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DEFINITION OF REFERENCE BUIDLING IN DEVELOPMENT OF REQUIREMENTS TO ENERGY EFFICIENCY INDICATORS

ABSTRACT

Solving the strategic task of changing the energy status of residential and public buildings depends significantly on the level of regulatory requirements for new construction and reconstruction. The need to improve the system of criteria that determine the possibility of reducing specific energy consumption in building operation while ensuring thermal reliability of structures is due to the use of innovative technical solutions in up-to-date construction. The article analyzes the available data on residential and public buildings in order to determine the principles of establishing reference approaches to regulating of energy efficiency indicators. The details of development of housing and public stock in Ukraine are given. The article is a continuation of the previous scientific work carried out by NIISK over the past fifteen years with main publications given in the references below and which are aimed at developing methodological framework for creating a system of norms and standards that ensures the introduction of modern innovative technical solutions in domestic construction. The paper covers the principles of normalization of energy characteristics, which have been changing in the domestic regulatory framework over time. The article considers the details of methodological provisions of presenting the building energy performance that exist in Ukraine and the European countries.

The criteria for selecting reference buildings should take into account both architectural and structural trends that exist in up-to-date construction and architectural and engineering solutions of existing buildings. There is a list of reference buildings and it takes into account the climatic features and functional purposes as well as determines the features of microclimate and, accordingly, energy costs to ensure the parameters of microclimate. The direction is defined for of further research on the development of minimum requirements for energy efficiency of residential and public buildings is defined.

KEYWORDS: building, energy efficiency, reference operation, assessment criteria, DBN.V.2.6–31:2016

ВИЗНАЧЕННЯ ЕТАЛОННИХ БУДІВЕЛЬ ПРИ ВСТАНОВЛЕННІ ВИМОГ ДО ПОКАЗНИКІВ ЕНЕРГОЕФЕКТИВНОСТІ

АНОТАЦІЯ

Вирішення стратегічного завдання із забезпечення зміни енергетичного статусу житлових та громадських будівель суттєво залежить від рівня нормативних вимог, при новому будівництві та реконструкції. Необхідність удосконалення системи критеріїв, які визначають можливість зниження питомих енерговитрат при експлуатації будинків з одночасним забезпеченням теплової надійності конструкцій під час експлуатації обумовлена застосуванням інноваційних технічних рішень у сучасному будівництві. У статті наводиться аналіз наявних даних по фонду житлових та громадських будівель з метою визначення принципів встановлення еталонних підходів при нормуванні показників енергоефективності. Розглянуто особливості формування житлового та громадського фонду будівель в Україні. Стаття є продовження попередніх наукових робіт, що здійснюються у ДП НДІБК на протязі останніх п'ятнадцяти років, основні з яких наведено у бібліографії і які направлені на розробку методологічних основ при створенні системи норм та стандартів, що забезпечує впровадження сучасних інноваційних технічних рішень у практику вітчизняного будівництва. Проведений аналіз принципів нормування енергетичних характеристик, які змінювались у вітчизняній нормативній базі у часі. В статті розглянуто особливості методичних положень, що існують в Україні та країнах Європейської спільноти, при представленні енергетичних характеристик будівель. Критерії вибору еталонних будівель мають враховувати архітектурні та конструктивні тенденції, які існують при новому будівництві, та конструктивний і інженерний парк існуючих в країні будівель. Визначений перелік еталонних будівель з урахуванням кліматичних особливостей їх експлуатації та функціонального призначення, яке визначає особливості формування мікроклімату і, відповідно, енергетичних витрат на забезпечення параметрів мікроклімату. Визначений напрямок подальших досліджень щодо встановлення мінімальних вимог до енергетичної ефективності житлових та громадських будівель.

