Legal and Regulatory Framework for Thermal Modernization in Construction

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Energy conservation and efficiency play a vital role in modern society. In particular, the need for thermal modernization of buildings has become ever more pressing. Energy-saving policy in construction is a top priority during overhauls and new construction. Accordingly, the choice of materials, products, and structures must address energy-efficiency goals and reduce overall energy consumption. When the right materials are selected, interior comfort improves: materials with excellent thermal insulation characteristics retain heat in winter and help keep spaces cool in summer, cutting reliance on heaters, fans or air-conditioning — and with it, energy use. This article aims to present the key rules and requirements for building energy efficiency during thermal modernization works and to analyze these projects by highlighting specific challenges encountered in practice. To fulfil this goal, we employ general (theoretical analysis and synthesis) and special methods (review of design documentation, analysis of the building materials used, thermographic inspection). We examine relevant building rules and standards governing such work and outline mandatory quality requirements. The study notes the need to strengthen regulations on upgrading thermal insulation of external envelopes and on replacing window, exterior-door, and balcony assemblies. We also address the following topics: energy conservation, energy-saving policy, building energy performance certificates, and the efficient use of fuel and power resources.

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Keywords: *energy audit; energy conservation; building envelope; heating; fuel and energy resources; heat loss; thermal insulation; insulation.*

Research Problem Formulation

Today, the challenge of securing energy resources is acute in Ukraine and worldwide.

The United Nations Framework Convention on Climate Change (hereinafter referred to as the *UNFCCC*) was adopted on May 9, 1992; Ukraine signed it on June 11, 1992, and ratified it on October 29, 1996 [1].

The UNFCCC is an international environmental treaty aimed at addressing the issue of greenhouse emissions (gases). Currently, it is vital to stabilize and then maintain greenhouse gas emissions at levels that do not harm the environment or exacerbate climate change. Under the Convention, participating countries commit to improving their energy-use efficiency.

Overall, Ukraine's energy-saving policy focuses on the rational and economical use of energy resources. Furthermore, it is important to recognize that the housing stock of our country predominately relies on heating units from outdated systems. Particularly the buildings commissioned before 1993 were erected under obsolete construction standards. Thus, to conserve fuel and power, we must implement energy-efficient measures aimed at promoting the introduction and production of energy-efficient products, technologies, and equipment.

One of the main requirements for any building's technical and technological design is energy efficiency and conservation. Contemporary realities demand that heating, ventilation, cooling, and lighting systems meet technical criteria ensuring low energy consumption during operation.

Research Purpose

The research paper's purpose is to study issues of energy conservation, energy-saving policy, and the efficient use of fuel and energy resources—specifically by analyzing the energy efficiency of building thermal modernization—and to draw attention to the necessity of improving the regulatory framework for the technical retrofitting of thermal insulation in external building envelopes, as well as the replacement of window, external door, and balcony units.

Research Methods

General methods employed include theoretical analysis and synthesis, while special methods comprise analysis of project documentation, assessment of applied building materials, and thermographic inspection.

Inspecting the project documentation facilitates an accurate evaluation of the compliance of the building's thermal envelope with energy-efficiency requirements.

The building materials assurance is conducted via laboratory testing, which allows for the calculation of the materials' thermal conductivity coefficients.

1 Рамкова конвенція Організації Об'єднаних Націй про зміну клімату : ратифік. Закон. України від 29.10.1996 р. № 435/96-ВР. URL: https://zakon.rada.gov.ua/laws/show/995_044#Text (date accessed: 11.05.2025).

Analysis of Essential Researches and Publications

This article presents a system of indicators and criteria which, in the author's view, will help bring the energy efficiency of Ukrainian buildings into alignment with current rules and standards. The legal basis for this study is provided by the Law of Ukraine: *On Energy Efficiency of Buildings* [2] and the corresponding modern construction rules addressing this issue. Improving existing Ukrainian building regulations, bringing them into conformity with international standards, as well as enacting a series of laws aimed at introducing advanced technologies and modernizing construction processes, will undoubtedly foster the emergence of buildings with low energy-consumption metrics, thereby significantly reducing their maintenance costs.

The issue of conserving and rationally using thermal energy is increasingly tackled by the scientific community. Technical retrofitting and thermal modernization of buildings have been examined in studies by O. Halinskyi, P. Hryhorovskyi, V. Ploskyi, C. Ushatskyi, V. Halushko, A. Necheporchuk, V. Torkatiuk, R. Tormosov, R. Tian, H. Fareniuk, A. Shpakov, V. Shalennyi, et al. Several researchers (V. Halushko, H. Sokha, V. Saviovskyi, H. Ratushniak, O. Ratushniak, S. Ponizov, I. Babii, O. Borysov, L. Kucherenko, N. Olinyk) have researched the range of building materials and the selection of technological solutions for carrying out thermal modernization works.

