Vol. 13, 2024, 23-34

DOI: 10.17512/bozpe.2024.13.03

Construction of optimized energy potential
Budownictwo o zoptymalizowanym potencjale energetycznym

ISSN 2299-8535 e-ISSN 2544-963X

Introduction to the "Theory of Compensation"

Andrii Fesenko[1*] (*orcid id: 0009-0003-4133-4947*)
Liudmyla Tsyhanenko[2] (*orcid id: 0000-0002-6628-3635*)
Nataliia Sribniak[2] (*orcid id: 0000-0003-3205-433X*)
Adam Ujma[3] (*orcid id: 0000-0001-5331-6808*)
[1] FALVI Limited Liability Company, Ukraine
[2] Sumy National Agrarian University, Ukraine
[3] Czestochowa University of Technology, University of Applied Sciences in Nysa, Poland

Abstract: In this article, we systematize and emphasize the information elements that are the starting point for step-by-step actions related to the improvement of technological maps in accordance with the “energy model” to ensure sustainable sanitary and hygienic standards throughout the life cycle of buildings. In particular, we draw attention to the lack of analytical methodologies to visually or technically incorporate optimization measures to achieve the final building outcome in accordance with energy models A, B and C throughout the life cycle of buildings. These findings serve as a basis for research aimed at improving the analytical methods and ensuring their compliance with the established legal standards.

Keywords: “compensation theory”, energy efficiency, life cycle, optimization

Please, quote this article as follows:

Fesenko A., Tsyhanenko L., Sribniak N., Ujma A., Introduction to the “Theory of Compensation”, Construction of Optimized Energy Potential (CoOEP), Vol. 13, 2024, 23-34, DOI: 10.17512/bozpe.2024.13.03

Introduction

One of the primary challenges in implementing energy-saving measures in buildings and structures is aligning them with the fundamental requirement of achieving energy savings and energy efficiency in compliance with the energy efficiency class of buildings. It is defined as a basic requirement according to the implementation of European energy efficiency regulations and is ratified in national legislation. The EU legal framework is based on Directives (in Ukraine, these are

* Corresponding author: starikco@gmail.com

laws and regulations, respectively), which are approved by the Council of Europe. These regulations typically assign energy efficiency classes such as A, B, or C. There are different approaches to determining energy efficiency classes of buildings in the EU: in Portugal, Austria, the Czech Republic, Denmark, Ireland and Sweden, the results are presented in the form of annual final energy consumption; and in Greece, Germany, France in the form of primary energy. In Spain and Finland, the results are presented in the form of heat transfer coefficients for individual elements of the external building envelope, such as walls, windows, and floors. In Norway, energy consumption and heat transfer coefficients of building envelopes are also taken into account (Bilous et al., 2015). In addition, it is necessary to ensure that the maximum value of the specific consumption of primary energy for heating and cooling does not exceed the limits set by the laws and regulations of Ukraine on energy efficiency. According to the "Ukrainian Law About Energy Efficiency", energy efficiency measures encompass various technical, organizational, economic, and informational actions or their combinations, which are aimed at improving energy efficiency (reducing specific costs) in a quantifiable manner (About Energy Efficiency, 2023). The law aims to implement the acquis communautaire of the European Union in the field of energy efficiency, namely: Directive 2012/27/EU on energy efficiency, Directive 2009/125/EC on a framework for establishing eco-design requirements for energy-related products and Regulation (EU) 2017/1369 establishing a framework for energy labelling. However, there are practically no analysis methods for visual or technical implementation in regulations and normative documents to optimise the actions for obtaining the final construction product in accordance with the energy efficiency category A, B, C for the entire life cycle of the buildings. In fact, there is no technological map, the so-called "construction model", which would lead to the desired result within an error of 5% in forecasting for the entire life cycle of the building and taking into account the relationship between technical, economic, environmental and social aspects. It is the lack of a "building model" with sustainable operational parameters in terms of energy consumption and comfort for the entire life cycle of a building that is the basis for the research. Consequently, determining the energy efficiency class serves as a form of evaluation of construction quality.

