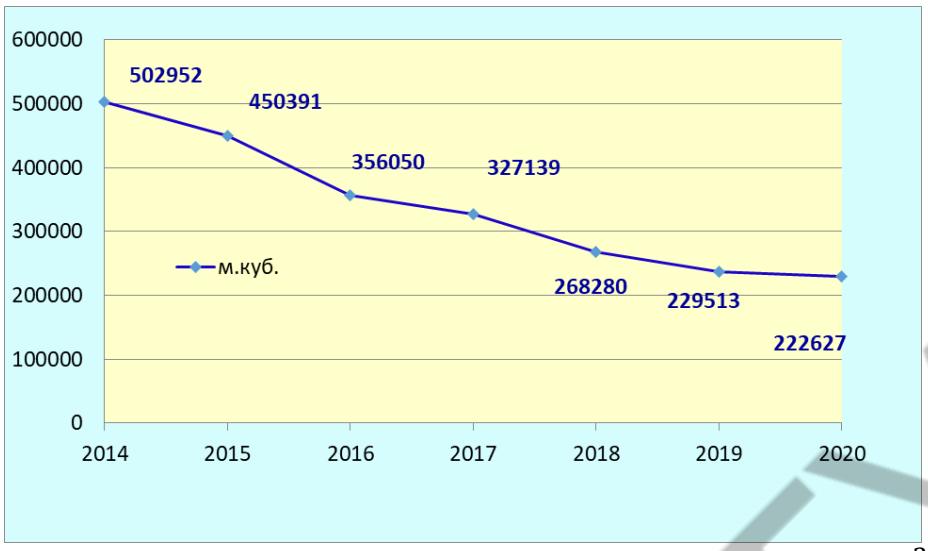

Fig.6. Dynamics of cold water consumption in 2014-2020, m^3

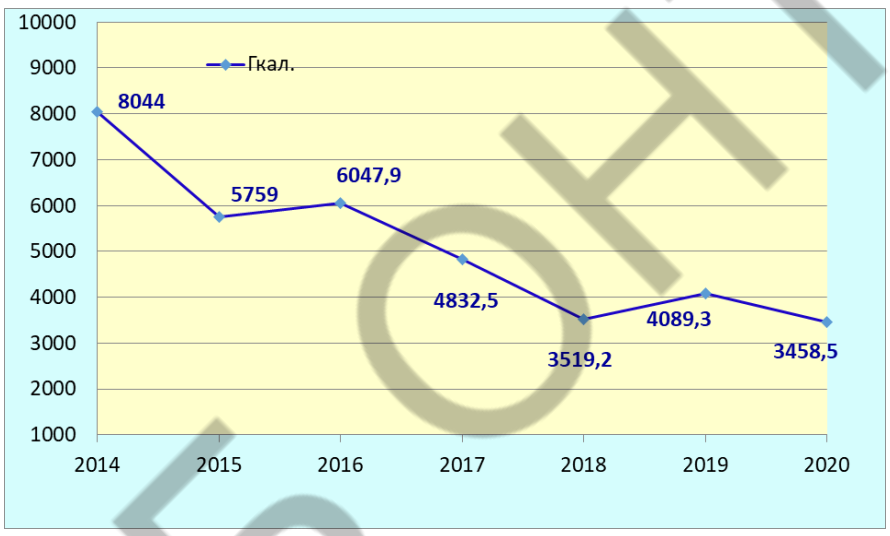

Fig.7. Dynamics of heat consumption for hot water preparation in 2014-2020, GKal

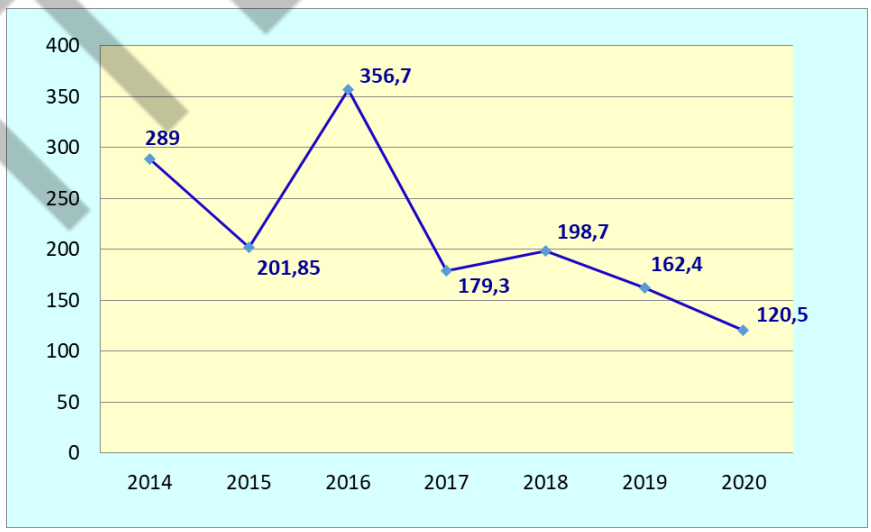

Fig.8. Dynamics of natural gas consumption in 2014-2020 in thousand m^3

Fig.9. Total expenses for energy carriers in 2013-2020

From a practical point of view, it became important to use the technical and intellectual potential of scientific and pedagogical workers of the energy efficiency center of NUBiP of Ukraine, and specialists of engineering services of the university. It was their effective work that made it possible to implement effective energy consevation activities, conduct comprehensive energy surveys of buildings and structures, propose ways of attracting material and financial resources for energy conservation measures, and modernize buildings and engineering networks.

Today, an energy management service based on the rationing of energy and water consumption in buildings is functioning in the university, specialized software and technical support for managing energy and water consumption is being implemented, and a motivation system for employees has been created.

It is worth mentioning the great work of engineering services, scientific and pedagogical workers, heads of structural units, who made a significant contribution to the realization of the university's energy conservation policy. So, for example, Fig. 10 shows the economic effect of the implementation of energy conservation measures until the year of 2014.

