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**USING THE UNIVERSITY'S ENERGY
EFFICIENCY KNOWLEDGE HUB FOR
ENERGY RENOVATION AND ENERGY
MODERNIZATION OF UNIVERSITY
BUILDINGS**

Valeriia SCHERBAK¹

¹*Kyiv National University of Technologies and
Design, Kyiv, Ukraine*

BACKGROUND AND OBJECTIVES. The most important socio-economic task in the current period is to transfer Ukraine's economy to an intensive way of development in order to improve the level and quality of life of the population and solve the full range of social problems. Implementation of such a policy dictates the need to solve problems of reconstruction and modernization of buildings and structures, primarily related to the public sphere (including higher education institutions), in order to eliminate the existing inconsistency of the technical condition and functional and consumer qualities of public buildings to current standards and consumer requirements. Therefore, one of the most urgent directions of development of higher educational institutions is the task of providing effective overhaul and reconstruction of buildings, increasing their energy efficiency.

METHODS. The theoretical and methodological basis of the study were the fundamental and applied developments of leading domestic and foreign scientists in the theory and practice of management of energy modernization and energy reconstruction of buildings, increasing energy efficiency of buildings. The factual basis of research were the legislative acts of Ukraine in the field of energy efficiency, normative and methodical documents on the modernization and reconstruction of buildings, Directive 2010/31/EC in the field of energy saving. When solving specific tasks the methods of system and comparative analysis, economic-mathematical methods of efficiency evaluation of energy

reconstruction and energy modernization projects were used.

FINDINGS. The method of calculation of the reduced resistance to heat transfer of the enclosing structures and the shell of the 4th building of Kyiv National University of Technology and Design as a whole taking into account the temperature and humidity conditions in the fencing marginal zones. It is shown that in the enclosure edge zones the heat protective properties decrease resulting in a deterioration of the heat protection of the whole building. Practical recommendations for the design of fencing structures of modern buildings taking into account the temperature-moisture regime are proposed.

CONCLUSION. For the analysis of complex processes of moisture transfer in enclosures, a mathematical model based on the moisture potential is most convenient. A certain difference from the thermal potential (temperature) to the definition of the moisture potential allows to diagnose the most general assessment of the moisture regime of exterior and interior fences on the basis of HUB knowledge on energy efficiency. At use of this model it is possible to consider process of moisture exchange in a wide range of humidity and temperature taking into account movement of a moisture as a basis of carrying out energy reconstruction and energy modernization of operating buildings of the university.

KEYWORDS: Energy Efficiency Knowledge HUB; university; energy reconstruction; energy modernization.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
17	3	2

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**ВИКОРИСТАННЯ УНІВЕРСИТЕТСЬКОГО
ХАБУ ЗНАНЬ З ЕНЕРГОЕФЕКТИВНОСТІ
ДЛЯ ПРОВЕДЕННЯ
ЕНЕРГОРЕКОНСТРУКЦІЇ ТА
ЕНЕРГОМОДЕРНИЗАЦІЇ БУДІВЕЛЬ
УНІВЕРСИТЕТУ**

Валерія ЩЕРБАК¹

¹ *Київський національний університет технологій
та дизайну, Київ, Україна*

ПОСТАНОВКА ПРОБЛЕМИ ТА ЗАВДАННЯ. Найважливішим соціально-економічним завданням у поточний період є переведення економіки України на інтенсивний шлях розвитку з метою підвищення рівня та якості життя населення та вирішення повного комплексу соціальних завдань. Проведення такої політики диктує необхідність вирішення проблем реконструкції та модернізації будівель та споруд, що насамперед належать до суспільної сфери (вищих навчальних закладів у тому числі), з метою ліквідації невідповідності технічного стану та функціонально-споживчих якостей громадських будівель чинним нормативам та вимогам споживачів, що має місце. Тому одним із найбільш актуальних напрямів розвитку вищих навчальних закладів є завдання забезпечення ефективного капітального ремонту та реконструкції будівель, підвищення їхньої енергоефективності.

МЕТОДИ. Теоретичною та методичною основою дослідження послужили фундаментальні та прикладні розробки провідних вітчизняних та зарубіжних науковців у галузі теорії та практики управління енергомодернізацією та енергореконструкцією будівель, підвищення енергоефективності будівель. Фактичною базою дослідження стали законодавчі акти України в галузі енергоефективності, нормативні та методичні документи з питань модернізації та реконструкції будівель, Директиви 2010/31/ЄС у сфері енергозбереження. При вирішенні конкретних завдань використовувалися методи системного та порівняльного аналізу,

економіко-математичні методи оцінки ефективності проектів енергореконструкції та енергомодернізації.