1. Objective of the study

The study concerns the energy efficiency of civilian buildings by implementing energy solutions and meeting the criteria set out in the National Energy Efficiency Action Plan for 2030 and takes into account the proclamation of the United Nations General Assembly resolution No. 70/1 of 25th September 2015. The Sustainable Development Goals for 2030, which must be met by Ukraine in accordance with the Decree of the President of Ukraine of 30 September 2019 No. 722/2019 "On the Sustainable Development Goals of Ukraine for the period up to 2030" (the goal of "ensuring access to affordable, reliable, sustainable and modern energy sources for all and sustainable and modern energy sources for all" and the goal of "taking urgent action to combat climate change and its effects”) and furthermore is guided by the principle declared by the EU in Regulation 2018/1999 of the European Parliament and of the Council of 11 December 2018 – “Energy efficiency first”, which provides for the prioritising of energy efficiency issues in the development of policies, programs and legislation. In addition, the development and implementation of the National Plan and the availability of medium-term energy efficiency policy planning are part of Ukraine’s policy of joining the European Green Deal, which is a roadmap of measures that will transform the EU into an efficient, sustainable and competitive economy and determine the means of transforming Europe into the world’s first climate-neutral continent by 2050, stimulating economic development, improving people’s health and quality of life, and transforming climate and environmental challenges into opportunities across all EU sectors and policies, ensuring a fair and inclusive green transition (On the National Energy Efficiency, 2021).

2. Theoretical prerequisites

In everyday use, the word “theory” often means an untested hunch, or a guess without supporting evidence. But for scientists, a theory has nearly the opposite meaning. A theory is a well-substantiated explanation of an aspect of the natural world that can incorporate laws, hypotheses and facts. A theory not only explains known facts; it also allows scientists to make predictions of what they should observe if a theory is true. Scientific theories are testable. New evidence should be compatible with a theory. If it is not, the theory is refined or rejected. The longer the central elements of a theory hold – the more observations it predicts, the more tests it passes, the more facts it explains – the stronger the theory (What Is a Theory?

Theories are ideas about how nature works. Therefore, it can be said that a scientific theory is a “history of ideas” or a type of conceptualization as opposed to observation. More specifically, a theory is a logical-deductive system consisting of a set of interrelated concepts from which testable statements can be deductively derived. Theory also relates to practice, i.e., scientists accept a theory (and its practical applications) only when its methodology has been clearly and logically explained. A scientific theory is a whole of logically coherent generalizations, deduced on the basis of established scientific facts and related to the current state of science. Its aim is to explain the cause or system of causes, conditions, circumstances of the emergence and specific course of a given phenomenon. The criterion of falsifiability is now crucial for distinguishing whether a theory is a scientific theory or not; this concept was introduced by Karl Popper, an Austrian philosopher of science, logician, methodologist and psychologist (Popper, 1935). According to this principle, a theory for which empirical criteria for falsification (refutation) cannot be determined is not a scientific theory. A good scientific theory is supposed to organize knowledge acquired through empirical methods. It is a source of testable hypotheses that guide research and can be verified by researchers. It can even predict the existence of undiscovered phenomena and their development. Researchers evaluate a theory in terms of its internal consistency, the accuracy of its empirical predictions, and the conceptual parsimony of its proposed explanations (Juszczyk, 2021).

Scientific theories evolve and mature. Therefore, each of them is characterized by different degrees of maturity. In this respect, the following theories can be distinguished (Kuzionko-Ochrymiuk, 2020): mature, maturing and nascent (Fig. 1).

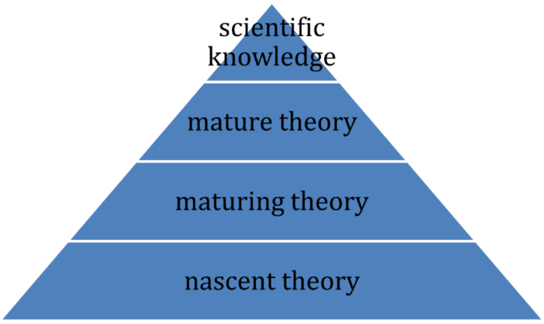

Fig. 1. Theories in different degrees of maturity (scientific canons) in creating scientific knowledge (Kuzionko-Ochrymiuk, 2020)

3. Main research

The procedure for studying the "energy compensation" of buildings is reduced to the task of optimising and controlling systems with distributed parameters. Its main stages are as follows:

- identification of physical features of the system response;
- development and justification of a mathematical model;
- development and selection of methods and tools for solving and implementing the formulated tasks;
- study of the mathematical model (checking the capability – adequacy) of the proposed mathematical model or algorithmic calculation of the thermal and humidity state of a real object);
- evaluation of the obtained solutions according to the set of requirements for the studied processes, states and methods of their management;
- selection of rational design solutions and operating modes, as well as determination of the optimal parameters of the system under study.