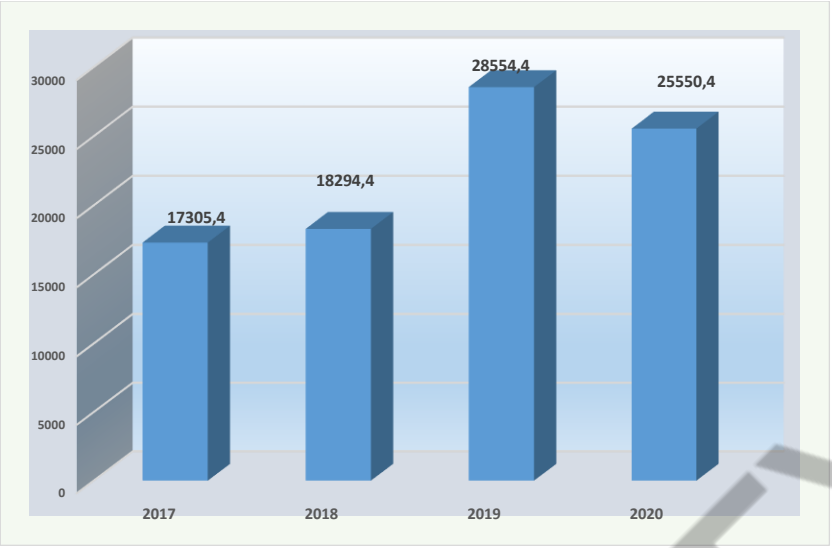

Fig.10. Economic effect to the basic in 2014

During the operation of the energy conservation program in NUBiP of Ukraine in 2017-2020, the total economic effect in the given tariffs of the year of 2014 for energy carriers and water was 89.76 million hryvnas, so the university would pay 89.76 million hryvnias more for energy carriers over the course of 4 years.

The further realization of the program involves the implementation of automated software and technical complexes for managing energy consumption modes and evaluating the economic efficiency of implementing energy conservation measures in university conditions. Modern possibilities of energy efficient improvement of buildings and systems, intelligent regulation of energy consumption require further development.

The experience gained at the university is unique. At the same time, it is available for distribution. NUBiP of Ukraine achieved a significant economic effect due to energy efficiency without attracting state funds by using internal reserves thanks to innovations that they developed themselves.

Energy efficiency should become a kind of criterion for the quality of functioning of the general university economy, coordinated interaction between engineering services, heads of structural and separate divisions, employees and students (Table 2, Table 3, Fig. 11).

