UDC 697.1
DOI: 10.15587/2706-5448.2025.347970

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OPTIMIZATION OF PUBLIC BUILDING GLAZING ACCORDING TO ENERGY EFFICIENCY CRITERIA

The object of research is a two-story office building. One of the problem areas in building envelopes is stained glass structures that do not meet modern energy efficiency requirements and have significant heat loss. The research aims to develop optimal design solutions for modernizing existing glazing, aimed at reducing heat loss while preserving the architectural appearance of the facade and the economic feasibility of implementing thermal renovation measures.

The research used a set of methods, namely the creation of a BIM model of the building, analysis of the thermal insulation properties of building envelopes, technical and economic comparison of thermal renovation options, and online calculation tools from window companies. The research results provided indicators of heat loss through the stained glass windows of the existing system and the proposed reconstruction options, as well as the amount of solar gain. Three options for replacing the stained glass windows were developed. One option involved the use of Rehau SYNEGO® MD-80 with 490 mm mullions and a reduction in the area of translucent structures. The heat loss savings are 56%, and the implementation cost is 3084 EUR, which is an acceptable indicator among the options considered. This is because the proposed option meets energy efficiency requirements and also takes into account the customer's restrictions on changing the architectural appearance of the facade by no more than 50%.

The proposed approach allows for a comprehensive assessment of the impact of the proposed measures on the energy balance of the building, taking into account architectural constraints and justifying an economically viable solution. Compared to traditional solutions for replacing stained glass windows based solely on thermal conductivity or standard facade solutions without taking into account the conditions of a specific object.

The results obtained can be used for implementation in similar objects in public and office buildings during reconstruction or new construction.

Keywords: *energy efficiency, glazing, facade, thermal insulation, Building Information Model, heat loss, energy conservation, thermal renovation.*

Received: 10.10.2025
Received in revised form: 03.12.2025
Accepted: 23.12.2025
Published: 29.12.2025

How to cite
Kosenko, L., Koval, O., Yurchenko, Y., Koval, A., Hryshyn, S. (2025). Optimization of public building glazing according to energy efficiency criteria. Technology Audit and Production Reserves, 6 (1 (86)), 57–63. https://doi.org/10.15587/2706-5448.2025.347970

1. Introduction

In the context of global climate change and constantly rising energy prices, the issue of energy efficiency in buildings is becoming increasingly important. Particular attention is paid to public buildings, namely office buildings, as they tend to consume significant amounts of energy and have large transparent enclosing structures. According to the literature, buildings consume about 40% of the world's primary energy. Office buildings account for a significant share of this consumption [1].

Based on recent studies concerning office buildings, there is a noticeable trend toward the use of large stained glass wall structures. While making facade systems lightweight and giving them a modern appearance, the question of the energy efficiency of such buildings arises. Studies indicate that such structures can experience significant heat loss throughout the year.

Today, Ukraine is implementing new NZEB (Nearly Zero Energy Building) building requirements aimed at reducing energy consumption. Thermal renovation of glazing systems can significantly reduce energy costs in administrative and public buildings.

Translucent enclosure systems are becoming more energy efficient. With the help of BIM modeling tools, it is possible to design or compare window system options and see how a particular glazing option will affect the performance of the building. BIM is well suited for analyzing thermal characteristics and allows to avoid mistakes that were previously discovered after the facade was installed.

Despite the large number of scientific papers on the energy efficiency of glazing, some topics remain underdeveloped. For example, facade design is often evaluated separately from its energy performance, although in practice these two parts are inseparable. Similarly, little attention is paid to how to combine actual operating conditions, local climate, and cost of work with the choice of structural solution. In the text analyzed, the authors propose a more comprehensive approach that takes into account architectural requirements, thermal performance, and financial feasibility – effectively creating a methodology for selecting the best scheme for renovating a stained glass facade.

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Similarly, little attention is paid to how to combine actual operating conditions, local climate, and cost of work with the choice of structural solution. In the analyzed text, the authors propose a more comprehensive approach that takes into account architectural requirements, thermal performance, and financial feasibility – effectively creating a methodology for selecting the best scheme for renovating a stained-glass facade.

A separate example in the article is a two-story office building in Dnipro. The authors describe its existing glazing in detail, offer several possible options for its improvement, and compare these solutions according to a number of criteria. This approach makes it possible not only to determine which option works best, but also to explain why it is justified.

The text also emphasizes that glass structures in public buildings must perform a number of functions, not just decorative ones. They must provide sufficient daylight and maintain acceptable conditions inside the premises. However, older systems often fail to meet these requirements: a lot of heat is lost in winter, and in summer the temperature inside rises too high, increasing heating and cooling costs. Other studies also draw attention to this issue [1–12].

The object of research is a two-story office building.

The aim of research is to determine the optimal design solution for modernizing the stained glass windows of an office building in order to improve its energy efficiency.

