Збірник наукових праць. Серія: Галузеве машинобудування, будівництво

Academic journal. Series: Industrial Machine Building, Civil Engineering

http://journals.pntu.edu.ua/znp
https://doi.org/10.26906/znp.2019.52.1695

UDC 697.347

Energy performance of buildings in European Union countries and Ukraine

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Complex comparative analysis of building energy performance rates in EU countries and Ukraine has been carried out. The relation between building insulation rates and European countries climate condition has been investigated. It is illustrated that there is a significant gap between building energy efficiency characteristics in Ukraine and in most of the EU countries. Economically justified rates of building envelope heat exchange resistance which can lead Ukraine to common European level based on optimized calculations are suggested. The necessity for further increase in building envelope heat exchange resistance rates in order to raise building energy efficiency and put Ukrainian building regulations in harmony with EU countries corresponding norms is proved.

Keywords: energy performance of buildings, the structure of building energy consumption, building envelope heat exchange resistance, room temperature in winter time.

Енергоефективність будівель у країнах Євросоюзу та Україні

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Розглянуто стан та методи оцінювання енергетичної ефективності будівель у країнах Євросоюзу та Україні. З’ясовано, що вони суттєво відрізняються, це зумовлено кліматичними, економічними й історичними особливостями регіонів. Виявлено, що у деяких країнах ЄС регулярно переглядаються і підвищуються вимоги до енергетичних характеристик будівель. З’ясовано, що одним із головних показників енергоефективності будівель є теплотехнічні характеристики огороджувальних конструкцій і передусім їх опір теплопередачі. У всіх країнах установлено власні вимоги до теплозахисних характеристик огороджувальних конструкцій, які періодично змінюються, як правило, у бік збільшення. Таку динаміку зростання нормативних показників теплозахисту огороджень будівель в Україні простежено за останні півстоліття. Засвідчено, що за цей період вони зросли у 3,5 – 4 рази. Виконано комплексний порівняльний аналіз показників енергоефективності будівель у країнах Євросоюзу та в Україні за декількома показниками теплозахисту: опором теплопередачі огороджувальних конструкцій, відносними втратами тепла через огородження й температурним режимом житлових приміщень. Проаналізовано зв’язок показників теплової ізоляції будівель з кліматичними характеристиками для країн Європи. Показано, що за характеристиками енергоефективності будівель Україна суттєво відстає від більшості країн ЄС. На основі оптимізаційних розрахунків з урахуванням сучасної вартості теплової енергії та теплоізоляційних матеріалів запропоновано економічно обгрунтовані значення опору теплопередачі огороджувальних конструкцій, які за цим показником виведуть Україну на загальноєвропейський рівень. Підтверджено необхідність подальшого збільшення опору теплопередачі огороджень з метою підвищення енергоефективності будівель та гармонізації українських будівельних норм з нормативними вимогами країн ЄС.

Ключові слова: енергоефективність будівель, структура енергоспоживання будівель, опір теплопередачі, огороджувальні конструкції.

Introduction

The issues of energy efficiency and creating of corresponding micro climate within the building is the component of government energy saving policy. In 2017 Ukraine adopted the Law of Energy Performance of Buildings [1], which determined legal, social and economic as well as organizational operational principles in provision of construction energy efficiency and was aimed at reduction of energy consumption in buildings, mainly: ensuring building energy performance according to existing technical standards, national standards, norms and regulations; stimulation of energy consumption reduction in buildings; assurance of the reduction of greenhouse gases emission; provision of building thermal modernization and stimulation of renewable energy sources usage, development and implementation of the national plan concerning the expanding the number of buildings with energy consumption level close to zero ("passive houses"). Despite of the fact that for the latest decades building thermal protection level has grown significantly, heating energy costs still remain unreasonably high, especially in building without thermal modernization.

That is why it is reasonable to study and introduce European practices to ensure energy performance of buildings.