In some cases, replacing more energy-intensive building envelopes with less energy-intensive ones has a positive effect. In other cases, replacing less energy-intensive structures with less energy-intensive and more durable ones can also result in energy savings.

This is the essence of designing with energy consumption limits in energy compensation. Only when the impacts of energy intensity, durability and thermal protection of building product components are considered together can energy savings be achieved over the long (more than 100 years) lifetime of a building.

Energy efficient buildings as a new trend in experimental construction emerged after the global energy crisis of 1974. They were a response to the criticism of the UN International Energy Agency (IEA) that modern buildings have large reserves for improving their thermal efficiency, but scientists have not sufficiently studied the peculiarities of their thermal regime and designers are not able to optimize the flow of heat and mass in building envelopes and buildings. In the same report, MERC experts formulated the main idea of energy saving: energy resources can be used more efficiently by applying measures that are technically feasible, economically justified and acceptable from an environmental and social point of view, i.e., cause a minimum of changes in the usual way of life (Lapa et al., 2017).

Modern construction projects are subject to increasing requirements for both safety and comfort, which is essential for the occupants of the premises. It is possible to ensure comfortable conditions for a person to stay indoors only through an integrated approach to normalising microclimate parameters, which includes space-planning, production and technological, sanitary and hygienic, and biomedical solutions (Fesenko & Tsyhanenko, 2023).

It is not appropriate to consider the characteristics separately from each other in terms of optimisation, as optimisation of one parameter will not always lead to automatic optimisation of another. Therefore, the “construction model” should be considered in the sense of a “closed loop”.

Any building solution cannot be separated from energy efficiency (Geikins, 2022; Hromadka et al., 2023; Hummel et al., 2023; Rodriguez et al., 2023; Vilinska et al., 2023; Walter et al., 2023). The main operational characteristics of civil buildings are durability, reliability and efficiency with guaranteed parameters of sanitary and hygienic standards. To this end, it is necessary to take into account the fact that energy intensity, thermal protection and durability of building products are closely related, so the energy efficiency of the industry as a whole depends on the total energy consumption during the construction of buildings and their operation.

Scientists have made a significant contribution to identifying the factors that influence performance indicators, the speed of the process and how to manage them.

In particular:

A comprehensive study of the energy efficiency dynamics of non-residential public buildings such as schools, swimming pools, hospitals and museums. A key element of this analysis emphasises the dual nature of technical modernisation, dividing interventions into passive and active measures. The study delves into the sustainability imperatives of energy measures, examining the economic motivations behind retrofit decisions and the complex relationship between advanced technological solutions and the behavioural trends of building operators and users. In summary, key performance indicators (KPIs) often have internal limitations due to their inconsistency across different areas, making direct comparisons or specific numerical calculations problematic (Papadakis & Katsaprakakis, 2023).

At the same time, a sufficient number of scientists prefer to improve and quantify the energy efficiency potential of improving the operation of the non-residential stock and to promote targeted actions aimed at creating a more sustainable building environment with optimisation through intervening in a limited number of building elements to ensure a reduction in specific consumption (Franco et al., 2022).

The scientific and rational application of management technology during residential construction affects the construction cost, construction progress and construction quality. In this regard, the construction department needs to comprehensively analyse the influencing factors of construction management technology and then select the appropriate management technology. Optimisation measures such as improving the management system, strengthening advanced management and control, and promoting information management and control are proposed to control the construction progress, improve the efficiency of manual work, ensure project quality, reduce project costs, ensure a good construction environment, optimize the economic and social benefits of the housing construction unit and promote the sustainable development of housing construction (Huang, 2023).