Research tasks:

– analyze existing stained glass windows and identify their shortcomings in terms of energy efficiency;
– develop options for modernizing the stained glass structure;
– conduct an analysis using the developed BIM model and online tools from window companies;
– determine the optimal solution based on a comprehensive analysis of all criteria.

2. Materials and Methods

The paper considers the issue of improving the energy efficiency of stained glass windows in a two-story office building in the city of Dnipro (Ukraine). The building has large stained glass windows, which is a typical solution for modern office buildings. Large stained glass windows are used in office buildings to improve natural lighting and architectural expressiveness of facades. Such solutions lead to increased heat loss, which makes the selected object a typical option for researching energy efficiency optimization measures.

The research uses a comprehensive approach, including modeling, analysis, and economic assessment based on the scientific principles of energy efficiency theory, namely:

– *thermal calculations in accordance with current Ukrainian standards.* DBN V.2.6-31:2021 – thermal insulation and energy efficiency of buildings, DSTU 9191:2022 – thermal insulation method for selecting thermal insulation material for building insulation, DSTU 9190:2022 – energy efficiency of buildings;
– *computer modeling of BIM models of buildings.* Modeling and calculation of structures using specialized software Veka Windoplan (manufacturer: VEKA AG, Germany), Rehau Window-Planning (manufacturer: Rehau, Germany), Autodesk Revit (manufacturer: Autodesk, USA);
– *economic analysis* (costs for implementing the proposed options, annual energy savings);
– *analysis of proposed solutions.* Comparison based on energy efficiency and economic feasibility criteria (energy criteria – annual heat loss through transmission, solar heat gain during heating and cooling periods, overall energy balance).

Optimization method. Optimization was carried out according to the target function of minimizing heat loss through translucent structures and capital expenditures while complying with the following restrictions:

– thermal requirements according to DBN B.2.6-31:2021: the heat transfer coefficient of enclosing structures (for translucent structures) must comply with the requirements of climate zone I of Ukraine

$$U(X) \le U_{\max} = 1/R_{q\min},\ R_{q\min} = 0.9\ \mathrm{m^2 \cdot K/W};$$

– architectural restrictions imposed by the customer (preservation of at least 50% of the original glazing area and architectural appearance of the facade), preservation of the aesthetic characteristics of the facade, and ensuring comfortable working conditions.

For each option, monthly calculations of heat transfer and solar heat gains were performed, graphs and diagrams were constructed for visual comparison, and compliance with regulatory requirements was verified. The final stage consisted of selecting a compromise solution that provides an optimal balance between energy efficiency, investment attractiveness, and preservation of the architectural concept of the building.

All calculations were obtained using formulas (1)–(6), in accordance with the regulatory requirements of the current DSTU 9190 methodology.

Algorithm for calculating the effectiveness indicator of a measure

$$F = (\Delta E_H; \Delta E_C; B_{EEM}; B_H; B_C), \tag{1}$$

where ΔE_H – annual savings during the heating season; ΔE_C – annual savings during the cooling period; B_{EEM} – cost of an energy efficiency measure; B_H – heating costs; B_C – cooling cost.

Determining annual savings during the heating season

$$E_H = Q_{tr}^H - Q_{sol}^H, \tag{2}$$

where Q_{tr}^H – heat loss through transmission during the heating season, kWh; Q_{sol}^H – heat supply during the heating season, kWh.

Determining annual savings during the cooling period

$$E_C = Q_{sol}^C - Q_{tr}^C, \tag{3}$$

where Q_{tr}^C / Q_{sol}^C – heat loss through transmission/heat gain during cooling period, kWh.

Calculation of heat loss through transmission

$$Q_{tr} = \frac{\sum A_i \cdot 24 \cdot U \cdot \sum(\theta_{int} - \theta_{ext}) \cdot n_m}{1000}, \tag{4}$$

where Q_{tr} – heat loss through transmission, kWh; A_i – glazing area, m^2; U – thermal conductivity coefficients, W/(m^2 · K); θ_{int} – internal temperature, °C; θ_{ext} – average monthly outside temperature, °C; n_m – number of days in the heating period.

Calculation of solar heat gains

$$Q_{sol} = F_{sh} \cdot A_{sol} \cdot g_{gl} \cdot I_m \cdot n_m, \tag{5}$$

where F_{sh} – shading coefficient of an element; A_{sol} – equivalent insolation area of the element, m^2; g_{gl} – solar heat gain coefficient (SHGC) of the structure; I_m – average daily insolation per month, kWh/m^2; n_m – number of days in the heating period.

Determining the most cost-effective measure in terms of annual energy savings

$$F = B_{EEM} - \Delta E_H - \Delta E_C \to \min, \tag{6}$$

where ΔE_H – annual savings during the heating season; ΔE_C – annual savings during the cooling period; B_{EEM} – cost of an energy efficiency measure.

The presented calculation algorithm using formulas (1)–(6) provides a consistent determination of the effectiveness indicators of thermal renovation measures.