H. Fareniuk, O. Filonenko, and M. Tymofieiev [3] have focused specifically on building modernization with respect to reducing energy consumption and curbing greenhouse gas emissions. They also put forward a contemporary approach to selecting the optimal modernization strategies.

R. K. Jain [4] examined economic, environmental, and efficient construction practices, highlighting the advantages of such construction in reducing greenhouse gas emissions.

Researchers J. Torkar, D. Goricanec, and J. Krope [5] addressed the reliability and uninterrupted operation of centralized heat-supply systems, emphasizing the importance of monitoring and control measures.

V. Semko [6] investigated the thermal failure challenges of the building envelope

2 Про енергетичну ефективність будівель : Закон України від 22.06.2017 р. № 2118-VIII (зі змін. та допов.). URL: https://zakon.rada.gov.ua/laws/show/2118-19#Text (date accessed: 11.05.2025).

3 Фаренюк Г. Г., Філоненко О. І., Тимофеєв М. В. Енергоефективність громадських будинків з врахуванням ергономіки теплового середовища. *Комунальне господарство міст. Серія: Технічні науки та архітектура.* 2017. Вип. 135. С. 119—124. URL: http://nbuv.gov.ua/UJRN/kgm_tech_2017_135_22 (date accessed: 11.05.2025).

4 Jain R. K. A Study on Eco-Friendly Cost-Effective Earthbag House Construction. *Kathmandu University Journal of Science, Engineering and Technology*. 2013. Vol. 9. No. 1. Pp. 200—211. DOI: 10.3126/kuset.v9i1.63925 (date accessed: 11.05.2025).

5 Torkar J., Goricanec D., Krope J. Economical heat production and distribution. Proceedings of the 3rd IASME/WSEAS Int. Conference on Heat Transfer, Thermal Engineering and Environment (Corfu, Aug 20—22, 2005). 2005. Pp. 18—23. URL: https://www.academia.edu/19945433/Economical_heat_production_and_distribution (date accessed: 11.05.2025).

6 Семко В. О. Методика визначення ймовірності теплової відмови огороджувальних конструкцій із сталевих холодноформованих елементів за теплотехнічними показниками. *Строительство. Материаловедение. Машиностроение. Серия: Инновационные*

as one of the principal causes of economic losses due to increased energy consumption.

B. Basok et al. [7] addressed the integration of architectural features with technical and technological parameters to maintain appropriate sanitary and hygienic conditions within building interiors.

A. Maksymov's research paper [8] presented a novel and rational approach to organizing the design process for thermal modernization measures for buildings, and provided examples of optimizing structural solutions during the implementation of such thermal modernization.

A. Perekrest examined the automation of monitoring heat-exchange parameters in buildings [9].

V. Babak et al. [10] explored contemporary tools and methods for supervising thermal-energy equipment.

I. Babii, O. Borysov, L. Kucherenko, and N. Oliinyk noted that, given the current condition of the residential building stock, 90% of all multi-story buildings require thermal modernization [11].

V. Saviovskyi also devoted his work to the promising field of building thermal modernization [12]. His research identified the causes by which structural elements of buildings lose their thermal-protective properties; the researcher highlighted the principal technological characteristics that must be considered during the design and execution of preparatory works; the author described the primary technical and technological solutions for carrying out these works and detailed the quality assurance for construction operations. Furthermore, he provided a step-by-step breakdown of the procedures for installing window and external door units and presented advanced technologies for installing the building's thermal envelope (methods for insulating external walls, roofs, floor slabs over unheated spaces, and the building's plinth).

технологии жизненного цикла объектов жилищно-гражданского, промышленного и транспортного назначения. 2016. Вып. 91. С. 140—147. URL: http://nbuv.gov.ua/UJRN/smmit_2016_91_21 (date accessed: 11.05.2025).

7 Басок Б. І., Недбайло О. М., Ткаченко М. В., Божко І. К., Новіцька М. П. Схемні рішення оснащення енергоефективного будинку системою теплозабезпечення. *Промышленная теплотехника*. 2013. Т. 35. № 1. С. 42—48. URL: https://dspace.nuft.edu.ua/server/api/core/bitstreams/231a7815-e412-4ae5-b6b8-296b31ca0ac9/content (date accessed: 11.05.2025).