КЛЮЧОВІ СЛОВА: будівля, енергоефективність, еталонна експлуатація, критерії оцінки, ДБН В.2.6–31

PROBLEM DEFINITION

The implementation of European regulations in state construction norms and standards should be carried out taking into account national technological traditions, engineering details and creation of the construction market. The task of maximum use of innovative design solutions is relevant for our country, but one should take into account the current state of knowledge on the performances of fundamentally new technical solutions and develop full and detailed methods of testing relevant technical criteria to establish reasonable requirements for energy performance of buildings.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Article [1] provides an analysis of the existing system of norms and standards for defining the energy efficiency of buildings. A feature of the national regulatory framework [2] is the principle of ensuring the thermal reliability [3-6] of envelope of buildings and their structural elements. European standards apply the system principle of representing the energy performance of building based on the definition of reference operation [7,8]. This approach has been introduced in national standards [9,10] and needs further refinement and development.

PROBLEM DEFINITION

The main task of this research is to analyze the criteria for selecting buildings as reference ones for describing and evaluating the energy efficiency of residential and public buildings.

MAIN TEXT OF RESEARCH

Until 2006, the main indicator that characterized the energy efficiency of buildings in the national regulatory framework was the resistance to heat transfer of envelope. The norms of 2006 [9] introduced an indicator of specific heating losses of buildings, and the norms of 2016 [10] established an indicator of building energy consumption for heating, cooling and hot water supply. The minimum requirements for the heat transfer resistance of envelope were also standardized, and this provided a flexible approach to design of thermal insulation. When comparing the minimum requirements for heat consumption through envelope represented by heat transfer coefficients U, W / (m2K), we can see (Table 1) that the current Ukrainian standards [10] set levels of requirements for the first temperature zone which are close to European standards.

Normative values of energy efficiency indicators are set for reference buildings and this requires careful reasoning of the choice of reference buildings.

The reference building is a building that reflects typical geometry and systems of building, typical energy characteristics of envelope of thermal insulation skin, engineering systems of building, typical functionality and typical cost breakdown with taking into account typical climatic conditions and

Table 1 – Levels of reference values of envelope heat transfer coefficients

Envelope	Standard value of envelope heat transfer coefficients U, W / (m^{2}K) accepted in the following countries:					
	Austria	Poland	Germany	Slovakia	The Czech Republic	Ukraine
External walls	0,35	0,30	0,24	0,22	0,30	0,30
Roof	0,20	0,25	0,24	0,10	0,24	0,19
Basement floor	0,40	0,45	0,30	0,50	0,60	0,27
Transparent curtain wall	1,40	1,80	1,30	1,00	1,80	1,33

geographical location. The definition of reference buildings should be based on an analysis of national construction, so the types of reference buildings may differ in each country.

Figure 1 shows the structure of housing in Ukraine [9], which shows that the main number of residential buildings was built in the second half of the twentieth century, and this structure can change only by increasing the number of modern buildings with high energy efficiency performances according to the requirements [8].

The energy efficiency of new structures started to increase since 1997, when the reform initiating standardization of thermal insulation of residential buildings in 1994 to 1996 became noticeable. The positive effects of the introduction of energy efficiency standards for buildings in general, which took place in 2007, became evident in 2009. In 2017, a new generation of energy efficiency standards was introduced, but the share of new buildings in the housing stock was not more than 10%.

Based on existing official statistics, it is not possible to analyze the impact of energy efficiency measures in residential buildings. The country's housing stock is constantly growing, for example, compared to 1997, the housing stock in 2009 has increased by 7%. At the same time, the amount of thermal energy produced and supplied to the population is constantly decreasing - in 2009 by 37% less than in 1997. Costs of building services decreased even more, by 46% for this period.

It should be noted that according to official statistics, the 37% decrease in heat energy is not coordinated with the volume of new housing with high energy efficiency and is mainly due to poor quality of building services related to heating and domestic hot water. In addition, in a number of cities in our country there are large scale unauthorized cuts by residents from district heating systems and the transition to individual heating in high-rise buildings. This transition does not have any macro-effect on energy conservation as more gas and electricity are used to heat premises, but at the same time significantly increases the risk of accidents during the operation of equipment that is unauthorized by the relevant operation service and uncertified. The number of such accidents with the collapse of buildings and deaths is serious in Ukraine and with the further concealment of this problem, an increase in tragic cases is inevitable.