Review of research sources and publications

The issue of energy efficiency and energy saving has been studied in many papers of scientists from Ukraine and other countries: H.H. Farenyuk [2 – 5], Yu. A. Tabunshchykov [6], V. L. Kurbatov [7], Yu. A. Matrosov [8] and others. The researchers consider the methodological grounds for establishing norms and standards alongside with provision of reasonable values for energy performance of buildings and enclosing structures thermal reliability, the increasing of basic heating-performance rates of heat-insulating envelope major elements etc. But these studies, as well as some other, do not deal with the issue of optimal (economically feasible) level of thermal protection - enclosing structures heat transfer resistance - based on the criteria of cost given and often neglect common European experience.

Problem statement

Recommendations for economically feasible values of walls and surfaces heat exchange resistance for non-industrial buildings in Ukraine are given based on calculations and comparative analyses of buildings energy performance rates in EU countries and Ukraine, especially the building envelope thermal protection levels.

Basic material and results

The methodology for evaluating and regulating energy performance of buildings differs in EU countries and in Ukraine. This is determined by their climatic, economic and historical peculiarities. It also has a negative impact on the development of civil engineering in general and creates certain difficulties at common European market due to incompatibility of different building energy efficiency rates.

Some differences in calculating methods, in requirements to building thermal characteristics and methodology of their control can be observed, as well as the proposed measures of building regulations harmonization in the energy efficiency sphere. The group of EU experts conducted a research into the issues mentioned above in 13 countries: Belgium, Great Britain, Denmark, Italy, the Netherlands, Germany, Norway, Romania, Slovenia, Hungary, Finland, France and Sweden.

In all these countries active measures are taken on both levels of energy efficiency provision standards and technology and engineering. In some countries regulations are being revised every 2–3-years and the demands towards building energy efficiency are increased according to long-term programmes.

The analysis shows that countries in Central Europe follow EU and European Institutions regulations in a stricter way in comparison with the countries on the outskirts. The countries with cooler climate traditionally pay much more attention to general energy efficiency issues on the contrast to ones with more favourable weather conditions, where the emphasis are on the matters of reducing energy waste for cooling the interior in summer. Among the leaders in consistent energy efficiency policy implementation one can name Germany, France, Great Britain as well as Denmark and some new EU members like Slovenia [9].

In all countries energy costs for heating, hot water supply and ventilated air heating (including infiltration) are regulated. In many countries air cooling and conditioning expenses are also included. Besides, the electric energy consumption used by heating, ventilation and conditioning systems is, as a rule, controlled. The structure of building energy consumption according to construction standards in Finland can be taken as an example (Fig. 1).

Most of the countries use natural energy losses as a criterion to express energy performance of buildings which is as a rule given as K Wh/m² per year (in Italy K Wh/m³ per year). Only Great Britain and Romania use the amount of CO_2 emission as a criterion for energy performance of buildings. Natural energy use level coefficient differs significantly for various countries, thus in most cases it is equal to 1 for all the fuels and 2.5 for electric power [9].

One of the major indicators for energy performance of a building is its enclosing structures (building envelopes) thermal and technical characteristics, mainly heat exchange resistance. In all countries have their in-house requirements to enclosing structures characteristics which are being changed regularly with a tendency towards increasing (Fig. 1 according to data from [9]). Such dynamics of raising standards for building envelope heat exchange resistance values for non-industrial buildings in Ukraine for the last 50 years was investigated in [10]. The study shows that within this period these values increased for 3.5–4 times. In some countries (Italy, Spain, France) the values of enclosing structures characteristics can vary according to the region depending on climatic conditions, determined by location, including proximity to the sea and the altitude. Using the same principal and with accordance to existing regulations [11], the territory of Ukraine is divided into two temperature zones with minimal required values for residential and civil building heat exchange resistance R = 3.3 m²·k/W in the first zone and R = 2.8 m²·k/W for the second one. The first zone includes central, western and northern regions of Ukraine, the second one - its southern parts.