8 Максимов А. С. Організаційні підходи до термомодернізації будівель на підставі оптимізації вибору конструктивно-технологічних рішень : дис. … канд. техн. наук. Одеса, 2021. 218 с. URL: https://uacademic.info/ua/document/0421U102386 (date accessed: 11.05.2025).

9 Перекрест А. Л. Методи та засоби створення високоефективних комп'ютеризованих систем автоматичного контролю параметрів теплового комфорту в будівлях : дис. … д-ра техн. наук. Покровськ, 2020. 493 с. URL: https://uacademic.info/ua/document/0520U101750 (date accessed: 11.05.2025).

10 Бабак В. П., Берегун В. С., Бурова З. А., Воробйов Л. Й., Декуша Л. В. та ін. Апаратно-програмне забезпечення моніторингу об'єктів генерування, транспортування та споживання теплової енергії : монографія. Київ, 2016. 298 с.

11 Бабій І. М., Борисов О. О., Кучеренко Л. В., Олійник Н. В. Визначення факторів, що впливають на терміни утеплення фасадів багатоповерхових будівель. *Сучасні технології, матеріали і конструкції в будівництві*. 2021. Т. 31. № 2. С. 32—36. DOI: 10.31649/2311-1429-2021-2-32-36 (date accessed: 11.05.2025).

12 Савйовський В. В. Термомодернізація будівель : навч. посіб. Київ, 2021. 278 с. URL: https://lira-k.com.ua/preview/12893.pdf (date accessed: 11.05.2025).

R. Carabano et al. analyzed building materials intended for thermal-insulation works (with respect to their life-cycle durability) [13].

L. Brojan, A. Petric, and P. L. Clouston conducted a comparative analysis of building materials from ecological and economic perspectives [14].

I. Babii and L. Kucherenko assessed existing thermal-insulation construction and installation technologies in terms of their techno-economic efficiency [15].

V. Serdiuk addressed the issue of aging residential buildings constructed during the large-scale construction of the 1980s and 1990s, which have exceptionally high energy consumption rates. He proposed addressing this issue by applying ventilated rainscreen facades and extending their functionality [16].

D. Stepanov et al. [17] emphasized the urgency of reducing greenhouse gas emissions and, within this framework, substantiated the establishment of regulatory parameters required to ensure the thermal resistance of building envelopes.

Main Content Presentation

The Law of Ukraine: *On Energy Efficiency of Buildings* [18], which is aimed at stimulating reductions in buildings' energy consumption, establishes the legal, social, economic, and organizational grounds for activities in the field of maintaining buildings' energy efficiency.

Pt. 1, Article 1 of this Law specifically defines the following terms: "nearly zero-energy building" (cl. 2), and "a building's energy efficiency" (cl. 5):

"2) Nearly zero-energy building – a building with an energy efficiency level exceeding the established minimum requirements, where energy primarily from renewable sources is used to form proper living conditions and/or human activities;

<...>

5) Energy efficiency of a building is the property of a building characterized by the

13 Carabano R., Hernando S. M., Ruiz D., Bedoya C. Life Cycle Assessment (LCA) of building materials for the evaluation of building sustainability: the case of thermal insulation materials. *Revista de la Construcción*. 2017. Vol. 16. No. 1. Pp. 22—33. DOI: 10.7764/RDLC.16.1.22 (date accessed: 11.05.2025).

14 Brojan L., Petric A., Clouston P. L. A Comparative Study of Brick and Straw Bale Wall Systems from Environmental, Economical and Energy Perspectives. *ARPN Journal of Engineering and Applied Sciences*. 2013. Vol. 8. No. 11. Pp. 920—926. URL: https://www.academia.edu/5439665/A_COMPARATIVE_STUDY_OF_BRICK_AND_STRAW_BALE_WALL_SYSTEMS_FROM_ENVIRONMENTAL_ECONOMICAL_AND_ENERGY_PERSPECTIVES (date accessed: 11.05.2025).

15 Бабій І. М., Кучеренко Л. В. Моделювання організаційно-технологічних факторів для визначення ефективних рішень проєкту утеплення фасадів з облицюванням штукатурками. *Сучасні технології, матеріали і конструкції в будівництві*. 2023. Т. 34. № 1. С. 84—90. DOI: 10.31649/2311-1429-2023-1-84-90 (date accessed: 11.05.2025).

16 Сердюк В. Р. Розширення функціональних властивостей навісних вентильованих фасадів при утепленні будівель. *Там само*. С. 91—99. DOI: 10.31649/2311-1429-2023-1-91-100 (date accessed: 11.05.2025).