РЕЗУЛЬТАТИ. Розроблено методичку розрахунку наведеного опору теплопередачі огорожувальних конструкцій та оболонки 4-го корпусу Київського національного університету технологій та дизайну загалом з урахуванням температурно-вологісного режиму у крайових зонах огорож. Показано, що в крайових зонах огорож теплозахисні властивості знижуються, що призводить до погіршення теплозахисту всієї будівлі. Запропоновано практичні рекомендації щодо проектування огорожувальних конструкцій сучасних будівель з урахуванням температурно-вологісного режиму.

ВИСНОВКИ. Для аналізу складних процесів волопереносу в огорожах найбільш зручна математична модель, що ґрунтується на потенціалі вологості. Певна відмінність від теплового потенціалу (температури) до визначення потенціалу вологості дозволяє на базі ХАБ знань з енергоефективності діагностувати найбільш загальну оцінку вологого режиму зовнішніх та внутрішніх огорож. При використанні цієї моделі можна розглядати процес вологообміну в широкому діапазоні вологості та температури з урахуванням переміщення вологи як основу проведення енергореконструкції та енергомодернізації експлуатованих будівель університету.

КЛЮЧОВІ СЛОВА: ХАБ знань з енергоефективності; університет; енергореконструкція; енергомодернізація.

INTRODUCTION.

Improvement of energy efficiency is a necessary element of the growth of energy independence of the country and reduction of energy intensity of the economy (Abu-Rayash and Dincer, 2020). The energy intensity of GDP in terms of purchasing power parity in Ukraine is three times higher than in most European countries (Di Stefano, 2000). Over the past three years, significant progress has been made in the implementation of the reform (especially in the residential sector): important laws, by-laws, the process of launching the Energy Efficiency Fund, etc. has been adopted. However, most of the implementation work is still ahead (Ganushchak-Efimenko et al., 2018).

The Ukrainian energy system is characterized by high energy dependence on imported energy resources – one third of primary energy is imported. 44% of energy is lost during transformation and transportation to the final consumer (while the EU average is 32%) – with 92 million tons of primary energy supply, the final consumption is 52 million tons. The largest consumer of energy is the domestic and industrial sectors – 17.6 million tons (or ~35%) and 15.0 million tons (or ~29%), respectively. The key sources of primary energy are coal (~33%), natural gas (28%) and nuclear energy (23%) (García et al., 2021).

The urgency of improving the efficiency of reproduction of housing and public buildings is determined by the strategic orientation of the economic development of Ukraine to the formation of energy-efficient economy, both on a national scale and on the scale of individual regions and municipalities (Gryshchenko et al., 2017). In the Ukrainian housing sector and public buildings there is a significant potential to improve energy efficiency (Kaplun and Shcherbak, 2016). According to the World Bank and Ukrainian researchers overhaul and reconstruction of existing buildings can bring savings of 30–60% of the energy consumed for heating purposes, public buildings – up to 50% (Liu et al., 2019). One of the essential potentials of use of energy efficiency have university buildings, which in most cases are very worn out and have exhausted their resource (Nayak et al., 2021). Therefore, the relevance of the use of new university education on the principles of university Knowledge Hub is now particularly high (Nicola et al., 2020).

The aim of the study is to propose a methodology for energy reconstruction and energy modernization of internal and external partitions of buildings on the basis of university Hub of knowledge on energy efficiency. The study was conducted in 2021 on the basis of the Kyiv National University of Technologies and Design.

MATERIALS AND METHODS

For a building envelope consisting of m building envelopes ($m \geq 1$), the reduced heat transfer resistance is calculated by equation (1):

$$R_{he}^{des} = \frac{A_e^{sum}}{\sum_{i=1}^m \frac{n_i A_i}{R_{hi}^{des}}}, \quad (1)$$

where n_i is the coefficient taking into account the position of the i -th enclosing structure relative to the indoor and outdoor air.

Assessment of the impact of edge zones on the energy performance of buildings calculation of the energy performance of the building for the heating period using the specific energy consumption for the operation of the building during the heating period is calculated by equation (2):

$$q = q_h + q_{hw} + q_e, \quad (2)$$

where q_h , q_{hw} , q_e are respectively specific heat consumption for heating, hot water supply and electric energy (direct or reduced to heat equivalent) for the heating period.