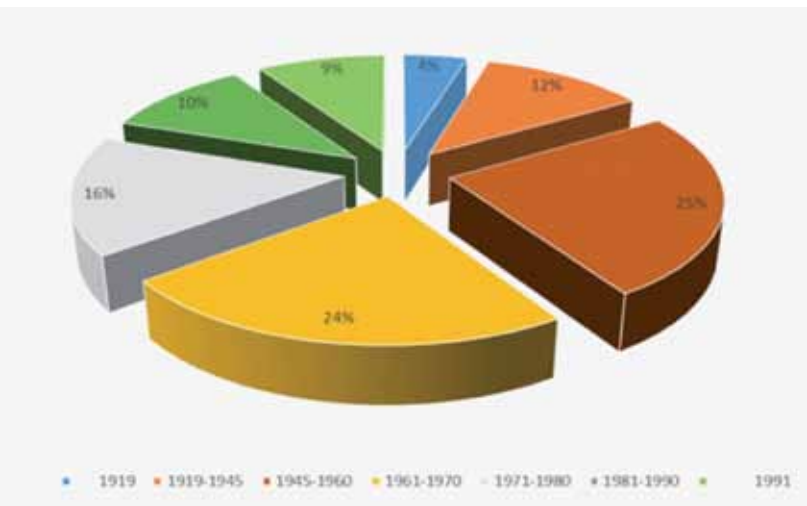

Figure 1 - Distribution of residential buildings by year of construction according to [11] in %

Considerable improvement of energy performance of existing buildings on the basis of relevant thermal modernization projects should be based on regulatory requirements for reference buildings.

The list of criteria for references includes a building compactness factor, a value of which depends on the number of storeys, a façade glazing coefficient and the historically established practice of construction in the climatic conditions of Ukraine.

Figure 2 shows the dependence of specific energy consumption for heating, cooling and domestic hot water of a one-storey individual

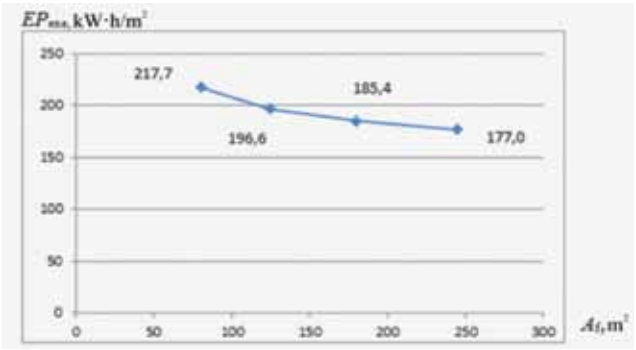

Figure 2 - Dependence of specific energy consumption on the heated area of a one-storey individual residential building

Figure 3 - Reference one-storey residential building

residential building and different conditioned (heated) areas for the first temperature zone of Ukraine.

With an error of ~ 9%, an one-storey residential building with an area of 100 - 150 m^2 can be a reference. Its facade and plan are presented in Fig.3.

In the urban area there are both apartment buildings and single family low-rise houses. In official statistics there is no information on the structural distribution of apartment and single family residential buildings in the urban area. There is only general information that does not allow to accurately establish the total value of calculated heat consumption for heating of the urban area housing stock in the absence of percentage ratio of representative units and total number of residential buildings. This fact therefore makes it impossible to estimate the share of each type of representative units in the total amount of calculated specific costs for heating the urban area housing stock. That is why some assumptions are made below.

Figure 4 - Representative five-story, three entrance halls residential building

Based on statistics for the city of Kyiv, the total number of apartment buildings in Kyiv is about 12 thousand, which is about 36% of the total number of residential buildings in Kyiv. We take it as a basis for calculation that the total number of apartment buildings is about 30% of the total number of residential buildings in the urban area of Ukraine.