17 Степанов Д. В., Степанова Н. Д., Оникієнко С. М., Мартиненко В. В. Показники енергоефективності громадської будівлі. *Там само*. С. 134—139. DOI: 10.31649/2311-1429-2023-1-134-139 (date accessed: 11.05.2025).

18 Про енергетичну ефективність будівель ... . URL: https://zakon.rada.gov.ua/laws/show/2118-19#Text (date accessed: 11.05.2025).

amount of energy required to create proper living conditions and/or human activities in that building" [19].

In recent years, the number of scientific and technical studies related to thermal modernization (insulation) of buildings has increased significantly. Most of these studies focus on assessing the scope and operational charges listed under the category of "energy-saving measures for building reconstruction". In addition, they provide detailed technical, spatial, and structural characteristics of the buildings undergoing facade thermal modernization. These include the building's shape, overall external dimensions, number of floors (specifying the height of each floor individually if they differ), presence of annexes or porches, total building volume, and the number of exterior doors.

Let's take the following example:

"The facility designated for thermal modernization is a building with a T-shaped floor plan, measuring 67.0 × 12.5 m in its principal dimensions. It comprises two main storeys, each with a height of 7.0 m, along with a projecting section measuring 40.5 × 12.5 m (single storey, 6.0 m high), and attached entrance porches with areas of 27.0 m^2, 4.5 m^2, 3.3 m^2, and 4.5 m^2. The total construction volume amounts to 10 465 m^3. The building includes six separately positioned and spatially distributed exits.

Structurally, the building follows a frameless design, characterized by parallel load-bearing walls constructed from silicate brick, placed atop strip reinforced concrete foundations. The floors and roof are formed by precast hollow-core reinforced concrete slabs.

The foundation system consists of prefabricated reinforced concrete blocks. The plinth is made from red clay brick, with a variable height ranging from 550 mm to 1200 mm.

The attic space is non-operational.

The external walls are constructed from 510 mm-thick silicate brick.

The internal walls are constructed from 380 mm-thick silicate brick.

The partitions are constructed from silicate brick, with thicknesses ranging from 120 mm to 150 mm.

The windows are uPVC-framed.

The external doors are metal.

The roof assembly is of the hipped type, supported by wooden rafters and battens, and covered with profiled metal sheeting".

The working project typically includes the execution of the following construction and installation works: replacement of window units and sills; facade thermal insulation; hydro- and thermal insulation of the plinth; insulation of the floor slab; and the modernization or replacement of heating system engineering networks.

Research is usually provided with design and cost estimate documentation related to the implementation of energy-efficiency measures in the building, comprising the following components:

"WORKING PROJECT (WP):

- *General Explanatory Note, Volume 1, Code XXXP-EN;*
- *Architectural and Structural Solution, Volume 1, Code XXXP-AS;*
- *Cost Estimate Documentation, Volume 2, Code XXXP-XXXX-CED".*

The implementation of energy efficiency measures in buildings not only contributes to the conservation of fuel and energy resources but also delivers significant social and environmental benefits. The latter is especially important today in light of efforts to raise living standards and improve housing conditions. Reducing energy consumption can only be achieved through a comprehensive approach to

19 Про енергетичну ефективність будівель ... . URL: https://zakon.rada.gov.ua/laws/show/2118-19#Text (date accessed: 11.05.2025)..

energy efficiency: one that incorporates enhanced architectural and structural design solutions as well as the replacement of building engineering systems taking into account climatic, technical, economic, social, and environmental factors.

One of the most important steps in conserving energy is additional insulation of external building walls. When additional insulation is added, a once-homogeneous wall becomes a multi-layered structure. This transformation increases the complexity of both the design and construction phases, as the use of multiple materials raises the risk of design and installation errors. These errors can diminish the thermal resistance and overall performance of the insulated structures.

Today, enhanced insulation of the building is executed using a wide range of construction and technological solutions, materials, and products. Unfortunately, these solutions are sometimes selected without adequate consideration of building thermophysics. Moreover, insufficient attention is often paid to the reliability of the chosen materials and the technological and structural soundness.

The primary goals and objectives of the technical standards for thermal modernization projects include the following:

- clarifying the requirements for design documentation developed for comprehensive thermal modernization and approving its scope;
- defining the necessary energy-saving measures;
- establishing the work procedure;
- explaining and general principles and methodological approaches to the development of technical documentation;
- outlining the main rules and operational requirements for buildings following the completion of work;
- setting qualification standards for construction companies involved in insulating structural elements of a building or reconstructing / upgrading energy supply networks;
- bringing the standard in line with applicable national and international building standards, as well as modernizing energy supply networks.