The specific heat consumption for heating is calculated on the basis of the heat balance of the building for the heating period according to equation (3):

$$q_h = q_{tr} + q_a - \eta(q_{int} + q_s), \quad (3)$$

where q_{tr} , q_a , q_{int} , q_s are respectively specific transmission heat losses through the building envelope, specific heat losses due to air infiltration and ventilation, specific internal domestic heat losses, specific heat gains due to solar radiation;

$\eta \leq 1$ –coefficient of heat gain into the building.

The influence of the peripheral zones of the enclosing structures on the specific energy consumption is taken into account when calculating the specific transmission heat losses q_{tr} . The total transmission heat loss through the envelope is the sum of the main heat loss and the additional heat loss through all the envelope edge zones and is calculated by equation (4):

$$Q_t = \frac{0.0864M_{ht}A}{R_h^{con}} (1 + \sum_{j=1}^l \omega_j), \quad (4)$$

where l is the number of edge zones;

$\omega_j = k_j^{ez} A_j^{ez} / A$ is the coefficient of additional heat loss through the j -th edge zone.

Equation (4) makes it possible to calculate the total heat loss of the envelope, taking into account the edge zones, and to evaluate the contribution of each edge zone to the heat loss.

For a building envelope consisting of m building envelopes ($m \geq 1$), specific transmission heat losses are calculated by equation (5):

$$q_{tr} = \frac{1}{V_h} \sum_{i=1}^m Q_{Ti}, \quad (5)$$

where Q_{Ti} is the total transmission heat loss through the i -th structure.

RESULTS AND DISCUSSION.

The developed method allows to take into account the influence of humidity on the temperature field of the structure, the non-stationarity of the temperature and humidity regime, three-dimensionality of the temperature and humidity fields, which is in the world trend with the energy saving program in the university buildings.

For widely used in practice of energy reconstruction and energy modernization of external and internal enclosures of the 4-th building of Kyiv National University of Technologies and Design (KNUTD) which contain marginal zones, there was executed the calculation of temperature and humidity conditions by the computer program "SOVT-3".

Based on the results of the calculation (Fig. 1–3), the effect of the marginal zones on the thermal protection properties of the enclosing structures was assessed.

The study shows that for all types of considered structures in the marginal zones the localization of temperature and moisture content with the formation of complex marginal effects due to the joint effect of heat and moisture transfer processes is noted. Deterioration of the temperature and moisture conditions in the marginal zones leads to a decrease in the thermal protection properties of structures. The maximum decrease in thermal protection properties (up to 47%) is noted in the corner of exterior walls with the placement of a thermal insulating insert near the inner surface.

The results obtained were used to assess the impact of the marginal zones of the enclosing structures on the thermal protection properties of the envelope of the 4th building of KNUTD. On the basis of the developed methodology, the thermal protection for the design of the 14-storey 4th building of KNUTD and the design was assessed for the following calculation variants: 1 – without edge zones (basic); 2 – including edge zones (Table 1).