3. Results and Discussion

The building has stained glass windows on the north and south facades. A preliminary analysis of the building showed that the existing stained glass windows don't provide enough natural light to create optimal working conditions in the office space. This means that artificial lighting is needed for a big part of the workday.

The identified insufficiency of natural lighting through stained glass windows indicates potential for optimization. Reconstruction or replacement of part of the stained glass windows with more energy-efficient designs can contribute to reducing operating energy costs. The use of stained glass windows in the office space, as shown in Fig. 1, has been reviewed with a view to optimizing or partially replacing them. This will ensure higher energy efficiency of the building, increase employee comfort and contribute to reducing the impact on the environment.

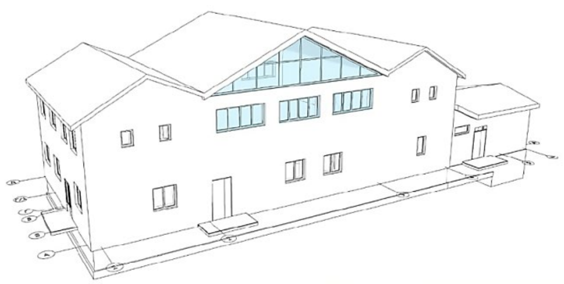

Fig. 1. General 3D view of the object (the color indicates the window enclosing structures of the office space)

Options for renovating the stained glass structure to improve its energy efficiency were considered. Variable calculations were performed and their technical and economic indicators were compared:

1. Replacement of glazing with the energy-efficient VEKA SOFTLINE 82 AD system (manufacturer: VEKA AG, Germany).
2. Use of the Rehau SYNEGO® MD-80 (manufacturer: Rehau, Germany) combined system with insulated mullions.
3. Complete replacement of the glazing with a brick enclosure structure.

To compare different envelope systems, it is firstly isolated heat loss through the existing Rehau Design 60 (manufacturer: Rehau, Germany) stained glass windows. The building has two similar stained glass windows on the north and south facades.

A comparative analysis of the options was conducted based on three main criteria:

1. Heat transfer through transmission.
2. Solar heat gain.
3. Economic indicators (capital costs for implementation and economic effect).

The calculation of heat transfer through the existing Rehau Design 60 stained glass windows for each month is shown in Table 1.

Table 1 shows the results of heat transfer calculations for each month through existing Rehau Design 60 stained glass windows (manufacturer: Rehau, Germany). The calculations were made taking into account the duration of the heating period and average monthly outdoor temperatures. The greatest heat loss during the year is observed in January (1176.12 kWh), due to the lowest outdoor air temperature. In the warm months of the year, negative values are obtained due to the heating of rooms from solar heat gains.

The total annual heat loss through the stained glass windows is 915 kWh. The results of annual losses will be used as initial values for further modernization of the glazing system and evaluation of the effectiveness of the proposed design solutions [13–15].

Option 1: VEKA SOFTLINE 82 AD (Aluminum cover profile).

The first thermal renovations option was chosen complete replacement of the existing stained-glass window with a new VEKA SOFTLINE 82 AD (manufacturer: VEKA AG, Germany) system with the following characteristics:

– profile system with aluminum overlay;
– energy-efficient double-glazed unit 4/12A/4/12A/4;
– heat transfer coefficient $U_w = 0.964$ W/(m$^2\cdot$K);
– reduced heat transfer resistance $R_{tr} = 1.037$ (m$^2\cdot$K/W);
– requirements of DBN B.2.6-31:2021 for the I climatic zone of Ukraine for thermal conductivity resistance $R_w > 0.9$ m$^2\cdot$K/Btu is met.

The design and calculation of energy efficiency values for glazing is performed using Veka Windoplan's proprietary software [16], as shown in Fig. 2. The type and dimensions of the structures (12,000 × 3,000 mm) are shown in Fig. 2.

Calculations show that the implementation of this solution will reduce heat transfer through the transmission to 484.42 kWh per year, which is a 47% saving compared to the existing design.

Table 1

Monthly calculation of heat transfer by transmission through existing Rehau Design 60 stained glass windows

Months of the year	Outside temperature	Number of days in a month	Hours per month t, h	Heat transfer by transmission Q_{tr}, kWh
January	–4.7	31	744	1176.12
February	–3.8	28	672	163.43
March	1.1	31	744	–52.38
April	9.6	13	312	–191.69
May	16	0	0	0.00
June	19.6	0	0	0.00
July	21.6	0	0	0.00
August	20.7	0	0	0.00
September	15.4	0	0	0.00
October	8.6	15	360	–198.14
November	2.2	30	720	–101.38
December	–2.5	31	744	119.04
$\theta_{int,se}$, H	20	–	–	–
Total				915.00