Among the scholars who have addressed energy efficiency in buildings are H. Ratushniak, Yu. Biks, and A. Lialiuk [20]. Their research highlights measures to be implemented for energy conservation and rational use of energy resources and the importance of monitoring the integrity of a building's thermal insulation over time.

The national standard ДСТУ-Н Б В.3.2-3:2014: *Guidelines for the Thermal Modernization of Residential Buildings* [21] was introduced to strengthen Ukraine's regulatory framework in the construction sector.

According to cl. 3.1 of the Standard, *"thermal modernization is a set of construction works aimed at improving the thermal performance of building envelope components, optimizing the energy consumption of engineering systems, and ensuring the buil-*

20 Ратушняк Г. С., Бікс Ю. С., Лялюк А. О. Моніторинг та експертно-аналітична оцінка надійності теплоізоляційної оболонки будівель. *Сучасні технології, матеріали і конструкції в будівництві*. 2023. Т. 20. № 1. С. 140—145. DOI: 10.31649/2311-1429-2023-1-140-145 (date accessed: 11.05.2025).

21 ДСТУ-Н Б В.3.2-3:2014 Настанова з виконання термомодернізації житлових будинків [Чинний від 15.10.2015]. Київ, 2014. 71 с. URL: https://enefcities.org.ua/upload/files/new_dstu-n-b-v_3_2-3-2014.pdf (date accessed: 11.05.2025).

ding's overall energy efficiency meets or exceeds minimum regulatory requirements" [22].

The above-mentioned State Standard primarily addresses work on conducting energy audits and certifying buildings, as well as thermal modernization measures aimed at improving the building's thermal performance. Key activities include the retrofitting and upgrading of utility networks, as well as the thermal insulation of building envelopes. Collectively, these measures contribute to reduced energy consumption and ensure comfort and coziness in premises.

Summarizing the foregoing, we can state that the adoption of ДСТУ-Н Б В.3.2-3:2014 is intended to:

- lower operating energy demands for building maintenance;
- promote efficient and sustainable use of energy resources;
- extend the service life of buildings.

Additionally, the current Ukrainian ДСТУ ISO/IEC 17000:2007: *Conformity assessment — Vocabulary and general principles* (an official translation of ISO/IEC 17000:2004, *Conformity assessment — Vocabulary and general principles*) outlines requirements that comply with the current legislation of Ukraine and defines general terms and definitions of concepts governing conformity assessment procedures. It covers the accreditation of conformity assessment bodies and the application of conformity assessment. Specifically, the standard states:

"2.1 Conformity assessment

Demonstration that specified requirements (3.1) related to products (3.3), process, system, person, or body have been fulfilled" [23].

Furthermore, ДБН В.2.6-31:2021: *Thermal Insulation and Energy Efficiency of Buildings* [24] sets technical parameters for energy efficiency in buildings, with a particular focus on regulating thermal conductivity of insulation materials used during the installation of building envelope components.

According to these building regulations, the building thermal envelope is defined as a system *"consisting of the enclosing structures of the heated (or conditioned) volume of the building that ensures the conservation of energy used for heating and/or cooling interior spaces"* [25].

Ukraine's national energy-saving policy is oriented toward the development of legal regulations and documents that support the implementation of high-efficiency technologies to meet defined targets for energy efficiency and conservation. This is due to the fact that excessive thermal energy consumption contributes directly to rising heating and water supply costs, which in turn negatively impacts household well-being by increasing utility expenses. Therefore, state-sponsored energy efficiency programs aim to improve the economic, environmental, and social conditions concurrently.

It is worth considering that the majority of Ukraine's residential building stock consists of Soviet-era constructions. Under

22 ДСТУ-Н Б В.3.2-3:2014 … . URL: https://enefcities.org.ua/upload/files/new_dstu-n-b-v_3_2-3-2014.pdf (date accessed: 11.05.2025).

23 ДСТУ ISO/IEC 17000:2007 Оцінювання відповідності. Словник термінів і загальні принципи (ISO/IEC 17000:2004, IDT). [Чинний від 19.02.2025]. Київ, 2008. 20 с. URL: https://quality.nuph.edu.ua/wp-content/uploads/2018/04/dstu_iso_iec_17000_2007.pdf (date accessed: 11.05.2025).