In response to this, the quality of architecture has shifted towards energy efficiency, which has affected the health of people indoors as well as the environment. Therefore, green buildings have emerged as a solution to this problem, aiming to improve indoor environmental quality (IEQ) and human well-being while minimising negative environmental impacts. A comprehensive review focuses on the role of green buildings in improving indoor health and energy efficiency and highlighting sustainable architectural practices that promote health (Karimi et al., 2023).

Consequently, it all comes down to comparing the efficiency of building envelopes and heating system changes, as in the case of the Invert models, which are based on a detailed representation of the existing housing stock at the national (or local) level through building archetypes. There are different potential renovation options and available heating technologies for each archetype (Hummel et al., 2023).

As a result, discussions on this issue are not subsiding, but rather gaining momentum. This is the scientific and technical approach to achieving a result with sustainable parameters.

In Ukraine and in the global information space, the issue of energy efficiency is very important in every developed society.

The criterion for the discussions is the law of energy conservation – implemented in Ukrainian and global legislation in the form of indicators – energy efficiency classes (A-G) – and according to building codes (Fig. 2).

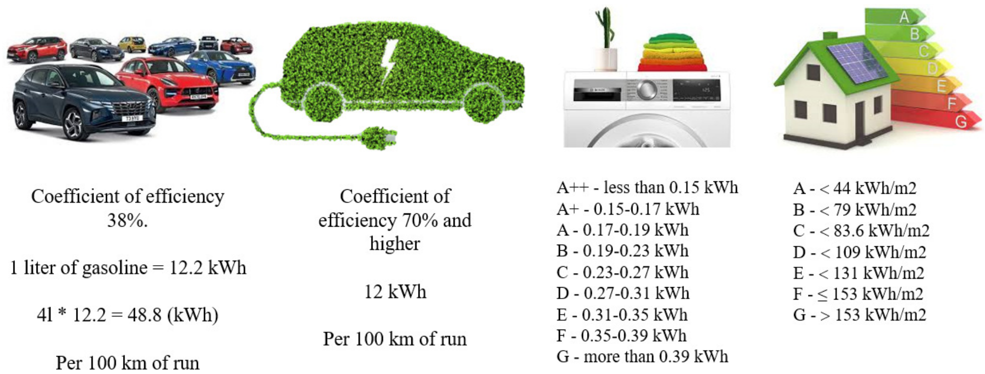

Fig. 2. Criteria for assessing energy efficiency in socially important areas (Hummel et al., 2023)

In a general sense, we use different theories and knowledge, while having stable structures and algorithms. It all comes down to information that needs to be structured into an algorithm of actions to be effective. Therefore, the initial data for modeling technological maps based on energy models is the criterion of energy demand for heating and cooling of buildings, which is calculated and given in building codes.

Given that the energy efficiency class is an “energy model” that is closely related to “comfort” (a parameter that requires further research and will be discussed in another article) and should take into account the operation of buildings, which accounts for up to 70% of the total life cycle of buildings, and is a point that requires full analysis and forecasting for the entire life cycle of a building. This is an urgent task that requires a new methodology that has been developed.

This approach draws upon the author’s “Theory of Compensation” and is designed for the analysis and prediction of energy conservation and the establishment of consistent “comfortable operating conditions” in buildings and structures. The “Theory of Compensation” expounds upon and outlines the parameters that must be inherent in a building model to guarantee its alignment with the designated energy efficiency category “Class A, B, C”. This compliance implies compliance with the established limits on the specific consumption of primary non-renewable energy for heating and cooling of residential and public buildings, as provided for in the legal framework and regulations governing energy efficiency.

EN 15603 (EN 15603:2008, 2008) provides a methodology for assessing total energy consumption and types of ratings; EN 13790 (EN 13790:2008, 2008) provides a methodology for calculating energy consumption for heating, ventilation, cooling, lighting and hot water; in EN 12831 (12831:2003, 2003) – the method of calculating thermal power is described; standards EN 13829 (EN 13829:2000, 2000), EN 14501 (EN 14501:2005, 2005), EN 13779 (EN 13779:2007, 2007) – provide an opportunity to compare energy efficiency indicators of buildings; EN 15217 (EN 15217:2007, 2207) – describes the methods of determining the energy efficiency of buildings and the level of automation of engineering networks; EN 15232 (EN 15232:2007, 2207) – establishes requirements for engineering systems of buildings; EN 15316 (EN 15316-2-1:2007, 2007) – defines requirements for the efficiency of heating systems; according to EN 7730 (EN 7730:2005, 2005), the microclimate of the premises is regulated.