ISSN-L 2664-9969; E-ISSN 2706-5448

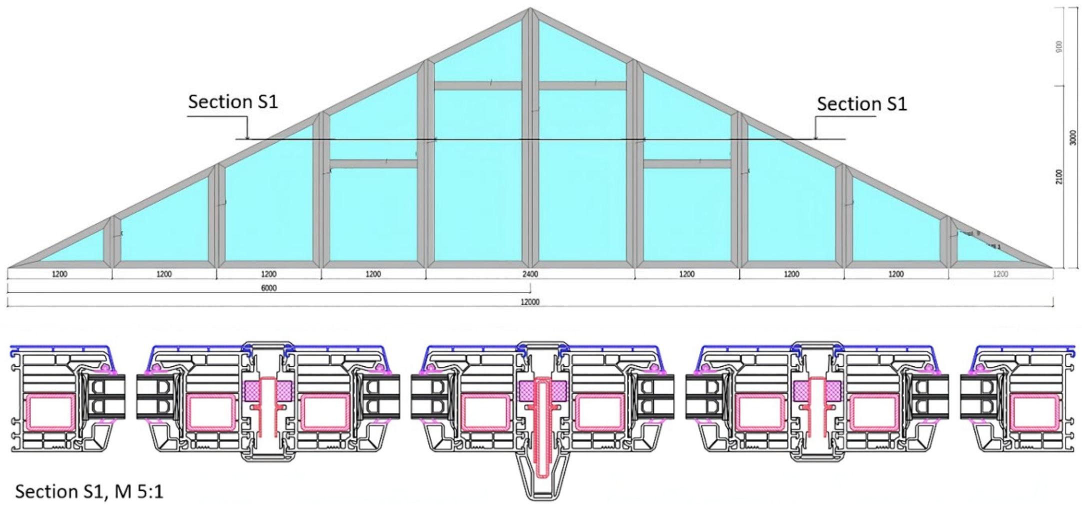

Fig. 2. Design and calculation of stained glass structures with Veka Windoplan software

Option 2: Rehau SYNEGO® MD-80 with 490 mm walls.

The second option is a combined solution that includes:

– three independent Rehau SYNEGO® MD-80 window constructions;
– energy-efficient double-glazed unit 44 mm 4 – 16Ar – 4 – 16Ar – 4;
– profile: REHAU SYNEGO® AD – 72 AD Synego – 1537605;
– imposts: 96 AD SYNEGO® lamellas – 1537405;
– insulated glass unit with 490 mm thickness;
– heat transfer coefficient of windows U_w = 0.83–0.94 W/(m^2 · K);
– heat transfer coefficient of partitions 0.242 W/(m^2 · K).

The design and calculation of glazing energy efficiency values is performed in the proprietary Rehau Window-Planning system [17], as shown in Fig. 3.

Rehau profile structures have a minimum angle restriction of 45°, so a design solution was adopted to divide the stained glass window into three independent windows and fill the spaces between them with a 490 mm partition wall (insulated on both sides). According to preliminary calculations, *U-value* = 0.242 W/(m^2 · K). The general view of the structure and the cross-section of the windows are shown in Fig. 4.

This option reduces heat transfer through the transmission by up to 401.31 kWh per year, which is a 56% saving compared to the existing design. The area of translucent structures is reduced by 24% from the initial value, which meets the requirement for a permissible reduction in glazing of no more than 50% while preserving the architectural appearance of the facade.

Option 3: Brick construction.

The third option involves the complete replacement of stained glass glazing with a 490 mm thick brick structure with the following characteristics:

– multilayer construction with insulation;
– total heat transfer coefficient of 0.242 W/(m^2 · K);
– the reduced heat transfer resistance is 3.91 (m^2 · K/W).

It is decided to abandon stained glass windows altogether and replace them with brick enclosing structures (490 mm). According to preliminary calculations, *U-value* = 0.242 W/(m^2 · K).

Option 3 provides the greatest reduction in heat transfer through the transmission system – up to 201.76 kWh per year, which represents a 78% saving. A comparison of heat transfer through the transmission system via the enclosing structures of the three options is shown in Fig. 5.