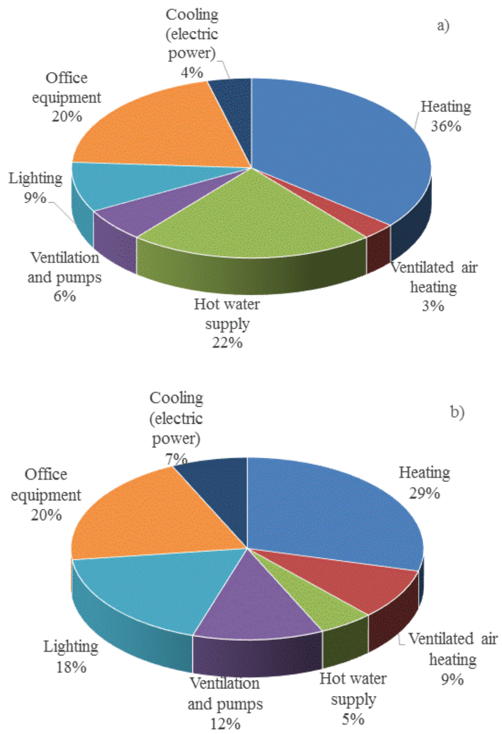

Figure 1 – The structure of building energy consumption in Finland:
a – one apartment building with total power consumption (heat and electric power) 78 K Wh/(m²·year);
b – office building – 123 K Wh/(m²·year)

Sometimes heat exchange resistance values in European countries can differ for residential and civil building as well as for building of different shapes. In Italy, Denmark, Slovenia and Germany (for residential buildings) heat exchange through enclosing structures is limited by usage of mid value of thermal characteristics and in Hungary - by demand for heating power. Finland and Norway use less severe requirement to thermal protection in wooden structures aiming at preserving traditional wooden house construction. In Sweden significantly higher building envelope heat exchange resistance values are set for buildings with electric heating.

Thermal protection values for translucent enclosing structures (windows) are also calculated and standardised in all the countries, including Ukraine [9, 11]. However, in Finland, besides this characteristic, limitations are set for areas covered by translucent enclosing structures.

In many European countries there are measures to reduce heat input with solar radiation, but only several as well set the limits for the numerical values of heat inputs with solar radiation through translucent enclosing structures (so-called g-window factor). In Ukrainian State Construction Regulations [11], instead, there are requirements for some regions to make calculation for heat resistance in summer time for structures with relatively low thermal inertia, which are based on setting limitation for temperature fluctuation amplitude at external enclosing structure surface.

Table 1 – Thermal resistance enclosing structures necessary values in Europe

Europe	Norms introduction year	Average January temperature τ_c	Walls		Roofs	
			R_0	$\Delta\tau/R_0$	R_0	$\Delta\tau/R_0$
Belgium	2008	2	2.00	9.00	3.33	5.41
UK	2010	3	5.55	3.06	6.67	2.55
Denmark	2006	0	5.00	4.00	5.56	3.60
Italy	2010	5	3.03	4.95	3.45	4.35
Nether-lands	2011	2	3.45	5.22	3.45	5.22
Germany	2009	-1	3.57	5.88	5.00	4.20
Norway	2007	-7	5.56	4.86	7.69	3.51
Romania	2006	-2	1.41	15.60	3.03	7.26
Hungary	2006	-1	2.22	9.46	4.00	5.25
Ukraine	2013	-5	3.30	7.58	4.95	5.05
Finland	2010	-8	5.88	4.76	11.11	2.52
France	2005	3	2.78	6.12	5.00	3.40
Sweden	2008	-6	5.56	4.68	7.69	3.38

As it is given in Table 1, the parameters given can change in different countries within a wide range. For instance, average temperature in January varies from –8˚C in Finland to +5˚C in Italy. Necessary heat exchange resistance values for walls are set within the range of 1.41m²·k/W in Romania up to 5.88 m²·k/W in Finland, and ones for the roofs are from 3.03 m²·k/W in Romania to 11.11m²·k/W in Finland.

In Fig. 2 there are dependencies of standard walls and roofs heat transfer resistance from average temperature in January in different countries. As one can see from this figure, there is not any proportional or other kind of dependency between those parameters, though logical tendency for increasing of required walls and roofs heat transfer resistance values at lower average January temperature is observed.