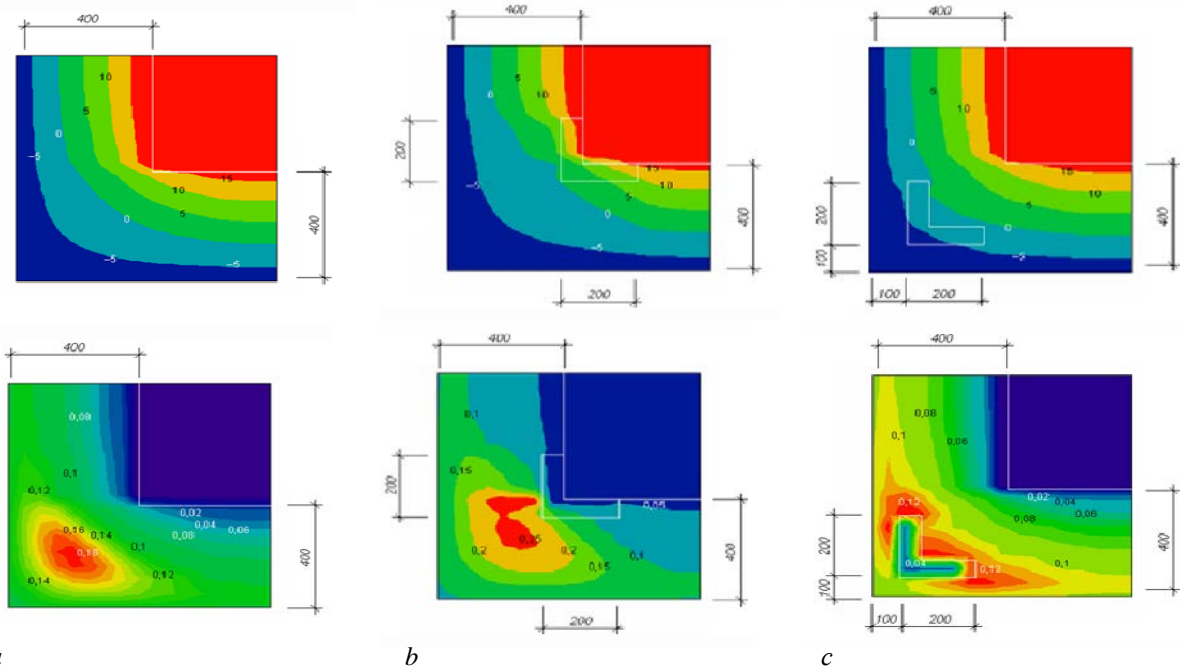


Fig. 1. Fields of temperature (top) and moisture content (bottom) in the outer corner of lightweight concrete walls

Legend: a – without thermal insulating insert; b – with thermal insulating insert at the inner surface of the corner; c – the same, at the outer surface of the corner

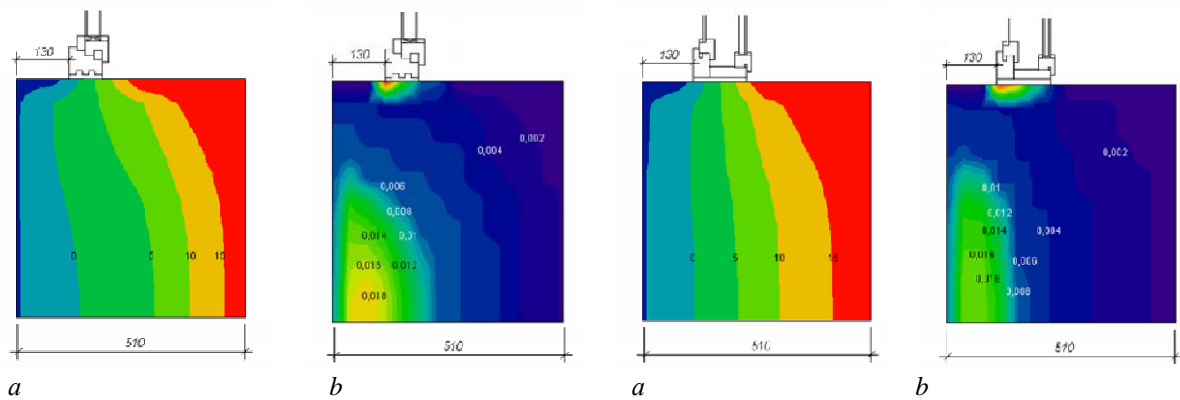


Fig. 2. Fields of temperature and moisture content at the junction of the window unit with the exterior wall

Symbols: temperature fields with a narrow box (a) and moisture fields with a wide box (b)

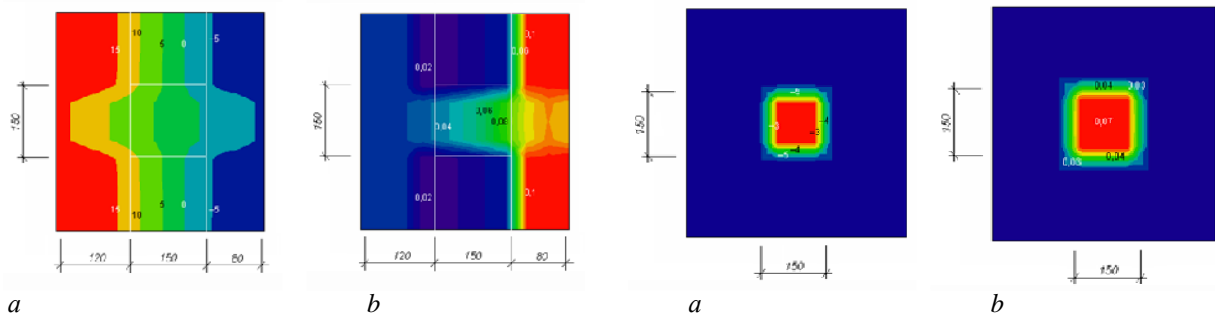


Fig. 3. Temperature and moisture fields in a three-layer wall panel

Symbols: temperature fields of the section along the keyhole (a) and moisture content at the junction of the insulation with the outer protective and finishing layer (b)