Buildings of 5, 9, 16 floors are accepted as representative units for calculations of energy consumption of apartment building in the urban area.

Energy indicators of existing buildings are as follows:

- Heat transfer resistance of external walls is 0.63 ÷ 1.0 m^2 • K / W.
- Heat transfer resistance of translucent structures is 0.32 ÷ 0.34 m^2 K / W.
- Heat transfer resistance of roofs is 0.8 ÷ 1.2 m^2 • K / W.
- Heat transfer resistance of basement floors is 1.0 ÷ 1.2 m^2 • K / W.
- Specific heat consumption for heating residential multi-storey buildings is from 175 to 250 kWh / m^2.

Five-storeyed residential buildings belong to mass series 1-464, 1-464A, BK-4, 1-437 1-438, 1-442, 1-443, 1-447, 1-480 (panel and brick buildings of 1960-1978 years of construction). An example of a representative five-story three entrance halls residential building is shown in Fig. 4.

Sixteen-storey residential buildings belong to the mass series as follows:

- series T-1, T-2, T-4, T-6, T-7, T-22 (14-16-storey panel buildings of 1980-1990 years of construction);
- KT series (12-16-storey panel buildings with years of construction from 1980 till present);

Figure 5 - Representative sixteen-story residential building

Figure 6 - Representative twenty-four-storey one entrance hall residential building

Figure 7 - Representative twenty-four-storey residential building with alternative energies

- APPS series (12-18-storey panel buildings with years of construction from 1984 till present);
- KTU series (12-18-storey panel, a modification of KT series taking into account demographics);
- ES series (10-18 –storey panel buildings of 1980-2000 years of construction).

An example of a representative sixteen-storey residential building is shown in Fig. 5.

Twenty-four-storey residential buildings overall have better energy characteristics, because the mass construction of these buildings began in the 90s of the last century and construction of these is carried out in large cities in the current century after the introduction of increased energy efficiency requirements. Examples of representative twenty-four-storey residential buildings are shown in Fig.6 and 7.

For each category of buildings, the standard operation is defined according to the climatic operation conditions and the main functional purpose. Climatic conditions are determined by temperature zones into which Ukraine is conditionally divided according to the provisions of DBN V.2.6-31.

The values of standard operation are spatial and temporal averages for all spaces of the building or thermal zone, including ancillary rooms, areas of movement, spaces with different design temperatures.

The energy needs of buildings are consequently determined:

- by climatic parameters of external environment;
- by parameters of internal environment and;
- by operation conditions.

Also, building energy characteristics are determined by indicators of engineering equipment, thermophysical properties of materials and products, thermal performance of thermal insulation skin; air consumption when ventilating construction project. The latter indicator considerably affects the energy balance of building and with modern requirements for envelope thermal performance, energy costs for air change can be more than a half of the total energy loss of building (Fig. 8). Frequency of air change is determined by functional purpose of building, which should be taken into account when establishing standard operating conditions of the reference building, which is especially relevant for public buildings.

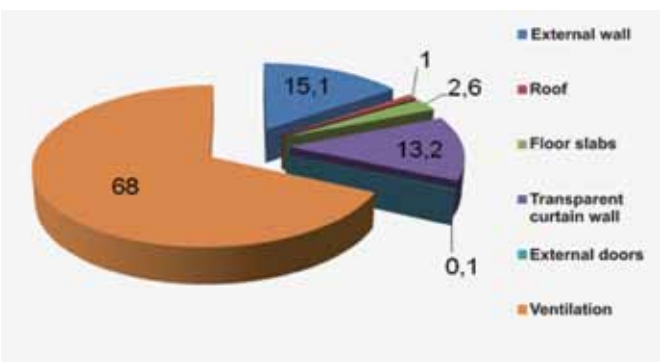

Figure 8 - Components of heat consumption of a new nine-storey residential building

Figure 9 - Facade of an administrative five-and/or six-storey building

Figure 10 - A representative public office building with a large area of glazing

A representative public administrative five- and/or six-storey building is shown in Fig. 9 and 10. A representative public building (trading company) is shown in Fig. 11.