Existing calculation methods under the current legislation are based on the “peak mode of operation” – the maximum energy compensation to meet sanitary and biological standards during building heating, characterised by peak temperature deltas depending on the climate zones in which the building is located, with the moments of operation without energy compensation and moments with partial energy compensation and taking into account coefficients (coefficient method).

This approach fails to account for the cyclic nature of physical processes that occur without energy compensation. In other words, it doesn’t consider scenarios where the external cladding may experience relative humidity levels of 80% or higher during the building's ten-year operational span. Consequently, the current calculation method effectively addresses only 3-7% of the total time period associated with energy compensation during the heating season. In conclusion, it is evident that the current methods of thermal engineering calculations are insufficient for optimizing actions aimed at aligning a building with energy efficiency categories A, B, or C as required by the law for the entire life cycle of the building. This is an issue that requires a different approach to solving the problem.

The "Theory of Compensation" introduces a model of energy compensation that enables the analysis and prediction of the energy distribution impulse (vector) in time.

Through research in the field of energy conservation, distancing itself from existing paradigms, fundamental laws governing the underlying physical processes in this theory have been successfully identified, which will be described in other articles.

The "building model" itself has to be "standardised" and measured with an energy offset coefficient (useful quality factor) at the stage of future energy offset during operation. The energy compensation coefficient is an analytical coefficient, a unit of measurement for optimising the energy compensation management system for further forecasting technical, economic, environmental and social measures in the parameters of the "energy model", denoted by the energy efficiency class, e.g. "Class A, B, C", which is divided into a direct optimal solution and a controlled inverse energy solution that takes into account all energy reactions of the system in time, frequency and temperature conversion (this issue requires research and will be published in other articles).

This will help reduce errors in design and construction since it will serve as a "standard". To take these indicators into account, the dependence is introduced that the inertia of the system will be maximum if the reaction of the system is maximum in relation to the counteraction forces.

The universality of the "Theory of Compensation" model lies in its applicability to various thermal zones – zones with specific air temperatures that differ in terms of heat quantity. The research method is based on information gathering, which is the initial step towards achieving the goals of categorizing building energy consumption according to standards (energy efficiency categories A, B, C).

The proposed "Theory of Compensation" serves as an algorithmic model for improving building systems, taking into account the new information conditions associated with the future concept of the national plan to increase the number of buildings with near-zero energy consumption.

As input data for the calculation, we take constant parameters of non-renewable primary energy consumption within the energy efficiency class for heating and cooling, namely: "Class A – 44.0 kW/m^2 per year", "Class B – 62.5 kW/m^2 per year", "Class C – 82.5 kW/m^2 per year".

Taking into account that the number of hours in a year are:
365 (days per year) · 24 (hours) = 8760 (hours per year) (1)
“Class A” 44 000 W/m^2 (year) : 8760 (hours) = 5.02 Wh/m^2 (2)
“Class B” 62 500 W/m^2 (year) : 8760 (hours) = 7.13 Wh/m^2 (3)
“Class C” 82 500 W/m^2 (year) : 8760 (hours) = 9.42 Wh/m^2 (4)
which are needed for heating and cooling.

Also, the input data for the “Theory of Compensation” is a temperature graph of the construction site location in averaged indicators to take into account the criteria for a comprehensive analysis of the entire closed system to study the energy momentum in a cycle or energy level, which constantly changes from one state to another and is cyclical in nature. In this case, the design temperature for analysis and forecasting is taken within 15.3 K (Fig. 3), which is calculated taking into account the difference between the internal comfortable temperature of 22 K and the average temperature per year of 6.7 K, which corresponds to the operational parameters of buildings that are taken into account in the existing calculations by the coefficients.

$$22 - 6.7 = 15.3 \text{ K} \quad (5)$$

In order to take into account all the parameters of the closed-loop energy study system with energy compensation, without energy compensation, and with partial energy compensation, a characteristic of the month of the year is introduced, which we call the “compensation moment”. As can be seen from the graph in Figure 3, this is September. The average temperature of September corresponds to the average annual temperature of the years under study.