Table 1

Thermal resistance of envelope enclosing structures of the 4th building of Kyiv National University of Technologies and Design

Enclosing structure	Square, m ²	Thermal resistance, m ² ·K/Bt	
		base case	including edge zones
Exterior walls	4494	4,06	2,16
Windows, balcony doors	1576	0,68	0,59
Entrance doors	55	0,78	0,78
Covering combined	412	4,22	3,38
Ceiling of warm attic	381	3,68	2,94
Ceiling over the technical floor	793	3,68	2,94

Thermal transmittance of the building envelope: according to the basic variant – 1.97 m²-K/W, taking into account the edge zones – 1.44 m²-K/W. Reduction of the reduced heat transfer resistance of the building envelope in comparison with the basic variant is 26.9%. Calculation of components q_h, q_{hw} and q_e is performed on the basis of the Directive 2010/31/EC. The proposed method has been implemented in the computer program "Energy Passport of a Building", developed on the basis of the University Knowledge Hub in the visual object-oriented programming system Delphi 3–7 for WINDOWS. The main advantages of the computer program are: calculation of energy consumption of the building taking into account all its components, including heat and electric energy consumption; determination of the structure of transmission heat losses through the fencing edge zones, which allows to improve the design solutions of energy reconstruction and energy modernization; possibility to assess the energy efficiency of the building at the stage of energy reconstruction and energy modernization.

By the example of the project of energy reconstruction and energy modernization of the building, the study shows that the temperature and humidity conditions in the marginal zones of the enclosures have a significant impact on the energy performance of the building. Consideration of the fencing edge zones increases specific transmission heat losses through the building envelope by 37%, heat energy consumption for heating by 32%, and energy consumption for building operation by 13%. Improvement of the structural solution of the outer envelopes leads to a decrease in specific transmission heat losses through the building envelope by 29%, the consumption of thermal energy for heating by 25%, the energy consumption for the operation of the building by 10%. Thus, the improvement of the edge zones of the building envelope structures has a high potential of energy efficiency.

In order to confirm the validity of the developed methods, the energy efficiency of the high-rise 14-storey operating building of the 4th building of KNUTD was assessed according to the results of the energy audit carried out by

the author. At the time of the energy audit the duration of operation of the building was about 40 years. Measurement and recording of heat energy consumption for building heating was performed by express method according to Directive 2010/31/EC. Thermal energy consumption for heating and hot water supply was monitored automatically once a day using a heat meter in the building of Building 4. The measurement results were used to test the building energy performance calculation methodology (Table 2).

Table 2

Comparison of calculated and actual specific energy indicators of the 4th building of Kyiv National University of Technologies and Design

Indicator	Value of the indicator, МДж/м ³		Deviation of the calculated value of the indicator from the actual, %
	actual	estimated	
Heat consumption for heating of the building	94.5	92.4	-2.2
Heat consumption for hot water supply	29.2	27.3	-6.5
Electricity consumption	22.2	24.1	+8.6
Total	146	144	-1.4

Comparison of the calculated values of the energy indicators obtained by the proposed method with the actual data confirms the validity of the methodology. Thus, taking into account the edge zones in the enclosures allows a more accurate assessment of the thermal protection and energy performance of buildings during the heating period, conducted on the basis of the University Hub of Knowledge.

CONCLUSION.

The effect of temperature and humidity conditions in the marginal zones of the enclosing structures on the thermal protection and energy performance of the building during the heating period on the basis of the university Hub of Knowledge was assessed. A methodology for calculating the energy performance of the building during the heating period was developed. When determining the transmission heat losses through the building envelope, additional heat losses in the marginal zones of the enclosing structures are taken into account. On the basis of this methodology, it is shown that the temperature and humidity conditions in the enclosure periphery zones have a significant impact on the building energy performance. Improving the structural solution of the external envelopes leads to a 10% reduction in the energy consumption for the operation of the building. Thus, the reduction of heat losses in the marginal zones of the enclosing structures has a high potential of energy saving of the 4th building of Kyiv National University of Technologies and Design.

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ABBREVIATIONS:

%	Percentage
COVID-19	Corona Virus Disease 2019, corona virus infection 2019-nCoV
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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AUTHOR (S) BIOSKETCHES



Shcherbak Valeriia, D.Sc in Economics, Professor, Department of Entrepreneurship and Business, Kyiv National University of Technologies and Design, Ukraine.

<https://orcid.org/0000-0002-7918-6033>

Scopus Author ID: 36053504500

Researcher ID: P-6903-2016

E-mail: valery_shcherbak@i.ua

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