In both graphs points that reflect requirements of the UK norms are to bigger side and values for Romania are to lesser side. The dot with large luminous marker, which reflects Ukrainian standards [11], is also on lower bound of both dependencies, indicating certain understatement of requirements [11] compared with other European countries.

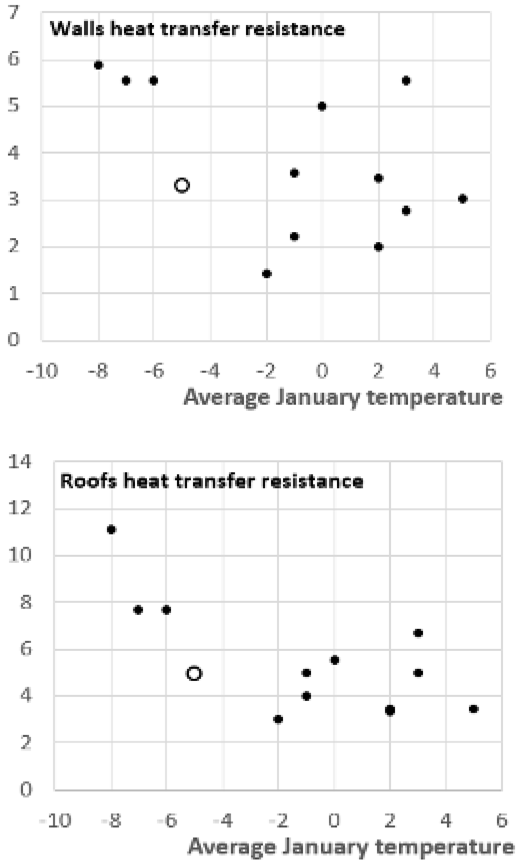

Figure 2 – Heat transfer resistance dependence from average January temperature

Table 1 also shows temperature difference ratio between internal and external air $\Delta\tau$ = 20ºC – τ_c to walls and roofs heat transfer resistance required R_0. This value is proportional to heat losses through enclosing structure and can serve as a material for analysing compliance of walls and roofs thermal characteristics of their operation climatic conditions. According to Table 1, values $\Delta\tau/R_0$, diagrams, shown in Figure 3, are plotted, indicating buildings thermal insulation relative efficiency in European countries.

Figure 3 diagrams indicate some requirements imbalance for walls and roofs in different countries. For example, France occupies 9th place for wall constructions effectiveness and 4th place for roofs effectiveness. The smallest heat losses are provided by Northern Europe designing norms, and the greatest heat losses are allowed by standards in Romania. Ukrainian norms for buildings thermal insulation [11] are in the 9...10th position among the 13 countries considered, with relative efficiency. This is confirmed by the results of dependencies analysis in Figure 1 and indicates increasing requirements expediency for required to enclosing structures heat transfer resistance in Ukraine.

In the research [12] by minimizing total reduced costs for enclosing structures building and heat energy cost for heating buildings, appropriate dependences of walls and roofs heat transfer resistance to thermal energy cost C_T: $R_C = 0.16\sqrt{C_T}$, $R_П = 0.21\sqrt{C_T}$ are obtained. Calculation according to these formulas indicates that according to existing norms [11] minimum required heat transfer resistance values of walls R_{0C} = 3.3 м^2·K/W and roofs $R_{0П}$ = 4.95 м^2·K/W correspond to thermal energy cost 425...556 UAH/Gcal.

At current heat cost about 1400 UAH/Gcal, walls heat transfer resistance in accordance with above formulas should be set equal to R_{0C} = 6.0 m^2·K/W, and for the roofs $R_{0П}$ = 7.9 m^2·K/W. Figure 2 shows that these values are in line with general trend for Europe. In this case, heat losses relative index through walls is $\Delta\tau/R_{0C}$ = 4.2, and through roofs v$\Delta\tau/R_{0П}$ = 3.2. It is evident from Table 1 and Figure 3 that such indicators lead buildings Ukrainian norms for thermal isolation to third place among 13 considered European countries.