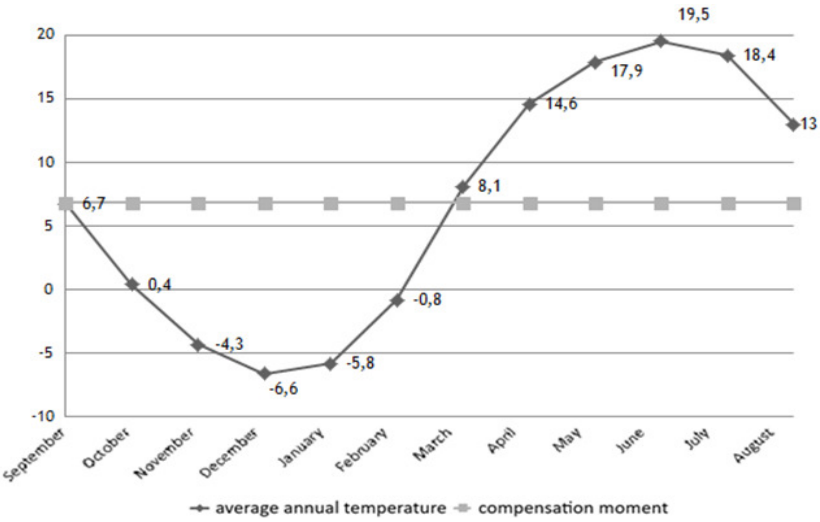

Fig. 3. Temperature chart of the city of Sumy (Ukraine) for a year (own research; DSTU 9190:2022, 2022)

The amount of consumed energy (2)-(4) and the temperature characteristic of energy (5) are the basis for the mathematical model "Theory of Compensation" for optimizing the reduction of the amount of non-renewable primary energy required to provide one unit of transmitted energy in the corresponding system, taking into account the energy required for production, transformation, transportation and distribution and also taking into account the durability, reliability and economy for the analysis and forecasting of all physical processes affecting the construction object over time and having a cyclical nature (this issue requires research and will be published in other articles).

Conclusion

This model of analyzing the life cycle of buildings and predicting stable parameters of energy consumption and ensuring stable microclimatic conditions during operation introduces new trends in the transition from energy efficiency to energy solutions regarding the "energy model".

The "theory of compensation" allows you to establish a link between the "energy model" and the process map within the energy consumption.

In order to ensure a high-quality technical and scientific approach at the first stage of the research, measures of an informational nature were applied, which are an element of successive steps towards the sustainable development of the industry.

The development of a calculation model can serve as the basis for a method of engineering calculation that has practical significance and scientific and technical support for production and construction to meet the requirements of production technologists, designers and architects when designing new, reconstructions. Or to overhaul existing civil buildings in order to ensure the "basic requirement" for the energy security of the European Union and its sustainable innovative development.

Bibliography

About Energy Efficiency of Buildings: Law of Ukraine of 22.06.2017 No. 2118-VIII: as of 3 August. 2023.

About Energy Efficiency. Bulletin of the Verkhovna Rada of Ukraine (VRU), 2022, No. 2, Art. 8. (As amended by Laws No. 2392-IX of 09.07.2022 No. 2710-IX of 03.11.2022 No. 3220-IX of 30.06.2023).

Bilous, I. Yu., Deshko, V.I. et al. (2015) Management of energy use efficiency of higher educational institutions. NTUU "KPI", 157p. [in Ukrainian].

DSTU 9190:2022 Energy efficiency of buildings. Method for calculating energy consumption during heating, cooling, ventilation, lighting and hot water supply – SE "UkrNDNC".

EN 15603:2008. Overall energy use and definition of energy ratings. CEN. European Committee for Standardization. 2008.

EN 13790:2008. Calculation of energy use for space heating and cooling. CEN. European Committee for Standardization. 2008.

EN 12831:2003. Heating system in buildings – Method for calculation of the design heat load. CEN. European Committee for Standardization. 2003.