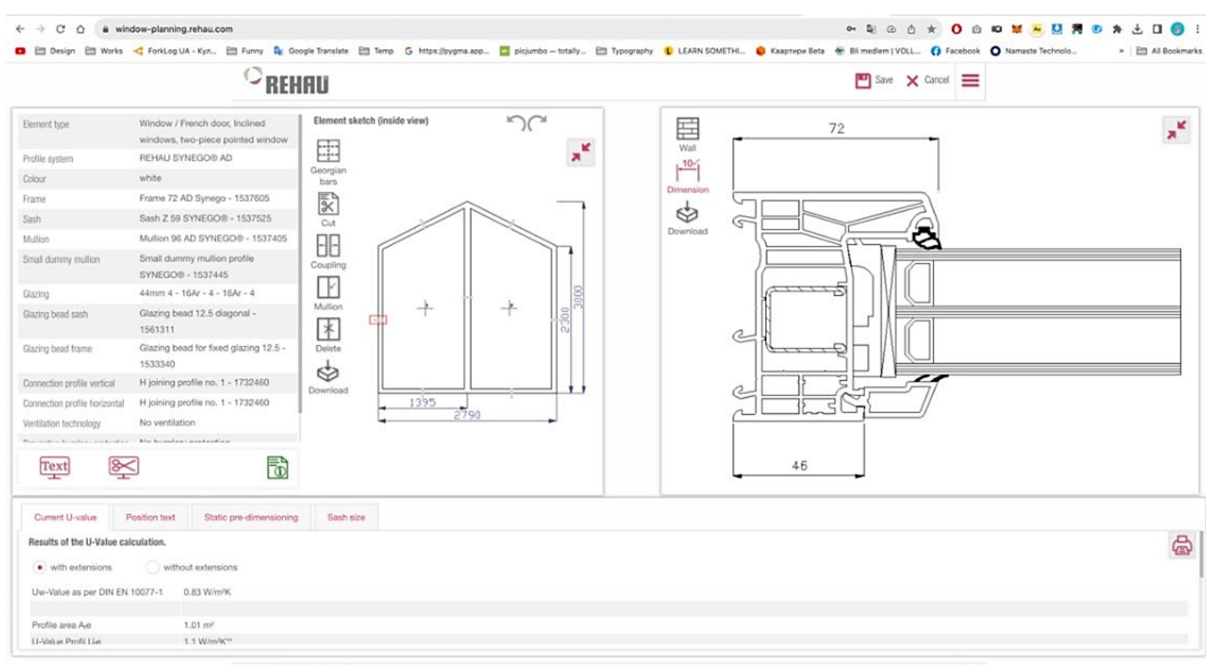

Fig. 3. Designing and calculating windows with Rehau Window-Planning software

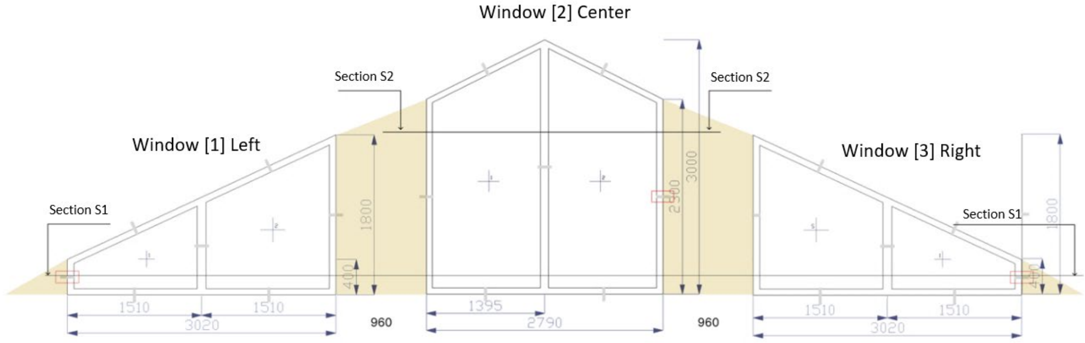

Fig. 4. General view of the structure

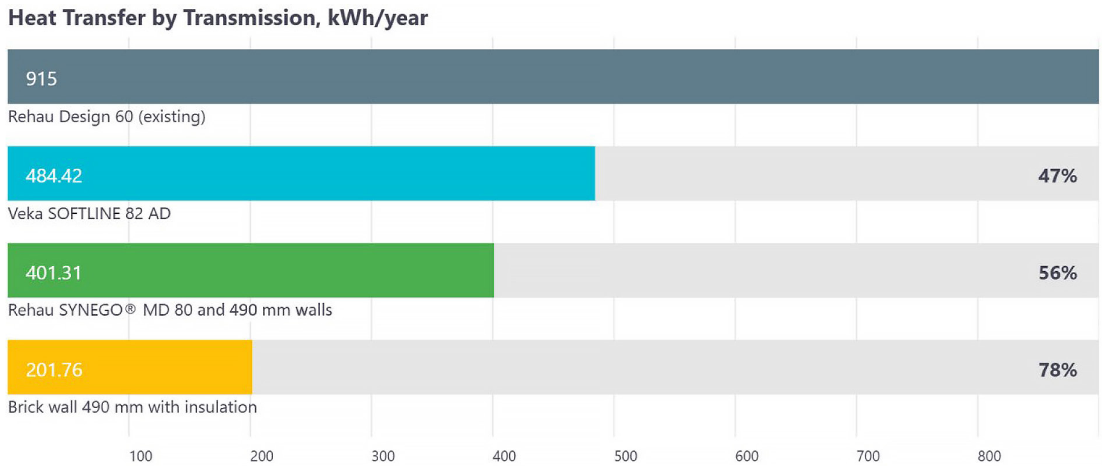

Fig. 5. Comparison of the difference in heat transfer by the transmission through the enclosing structures

Solar heat gains for three options during the heating period and during cooling.

According to the formula for calculating solar gains through translucent structures, they depend only on the solar energy transmittance coefficient (Solar Heat Gain Coefficient).