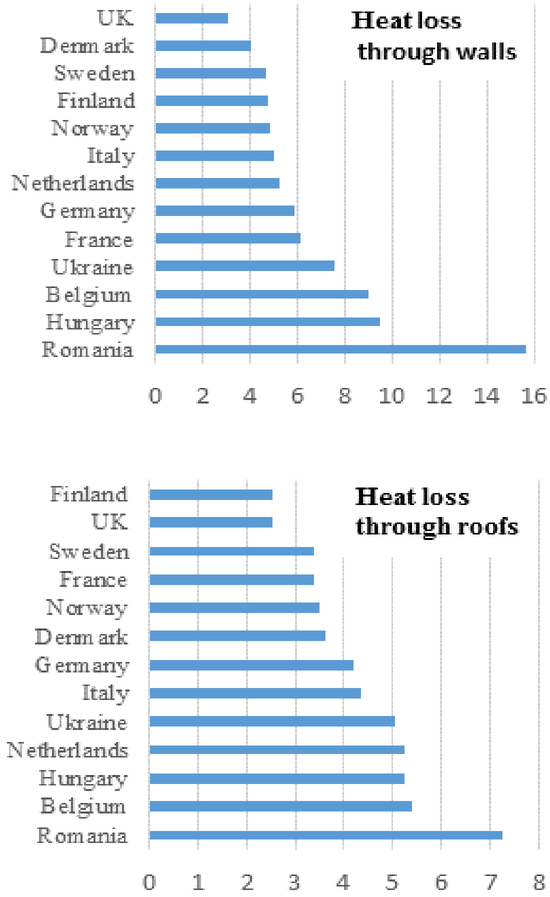

Figure 3 – Heat loss through enclosing structures relative indicators

German company Tado, which produces intelligent thermostats that are connected directly to the Internet, published interesting statistical data of average overnight (lower) temperatures that the users maintain in their apartment or house bedrooms. Data was obtained from tens of thousands of thermostats installed in different European countries (Table 2) [13].

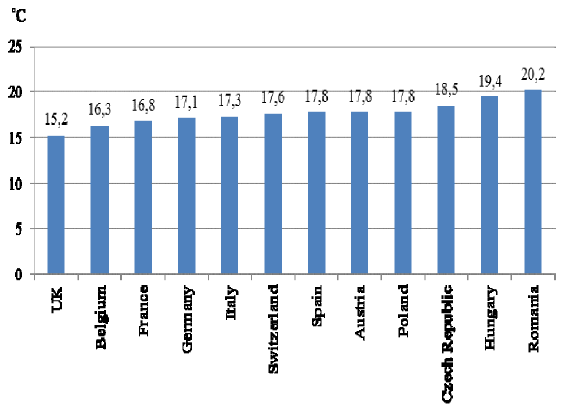

Figure 4 – Average overnight temperatures in bedrooms in European countries (winter time)

Calculated temperature in rooms in Ukraine is 20˚C as it is set by the design specification [14]. If to assume that actual temperature in winter is close to that value, then Ukraine is next to Romania according to this energy saving rate.

As it appears, Britons tend to save more and keep the average temperature at 15.2˚C at night. The highest temperature is in Romania – 20.2˚C. It is notable that data from Table 2 corresponds well to the heat losses through enclosing structure values given in Fig. 3. It means that such countries as Great Britain as well as some others take the systemic approach to heat energy saving: Adopt high levels of building envelope heat exchange resistance and, at the same time, maintain relatively low temperatures inside in winter. The conclusion that can be made based on the given data is the more prosperous the country is, the more practical its residents are, and vice versa, if the citizens take more reasonable approach to energy saving, it can help the country to thrive.

Conclusions

The analysis made has indicated that in terms of building energy saving and energy efficiency rates Ukraine takes one of the last positions in Europe. The actual requirements to building for thermal isolation do not correspond to common European standards and call for increasing of minimal heat transfer resistance value for enclosing structures. It should be applied to both newly constructed buildings and thermal modernization of already existing ones. The proposed economically justified values for walls and roofs heat resistance based on calculation with account for current power costs can help Ukraine take its thermal protection standards to European level.

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