EN 13829:2000. Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method. CEN. European Committee for Standardization. 2000.

EN 14501:2005. Blinds and shutters. Thermal and visual comfort. Performance characteristics and classification. CEN. European Committee for Standardization. 2005.

EN 13779:2007. Ventilation for non-residential buildings. Performance requirements for ventilation and room-conditioning systems. CEN. European Committee for Standardization. 2008.

EN 15217:2007. Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings. CEN. European Committee for Standardization. 2007.

EN 15232:2007. Energy performance of buildings – Impact of building automation, controls and building management. CEN. European Committee for Standardization. 2007.

EN 15316-2-1:2007. Heating system in buildings – Method for calculation of system energy requirements and system efficiencies. Part 1. CEN. European Committee for Standardization. 2007.

EN 7730:2005. Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. CEN. European Committee for Standardization. 2005.

Franco, A., Miserocchi, L. & Testi, D. (2023) Energy efficiency in shared buildings: Quantification of the potential at multiple scales. *Energy Reports*, 9, 84-95.

Fesenko, A. & Tsyhanenko, L. (2023) On the issue of energy efficiency of residential buildings. Proceedings of the International Scientific and Technical Online Conference. Problems of Building and Transportation, Problems of the Construction and Transport Complexes. Central National Technical University, p. 161-162 [in Ukrainian].

Geikins, A. (2022) Methodology for Evaluation of Energy Efficiency of Unclassified Buildings. RTU Press.

Hromadka, V. (2023) Optimizing energy-saving measures in new residential buildings regarding life-cycle costs. *Buildings*, 13(8), 1907.

Huang, C. (2023) Discussion on optimization measures of building construction management technology. *Journal of Architectural Research and Development*, 7(1), 17-24.

Hummel, M., Müller, A., Forthuber, S., Krenzl, L., Mayr, B. & Haas, R. (2023) How cost-efficient is energy efficiency in buildings? A comparison of building shell efficiency and heating system change in the European building stock. *Energy Efficiency*, 16(5), 32.

Juszczyk, S. (2021) Theory and its characteristics: discourse in the field of social sciences. *Athenaeum. Polskie Studia Politologiczne*, 69(1), 134-144.

Karimi, H., Adibhesami, M.A., Bazazzadek, H. & Morafagh, S. (2023) Green buildings: Human-centered and energy efficiency optimization strategies. *Energies*, 16(9), 3681.

Kuzionko-Ochrymiuk, E. (2020) Scientific canons in the process of knowledge creation. In: Grząba, M., III Ogólnopolska Konferencja Naukowa Współczesne problemy ekonomiczne w badaniach młodych naukowców (online). Białystok, Wydawnictwo Uniwersytetu w Białymstoku.

Lapa, M., Dvoieglazova, M., Pechonkin, I. & Lapa, Y. (2017) Providing of buildings energoefficiency. *Technical Sciences and Technologies* (online), 1(7), 225-233 [in Ukrainian].

On the National Energy Efficiency Action Plan for the period up to 2030: Decree of the Cabinet of Ministers of Ukraine dated 29.12.2021.

Papadakis, N. & Katsaprakakis, D.A. (2023) A review of energy efficiency interventions in public buildings. *Energies*, 16(17), 6329.

Popper, K. (1935) Logik der Forschung. Verlag Vox Julius Springer.

Rodríguez, J.S.T. et al. (2023) The interconnection between energy efficiency and CO_2 mitigation in the development of multifamily buildings. *International Journal of Membrane Science and Technology*, 10(3), 1333-1339.

Vilinska, L.M., Burlak, H.M. & Gurska, A.V. (2023) Energy efficiency of an apartment building. *Ukrainian Journal of Civil Engineering and Architecture*, 3(015), ISSN 2710-0367 (Print), ISSN 2710-0375 (online) [in Ukrainian].

Walter, I., Tanasković, M. & Stanković, M. (2023) Energy efficiency assessment for buildings based on the generative adversarial network structure. *Eng-Advances in Engineering*, 4(3), 2178-2190.

What Is a Theory? A Scientific Definition – AMNH (online), (no date). American Museum of Natural History.