However, for translucent structures, the additional heat flow resulting from thermal radiation to the sky from the element is zero. Thus, the U_w value of the window does not affect the calculation. The existing glazing also has a solar energy transmittance coefficient of 0.7, the same as the Veka stained glass system.

Let's assume that Rehau Design 60 and VEKA SOFTLINE 82 AD have the same heat gains.

The Rehau SYNEGO® MD 80 + 490 mm partition wall solution must take into account the heat flow resulting from thermal radiation to the ceiling of brick partition walls and other areas of translucent structures.

The results of solar heat gains during the cooling period of the building are shown in Fig. 6 and during the heating period in Fig. 7.

The analysis of enclosing structures is shown in Fig. 8.

The figure shows the analysis of four building envelope structures – Rehau Design 60, VEKA SOFTLINE 82, Rehau SYNEGO + partitions and walls 490 mm with reflection of their annual heat transfer in kWh, percentage of savings and related costs in thousand EUR.

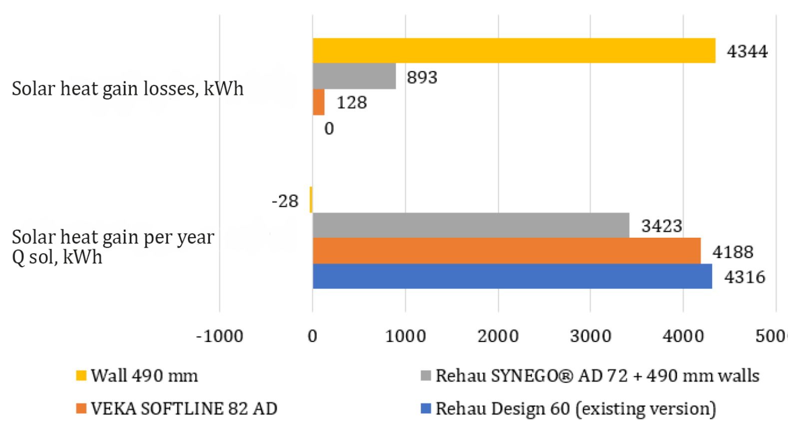

Fig. 6. Comparison of enclosure design options for solar gains during the cooling period

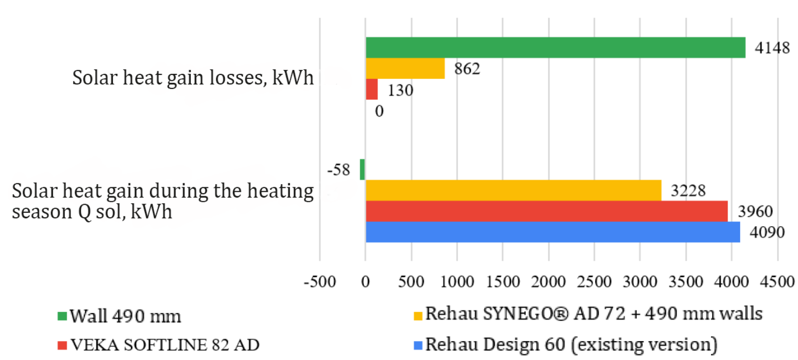

Fig. 7. Comparison of enclosure design options for solar gains during the heating season

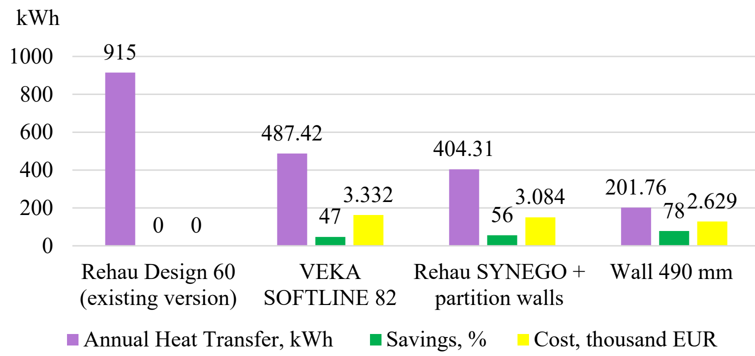

Fig. 8. Analysis of enclosing structures

Fig. 8 shows that the basic Rehau Design 60 version has the highest heat loss (915 kWh/year), while modernized systems, in particular Rehau SYNEGO with partitions, provide up to 56% energy savings at optimal implementation costs.

Validation of research results: Analysis of stained glass windows showed a correlation between a reduction in stained glass area and a reduction in heat loss. Replacing stained glass windows with insulated walls showed the greatest energy savings but demonstrated a complete lack of solar heat.

The use of VEKA SOFTLINE 82 AD window systems without changing the appearance of the facade showed the smallest heat loss savings among the options considered. Based on the results obtained in terms of heat loss savings, this option is not economically viable for implementation.

The Rehau SYNEGO MD-80 system with 490 mm partitions demonstrates the best result in terms of the ratio of implementation cost to heat loss savings.