When setting requirements for the buildings of educational and medical institutions one should take into account the increased requirements for air quality, natural light and a considerable proportion of envelope adjacent to the ground. Representative buildings of educational institutions are shown in Fig.12-14.

When finding reference buildings, there is the following classification:

- Residential buildings with storeys:
  - from 1 to 3
  - from 4 to 9
  - from 10 to 16
  - 17 and more
- Hotels
- Public buildings with storeys:
  - from 1 to 3
  - from 4 to 9
  - 10 and more
- Other public buildings:
  - educational institutions
  - preschool education institutions
  - health care facilities
  - trading companies
  - entertainment and leisure centers.

Energy performance of reference buildings is set for two temperature zones of Ukraine.

To determine the minimum requirements for energy performance of buildings of the appropriate class one should consider the following options to improve energy efficiency (table 2 –5):

Figure 11 - A representative public building (trading company)

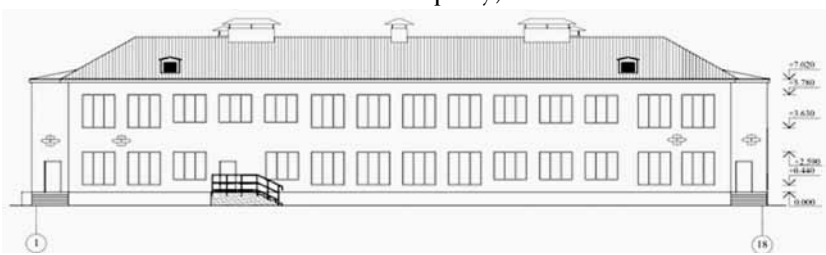

Figure 12 - Layout of the main facade of kindergarten

Figure 13 - Layout of the facade of lyceum

Figure 14 - Representative building of higher educational institution

Table 2 – Buildings constructed before 1994 with the values of reduced heat transfer resistance of envelope

Temperature zone of Ukraine	Reduced heat transfer resistance of envelope in m^2K/W			
	walls	windows	roofs	Floor slabs
I	0,8	0,35	1,2	1,0
II	0,8	0,35	1,2	1,0

Table 3 – Buildings constructed in the period from 1995 to 2006 with the values of reduced heat transfer resistance of envelope

Temperature zone of Ukraine	Reduced heat transfer resistance of envelope in m^2K/W			
	walls	windows	roofs	Floor slabs
I	1,5	0,5	2,5	2,1
II	1,5	0,5	2,5	2,1

Table 4 – Thermo-modernized buildings or new buildings constructed after 2006 according to the standards of DBN V.2.6-31: 2016, with the values of reduced heat transfer resistance of envelope

Temperature zone of Ukraine	Reduced heat transfer resistance of envelope in m^2K/W			
	walls	windows	roofs	Floor slabs
I	3,3	0,75	5,0	3,75
II	2,8	0,60	4,5	3,3

Table 5 – Thermo-modernized buildings or new buildings constructed after 2006 according to the standards of DBN V.2.6-31: 2016, with the values of reduced heat transfer resistance of envelope

Temperature zone of Ukraine	Reduced heat transfer resistance of envelope in m^2K/W			
	walls	windows	roofs	Floor slabs
I	3,67; 4,0; 5,0	0,9; 1,1; 1,2	6,0; 7,0; 8,0	5,0; 6,0; 7,0
II	3,3; 3,67; 4,0	0,75; 0,9; 1,0	5,0; 6,0; 7,0	3,75; 5,0;6,0

CONCLUSIONS

The main task of further research is to conduct analytical calculations and to develop scientifically sound proposals for establishing minimum requirements for thermal characteristics of envelope and energy efficiency requirements of buildings in accordance with economically feasible level and differentiated functional purpose of buildings, height and type of construction such as new construction, reconstruction, refurbishment and thermal modernization.

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