24 ДБН В.2.6-31:2021 Теплова ізоляція та енергоефективність будівель [Чинний від 01.09.2022]. Київ, 2022. 23 с. URL: https://e-construction.gov.ua/laws_detail/3075196638495507996?doc_type=2 (date accessed: 11.05.2025).

25 Там само.

the economic model of that time, energy was considered cheap, and conservation was not a priority. Today, however, the country faces new realities. Modern construction—whether in the construction of new buildings or during overhauls—must incorporate contemporary energy-economic considerations and adopt measures that significantly reduce energy consumption.

In general, thermal modernization of buildings should be carried out through comprehensive insulation measures, which necessarily include the replacement of windows and doors, as well as the modernization or full replacement of the heating system. During these works, particular emphasis must be placed on upgrading the heating system, as practical experience demonstrates that the effectiveness of thermal modernization largely depends on its performance. Understandably, such modernization efforts entail substantial financial investment.

Upon closer examination, it becomes evident that one of the primary causes of excessive heat loss is the inadequacy of the external building envelopes. As previously noted, a significant portion of Ukraine's building stock exhibits poor thermal insulation performance. Thermal engineering calculations used during the old housing stock period differ markedly from contemporary standards: mainly because they did not prioritize energy efficiency. That's why the then thermal protection requirements were several times lower than the current norms. This explains why structural components of older buildings experience substantially higher heat losses compared to modern counterparts.

Compounding this issue are outdated windows—often poorly sealed, with subpar thermal properties, and sometimes unnecessarily large in surface area—contributing significantly to heat loss. Another critical factor is the low energy efficiency of heating systems installed during that time, which are now both technically and morally obsolete. Unauthorized modifications, such as the replacement of radiators and piping, or the improvised installation of heating layouts, further degrade system efficiency. Additional shortcomings include clogged pipelines and the complete absence of their thermal insulation: both in basements and outside.

Obviously, this is not an exhaustive list of deficiencies associated with the old heating systems. It is therefore entirely reasonable to conclude that energy efficiency cannot be achieved through the insulation of buildings' facades and their structures alone if the heating infrastructure remains outdated. Meaningful reductions in fuel and energy consumption can only be realized through comprehensive thermal modernization of the building.

Thermal modernization measures typically include the following construction interventions:

- insulation of the roof (roof assembly) structure;
- insulation of ground-level floors;
- insulation of the floor slab above unheated basements;
- thermal insulation of building facades (external walls);
- replacement of window and external door units;
- replacement or modernization of the building's heating system;
- modernization of the heating distribution substation.

Building insulation is typically performed on the exterior face of the load-bearing component of the building envelope. This is achieved by adding one or more layers of material with adequate thermal resistance. The goal of this work

is to reduce heat loss and raise the internal wall surface temperature, thereby improving the structure's thermal performance and mitigating the risk of surface condensation and mold growth.

The degree of thermal insulation of walls is determined by the thermal resistance coefficient *R*: the higher the *R*, the lower the heat loss. Modern State Building Regulations (ДБН В.2.6-31:2021) establish minimum permissible thermal resistance values ($R_{q\ min}$) in 4,00 m² × K/W (Climate Zone I) and 3,50 m² × K/W (Climate Zone II). Older buildings, however, typically do not meet these standards. The only effective way to reduce heat loss in such structures is through insulation. Proper insulation ensures continuous thermal protection across the entire wall surface and effectively prevents energy loss.

The correct selection of thermal insulation material is crucial for a long service life and efficient operation of a building. National Standard ДСТУ 9191:2022: *Building insulation. Method for selecting insulation material for thermal retrofitting* stipulates *"methods of choosing insulation materials in residential, public, and industrial buildings during design, new construction, reconstruction, or overhaul, including thermal modernization"*[26]. This standard is aimed at implementing the provisions of ДБН В.2.6-31.

According to the Law of Ukraine *On Construction Regulations*[27], compliance with state building regulations is mandatory, particularly when selecting materials for building insulation. ДСТУ 9191:2022 regulations apply to opaque building envelope components, prescribing the methodology for determining their thermal performance, providing the calculated thermal performance values of building materials, and serving as the foundation for the development of design documentation on energy conservation and energy efficiency in general. Therefore, the selection of thermal insulation material must be carried out in accordance with this Standard, taking into account its thickness, density, and other physical and technical indicators, as well as methods of fastening.

In line with regulatory requirements, insulation materials must be selected for the following types of opaque building components:

- embedded and plinth-level structures;
- ground-contact floors;
- external walls;
- floor slabs (including ground-level, intermediate, and attic slabs);
- roof assemblies;
- partitioning structures separating rooms with a temperature difference exceeding 4° C.