Table 1.2 Analysis of tariff growth (by year)

Type of service (energy carriers)	Units of measurement	2019 p	2020 p	2021 p	The nearest perspective from 01/04/21
Electricity	kW/h (educational building)	2,29	2,29	2,49	3,49 (+30%)
	kW/h (dormitories)	0,9	0,9	1,68	1,68
Heating	Gcal	1259	1360	1679	1679 (+23%)
Hot water	Gcal	1246	1356	1522	1654 (+22%)
Cold water	Square meters	20,82	22,99	25,48	25.8 (+11%)
Gas	Square meters (educational building)	9,42	7,17	9,87	9.18 (+28%)
	Square meters (dormitories)	5,69	7,17	7,33	9.18 (+28%)

Table 3. Analysis of energy consumption in 2020

Energy carriers	Unit of measurement	2019		Outlay, thousand UAH
		consumption	value, thousand UAH	
Electricity	kW·h (educational building)	2742000	7936,3	**9570**
	kW·h, (dormitories)	3353084	3017,7	**5969**
Heating	Gcal	8589,5	14103,2	**14422**
Hot water	Gcal	4089,3	6160,2	**6764**
Cold water	m^3	251252	4915,5	**6482**
Gas	m^3, (educational building)	97450	918	**895**
	m^3, (dormitories)	59950	564	**550**
In all			**37614,9**	**44652**

Fig. 11. General expenses for payment of energy carriers

V. CONCLUSIONS

The development of the Comprehensive scientific and technical program of energy efficiency management at the National University of Life and Environmental Sciences of Ukraine for 2021-2025, the introduction of system energy management based on the results obtained and the experience gained in recent years, made it possible to focus attention on the introduction of modern principles of energy management and optimization of the university's expenditure management for energy carriers and water in conditions of constant increase in tariffs.

VI. REFERENCES

1. Ministry of Energy of Ukraine. (2017). Energy Strategy of Ukraine for the period until 2035. Ministry of Energy and Coal Industry of Ukraine. URL: http://mpe.kmu.gov.ua/minugol/control/uk/publish/article?art_id=245239564&cat_id=245239555.
2. Maissner, F., Naumenko, D., Radeke, Y. (2012). Pidvyshchennia enerhoefektyvnosti v Ukraini: zmenshennia rehuliuvannia ta stymuliuvannia enerhozberezhennia [Increasing energy efficiency in Ukraine: reducing regulation and encouraging energy conservation]. Retrieved from http://www.ier.com.ua/files/publications/Policy_papers/German_advisory_group/2012/PP_01_2012_ukr.pdf

3. Rocha, P., Siddiquia, A., Stadlercd, M. (2015). Improving energy efficiency via smart building energy management systems: A comparison with policy measures / Energy and Buildings. Vol. 88, 1 February 2015, 203 – 213.
4. Zhovtianskyi, V.A., Kulyk M.M. & Stohnii B.S. (2006). Stratehiia enerhozberezhennia v Ukraini: analitychno-dovidkovi materialy v 2-kh tomakh [Strategy of energy saving in Ukraine: analytical and reference materials in 2 volumes]. Kyiv: Akademperiodyka. (in Ukr.).
5. ISO 50006:2016 (ISO 50006:2014, IDT). Energy management systems. Measuring the level of achieved / achievable energy efficiency using basic levels of energy consumption and energy efficiency indicators. General provisions and guidelines.
6. Verkhovna Rada of Ukraine (2020, December 17). Zakon Ukrainy «Pro enerhetychnu efektyvnist» [About energy efficiency]. Retrieved from:
7. http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=70687.
8. Radko, I. P., Nalyvaiko, V.A., Okushko, O.V., Mishchenko, A.V. Antypov, Ye.O. (2018). Pidvyshchennia zakhodiv z enerhoefektyvnosti ta enerhozberezhennia u vyshchykh navchalnykh zakladakh [Increasing energy efficiency and energy saving measures in higher education institutions]. Naukovyi visnyk NUBiP Ukrainy [Scientific bulletin of NULES of Ukraine], 283, 275 – 280.
9. Kaplun, V.V., Radko, I.P., Nalyvaiko, V.A., Mishchenko, A.V., Okushko, O.V., Antypov, Ye.O. (2021). Kompleks zakhodiv z enerhozberezhennia of NULES of Ukraine [A complex of energy-saving measures in the National Institute of Environmental Protection of Ukraine] (Radko, I.P.). Kyiv: Vydavnychyi tsentr of NULES of Ukraine. (in Ukr.).
10. Zhyltsov, A.V., Lut, M.T., Nalyvaiko, V.A., Radko, I.P., Mishchenko, A.V., Antypov, Ye.O. & Okushko O.V. (2021) Avtomatyzovani modulni teplovi punkty dlia system teplopostachannia VNZ [Automated modular heat points for heat supply systems of universities of HEI]. Kyiv: Vydavnychyi tsentr of NULES of Ukraine. (in Ukr.).
11. Nalyvaiko, V., Radko, I., Zhyltsov, A., Okushko, O, Mishchenko, A., Antypov, I. (2020). Investigation of Termomodernized Building's Microclimate with Renewable Energy. E3S Web of Conferences 154,07011.