Replacing stained glass windows with brick walls completely minimizes heat loss, but changes the architectural appearance of the facade and reduces the level of natural lighting. Due to the customer's restrictions on changing the architectural appearance of the facade by no more than 50%, this option does not meet the requirements for implementation in the building.

The research results are of practical importance for designers, energy auditors, and architects and can be used to implement similar solutions in public and office buildings.

The main limitation is that the research was conducted for a specific type of building and climatic region in the city of Dnipro. The research results may differ in other climatic regions. Also, the modeling is based on the calculated parameters of materials and does not take into account possible technological deviations during installation. For the full implementation of the proposed solutions, it is necessary to conduct a detailed check at the project implementation stage and monitor the actual energy consumption indicators after modernization.

Further research should be aimed at improving the methodology for assessing the energy efficiency of facade systems, taking into account factors such as the thermal insulation properties of enclosing structures, the light transmission of glass, the influence of solar radiation, and the microclimate parameters of premises.

A promising direction is the integration of BIM models with energy models, which will allow combining energy analysis with a technical and economic assessment of the proposed modernization options. It is also relevant to develop standard recommendations for administrative buildings in accordance with energy efficiency standards.

4. Conclusions

1. An analysis of the existing stained glass windows was conducted and deficiencies were identified. Based on the research results of structural solutions in terms of their energy efficiency and economic feasibility, it was found that the existing stained glass windows have significant heat loss, especially during the heating season, and do not provide an optimal balance of annual energy consumption. This makes them economically and energetically inefficient and in need of modernization.

2. Options for modernizing the stained glass structure were developed. Three options for replacing the stained glass were developed. In particular, the option with the VEKA SOFTLINE 82 AD system, which proved to be unprofitable without a comprehensive thermal renovation of the entire building: the cost of implementation is 3332 EUR, which is the highest among all the options considered. In addition, this option provides the lowest savings in transmission heat loss, namely 47%. The level of solar gains in the summer remains at the current level.

The option using Rehau SYNEGO® MD-80 with 490 mm mullions and a reduction in the area of translucent structures showed favorable characteristics. Transmission heat loss savings are 56%, and the average implementation cost is 3084 EUR, which is an acceptable indicator among the options considered. The savings on cooling are offset by increased heat loss during the heating season. To make a final decision on the feasibility of this option, it is necessary to conduct additional studies of the microclimate of the premises in the summer and assess the level of comfort for office workers.

The most effective option was to replace the stained glass window with a 490 mm thick brick structure. This solution provides significant savings in energy costs for cooling and reduces transmission losses by 4.5 times during the heating period and has the lowest implementation cost of all options at 2629 EUR.

3. Analysis using BIM models and online tools. The research developed a methodology for evaluating the optimal glazing solution using online tools provided by window companies. A BIM model of the research object was developed, and all subsequent calculations were based on this model. The modeling results confirmed that even a slight reduction in the thermal conductivity of the structure and optimization of the glazing area can significantly affect the annual energy balance of the building. At the same time, the choice should not be based solely on maximum heat loss savings, as an excessive reduction in light-transmitting surfaces can lead to increased artificial lighting costs and reduced visual comfort. Taking these factors into account made it possible to choose an option that not only meets the regulatory requirements of the DBN and ensures a significant reduction in energy consumption, but also preserves the architectural integrity of the building and the comfort of its operation.

4. Determination of the optimal solution based on a comprehensive analysis. The rationale for the final decision is based on a comprehensive comparison of energy, economic, and architectural criteria. Based on the analysis and taking into account the customer's architectural requirements for further thermal renovation of the facility, option 2 was selected – Rehau SYNEGO® MD-80 with 490 mm mullions. This option provides the necessary thermal insulation properties and changes the overall appearance of the glazing by less than 50%, which meets the customer's requirements and is economically feasible.

Acknowledgments

The research results presented in this paper were carried out as part of the UKRENERGY project "Innovative Master Courses Supporting the Improvement of the Energy and Carbon Footprint of the Ukrainian Building Stock" and the EC ERASMUS + KA2 Project ID number: 101082898 ERASMUS-EDU-2022-CBHE/.

The research was conducted with the help of the Energy Innovation DniproHub team within the framework of the UKRENERGY project "Innovative Master Courses Supporting the Improvement of the Energy and Carbon Footprint of the Ukrainian Building Stock" and the EC ERASMUS+ Program. We are grateful for participating in the research: L. Kosenko, O. Koval, Y. Yurchenko, S. Hryshyn, A. Koval, O. Demydov.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The research was performed without financial support.

Data availability

Manuscript has no associated data.

Use of artificial intelligence

The artificial intelligence "ChatGPT" (version GPT-5) was used to find sources for the literature review, and in some cases to edit grammar. The results provided by the AI were verified by careful proofreading and analysis of the information.

The results obtained by the AI did not in any way influence the research results.