Currently, the most widespread thermal insulation method in Ukraine involves the insulation of external walls. This method consists of adhering and mechanically fastening insulation boards—typically expanded polystyrene or mineral wool—to the building's external surfaces. A protective and decorative plaster layer, reinforced with fiberglass mesh, is then applied. When performed using quality materials and proper construction techniques, this approach is considered among the simplest, most effective, and durable thermal retrofitting solutions.

26 ДСТУ 9191:2022 Теплоізоляція будівель. Метод вибору теплоізоляційного матеріалу для утеплення будівель [Чинний від 01.03.2023]. Київ, 2023. 60 с. URL: https://surl.li/hvcguf (date accessed: 11.05.2025).

27 Про будівельні норми : Закон України від 05.11.2009 р. № 1704-VI (зі змін. та допов.). URL: https://zakon.rada.gov.ua/laws/show/1704-17#Text (date accessed: 11.05.2025).

When selecting a thermal insulation material, it is essential to consider the following physical and technical properties:

- maximum service temperature;
- moisture content;
- water absorption capacity;
- frost resistance;
- vapor permeability;
- fire resistance classification;
- compressive strength;
- shear strength limit;
- tensile strength perpendicular to the surface;
- density;
- geometric accuracy.

These physical and mechanical indicators must comply with the requirements of ДСТУ Б В.2.7-195 [28].

In addition, to ensure that the chosen insulation meets regulatory thermal (and energy-economic) performance criteria, the following indicators should be taken into account: calculated thermal conductivity coefficient and expected effective service life.

Insulation of roofs and floor slabs typically involves installing an additional thermal barrier layer. Floor slabs over an unheated basement are insulated from the basement side using adhesive-mounted insulation panels. Special attention should be paid to the layer of thermal insulation material during these works, since its characteristics are decisive for the efficiency of the work performed. That is why it is essential to use high-quality materials of appropriate thickness. Roof insulation generally follows a standard technique involving several layers of thermal insulation materials arranged in a way that is commonly referred to as a "thermal sandwich". This technique is necessary for ensuring proper heat retention. Undoubtedly, the effectiveness of any thermal insulation depends on the workmanship involved.

Ground-bearing floors represent a cost-effective flooring solution. They typically consist of a concrete slab not connected to the building's foundation or walls. This method can be implemented in two ways: by installing prefabricated concrete slabs or by in-situ casting.

In heated spaces, insulating ground-bearing floors is essential to minimize thermal losses. However, if the room is unheated, such insulation is unnecessary. In those cases, it is more appropriate to insulate the intermediate floor slab that separates the unheated basement from the heated first floor. To insulate ground-contact floors effectively, it is essential to use a moisture-resistant thermal insulation material capable of withstanding significant loads. Extruded polystyrene foam, for example, meets these requirements.

The replacement of windows and balcony doors plays a crucial role in reducing heat loss, as these components typically account for a substantial share of thermal energy leakage in buildings. Today, there are many different types of energy-efficient structures that provide superior thermal and acoustic insulation and are easy to install and maintain.

Another major factor influencing thermal energy efficiency is the condition of the building's heating system. To ensure optimal performance, a complete modernization of the heating system is required. This includes upgrading all key components of the system, such as heat exchangers, circulation pumps, and control units, especially those located within

28 ДСТУ Б В.2.7-195 Будівельні матеріали. Матеріали і вироби теплоізоляційні. Номенклатура показників [Чинний від 01.08.2010]. URL: https://dnaop.com/html/60909/doc-%D0%94%D0%A1%D0%A2%D0%A3_%D0%91_%D0%92.2.7-195_2009 (date accessed: 11.05.2025).

the building's heat substation or boiler room.

Additionally, improving the ventilation system is a critical prerequisite for achieving sustainable thermal modernization outcomes.

Thermal modernization measures should follow the following sequence. First of all, for high-quality and efficient building insulation, it is crucial to conduct an energy audit: an assessment aimed at evaluating current energy consumption levels and, if necessary, identifying areas for improvement. This step helps pinpoint the primary sources of heat loss and informs the appropriate selection of insulation materials. The next step involves selecting and installing energy-efficient equipment. Following this, careful attention must be paid to selecting and applying insulation materials for the building's external envelope. Proper insulation requires a multi-layered assembly—or "thermal insulation sandwich"—that provides comprehensive protection for enclosing structures. Finally, existing window units and balcony doors should be replaced with modern, heat-retaining structures.

When executed correctly, thermal modernization significantly reduces heat loss and energy demand. The table below presents the comparative efficiency of various modernization measures when implemented to a high standard.