Authors' contributions

Leonid Kosenko: Writing – original draft, Writing – review and editing, Investigation; ***Olena Koval***: Validation, Project administration, Supervision; ***Yevhenii Yurchenko***: Conceptualization, Validation, Project administration; ***Artem Koval***: Writing – original draft, Investigation, Writing – review and editing; ***Serhii Hryshyn***: Writing – original draft, Investigation, Writing – review and editing.

References

1. *Action Plan: Energy Efficiency in Buildings. Low Carbon Technology Partnerships Initiative* (2015). World Business Council for Sustainable Development. Available at: https://docs.wbcsd.org/2015/12/LCTPi-EEB-Action-Plan.pdf
2. Davis, A. (2018). *Neither a borrower nor a lender be: Energy efficiency decision- making among class B and C offices in Pittsburgh.* https://doi.org/10.31234/osf.io/z76xg
3. Ur Rehman, H., Heimonen, I., Vainio, T., Ramesh, R., Wallin, A. (2022). *Technical recommendations of the new built Nearly Zero Energy Building (NZEB) in Ukraine.* VTT. Available at: https://www.vttresearch.com/sites/default/files/2022-12/NZEB_Final_Workshop_VTT_Presentation.pdf
4. Primasetra, A., Larasati, D., Wonorahardjo, S. (2022). BIM Utilization in Improving Energy Efficiency Performance on Architectural Design Process: Challenges and Opportunities. *IOP Conference Series: Earth and Environmental Science, 1058 (1),* 012018. https://doi.org/10.1088/1755-1315/1058/1/012018
5. Fürtön, B., Nagy, B. (2022). BIM based hygrothermal modelling of building constructions. *Acta Polytechnica CTU Proceedings, 38,* 340–346. https://doi.org/10.14311/app.2022.38.0340
6. Erebor, E. M., Ibem, E. O., Ezema, I. C., Sholanke, A. B. (2021). Energy Efficiency Design Strategies in Office Buildings: A Literature Review. *IOP Conference Series: Earth and Environmental Science, 665 (1),* 012025. https://doi.org/10.1088/1755-1315/665/1/012025
7. Arends, I., Prinz, C., Abma, F. (2017). Job quality, health and at-work productivity. *OECD Social, Employment and Migration Working Papers, No. 195.* Available at: https://www.oecd.org/content/dam/oecd/en/publications/reports/2017/06/job-quality-health-and-at-work-productivity_e4c3283e/43ff6bdc-en.pdf
8. Kosenko, L., Koval, O., Yurchenko, E., Koval, A. (2023). Analysis of European regulatory requirements for near to zero energy consumption buildings and the possibility of implementation in Ukraine. *Ventilation, Illumination and Heat Gas Supply, 47,* 28–35. https://doi.org/10.32347/2409-2606.2023.47.28-35
9. Bondarenko, A., Yurchenko, E., Olena, K., Savytskyi, M. (2023). Comparative analysis of microclimate parameters of residential low-rise buildings with different heating systems. *Innovative technologies in construction, civil engineering and architecture, 2678.* https://doi.org/10.1063/5.0119318
10. Lyachovetskaya-Tokareva, M., Yurchenko, Y., Koval, O., Tymoshenko, O. (2023). Mathematical modeling of the refrigerating equipment in the air conditioning system during industrial energy audit. *Innovative technologies in construction, civil engineering and architecture, 2678.* https://doi.org/10.1063/5.0118991
11. Demydov, O. (2024). *Metody pidvyshchennia enerhoefektyvnosti ofisnoi budivli.* Kvalifikatsiina vypuskova robota. Available at: http://srd.pgasa.dp.ua:8080/xmlui/handle/123456789/13430
12. Demydov, O., Kosenko, L., Koval, O., Yurchenko, E. (2024). Research and simulation of an office lighting. *Ventilation, Illumination and Heat Gas Supply, 49,* 7–15. https://doi.org/10.32347/2409-2606.2024.49.7-15
13. *DSTU 9191:2022. Teploizoliatsiia budivel. Metody vyboru teploizoliatsiinoho materialu dlia uteplennia budivel* (2023). Tekhnichnyi komitet standartyzatsii TK 302 "Enerhoefektyvnist budivel i sporud". Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=98996
14. *DBN V.2.6-31:2021. Teplova izoliatsiia ta enerhoefektyvnist budivel* (2022). DP "Derzhavnyi naukovo-doslidnyi instytut budivelnykh konstruktsii". Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=98037
15. *DSTU 9190:2022. Enerhetychna efektyvnist budivel. Metod rozrakhunku enerhospozhyvannia pid chas opalennia, okholodzhennia, ventyliatsii, osvitlennia ta hariachoho vodopostachannia* (2023). Tekhnichnyi komitet standartyzatsii TK 302 "Enerhoefektyvnist budivel i sporud". Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=98995
16. *VEKA's online service for designing and calculating the energy efficiency of glazing.* Available at: https://windoplan.veka.com/
17. Energy Efficiency. *REHAU Window Solutions.* https://window.rehau.com/uk-en/why-choose-pvcu/energy-efficiency

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