Thermal modernization efficiency measures

No.	Thermal modernization measures	Heat Loss Reduce in %
1	Thermal insulation of exterior walls, roof coverings, and floor slabs above unheated spaces	20—45
2	Thermal insulation of roof assemblies and floor slabs above unheated spaces	10—25
3	Thermal insulation of floor slabs above unheated spaces (basements)	3—6
4	Replacement of window units and external entrance doors	25—47
5	Modernization of the ventilation system	30—40
6	Modernization of the engineering networks within the building's heat substation	10—30
7	Modernization of the internal heating system	10—25

When drafting a thermal modernization contract for a building, the findings of a preliminary energy audit should be used to determine the full scope of work and required materials. Building thermal insulation should be conducted on the basis of the design. In our view, planning a project is essential even in cases where building codes do not explicitly require it, since a well-developed project defines and describes the insulation materials to be used (specifying their type, properties, and compliance with Ukrainian construction and sanitary standards). It also outlines how these materials should be installed. This includes surface preparation, fastening methods, installation of the thermal insulation layer on the floor slab, application of the anchoring layer, and how insulation will interface with structural elements.

Project and cost-estimate documentation on thermal modernization measures must comply with construction regulations.

If project documentation is prepared prior to thermal modernization, a post-construction inspection of the building should be carried out to verify whether the completed work meets energy efficiency requirements. If needed, a state-mandated energy efficiency examination may be conducted to confirm that the building's performance meets the requirements outlined in corresponding legal regulations for energy use. This process concludes with the issuance of an Energy Performance Certificate (EPC) and a summary the findings.

Conclusions

The purpose of thermal modernization and heating system upgrades is to achieve optimal efficiency during the use of fuel and energy resources and reduce corresponding costs.

State regulations set clear standards for the thermal resistance of envelope components. Design solutions for the creation and modernization of the thermal building envelope must therefore consider not only the requirements for the rational use of energy resources but also meet the requirements of sanitary and hygienic standards and ensure the durability of components during building operation.

The modern construction market offers a wide array of thermal insulation materials, not all of which meet current regulatory requirements. Therefore, the right choice of energy-efficient products that would ensure the rational use of fuel and energy resources is a highly important task.

One should keep in mind that all selected products must meet thermal performance criteria and be certified as safe for use in occupied spaces. High-quality thermal insulation materials must be approved by the Ministry of Health of Ukraine and have a valid hygienic and epidemiological certificate.

Нормативно-правові засади виконання термомодернізаційних робіт у будівництві

Наталія Мацак

У сучасному суспільстві енергоекономічність та енергоефективність відіграють дуже важливу роль. Зокрема, зростає актуальність проблеми термомодернізації будівель. Енергоекономічна політика в будівництві — одне з першорядних завдань під час проведення капітальних ремонтів і нового будівництва. Тож вибір будівельних матеріалів, виробів та конструкцій обумовлюють потреби енергоефективності та зменшення рівня енергоспоживання. Якщо будівельні матеріали дібрано правильно, умови перебування людей усередині будівлі стають комфортнішими, оскільки матеріали з високими теплоізоляційними характеристиками взимку сприяють підтриманню в будівлі тепла, а влітку — прохолоди, зменшуючи потребу в обігрівачах або вентиляторах чи кондиціонерах, отже, і у споживанні енергії. Метою цієї статті є ознайомити з основними правилами й вимогами щодо енергетичної ефективності під час проведення робіт з термомодернізації будинків і проаналізувати здійснення цих робіт із висвітленням окремих проблем, що виникають під час їх проведення. Для досягнення мети застосовано загальні методи (теоретичний аналіз і синтез) та спеціальні (аналіз проєктної документації, аналіз застосованих будівельних матеріалів, тепловізійне обстеження). Приділено увагу будівельним нормам і правилам, що стосуються виконання такого виду робіт, опрацьовано обов'язкові вимоги до їхньої якості. Зауважено про потребу вдосконалити нор-

мативну базу з питань технічного переоснащення теплової ізоляції зовнішніх огороджувальних конструкцій, а також із заміни віконних, зовнішніх дверних і балконних блоків. Порушено питання щодо енергозбереження, енергозберігаючої політики, енергетичного паспорта будівлі, економії паливно-енергетичних ресурсів.

Ключові слова: *енергетичний аудит; енергозбереження; огороджувальні конструкції; опалення; паливно-енергетичні ресурси; тепловтрати; теплоізоляція; утеплення.*

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The author declares no conflict of interest.

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