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ECONOMIC FEASIBILITY OF ENERGY-EFFICIENT AND PASSIVE HOUSE CONSTRUCTION IN UKRAINE

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Formulation of the problem. The new version of the European Union Directive on the energy efficiency of houses requires bringing construction standards and requirements of the European countries for the house construction with minimal energy consumption, namely houses with a high level of energy efficiency. Considering the difficult economic situation in Ukraine, there is the economic component of energy efficiency, based on an economic assessment of the design solutions feasibility to housing. On that basis, the urgent problem in low-rise housing construction of Ukraine is improving scientific statements of the energy-efficient building design based on life cycle.

The main objective is to present the theoretical principles of rational design methods of energy-efficient low-rise residential buildings to meet their life cycle, as well as coverage obtained with the developed technique results.

The basic material research presentation. The methodology of residential building rational design is based on calculating the total (discounted) value method that is to bring the total cost for the construction site building and dismantling, as well as the costs of operating a residential building for the entire lifetime of the estimated amount in the year of house expected demolition (accrued expenses).

The total costs for construction, operation and dismantling of the building are defined according to correspondence:

$$3_{i,t} = \mathrm{K}_i g^t + E_i \frac{g^t - 1}{g - 1} + D_\mathrm{i}, \qquad (1)$$

where K_i – capital investments for the building construction in accordance with *i*-variant;

E_i – annual operating costs of building maintenance according to *i*- variant;

D_i – costs associated with the removal of building project (disposing its building materials);

t – life cycle (service life), year;

g – build-up factor: $g=1+p$;

p – discount rate that equals the investor's acceptable profit rate divided by capital;

g^t – discount factor (present value factor) at the end of the billing period: $g^t=(1+p)^t$;

$(g^t-1)/(g-1)$ – growth factor of current payments, equated to the future point in time for a number of homogeneous periods of payments.

Mathematical task model of finding an optimal energy-efficient building is formulated in the form of a nonlinear programming task: to minimize the total costs of the building construction, operation and dismantling (1) under certain restrictions. Taking into account the cost components, mathematical model is:

$$3_{i,t} = \left(\Pi 3 + HP + C\Pi + IC + \Pi_p 3\right)_i g^t + \\ + \left[\begin{array}{l} \mathrm{C}_{heat} \times Q^{heat} + C_{el} \times Q^{el} + C_v \times \mathrm{V}^v + C_{gas} \times \mathrm{V}^{gas} + \\ + 0.0245\left(\Pi 3 + HP + C\Pi + IC + \Pi_p 3\right) \end{array}\right]_i \frac{g^t - 1}{g - 1} + D_{\mathrm{i}} \to \min \quad (2)$$

ПЗ – direct expenses;

HP - overhead;

СП – estimated profit (planned savings);

IC – the purchase and installation cost of process equipment and engineering systems;

$П_p З$ – other costs associated with additional costs for construction and installation and commissioning in the winter time, the costs for construction of temporary buildings and structures, etc.

C_{heat} – thermal energy cost (UAH / Gcal);

C_{el} – electricity cost (UAH/kW per per year);

C_v – water supply cost (UAH/m^3);

C_{gas} – gas cost (UAH/m^3);

Q^{heat} – annual heat consumption of the building during the heating period, Gcal;

Q^{el} – annual electricity consumption of the building, kW per per year;

V^v – annual water consumption of the building, m^3;

V^{gas} – annual gas consumption of the building, m^3

Limitations of the optimization task are::

- The duration of the heating period, *GD*;
- The cost of heat, electricity, gas and water;
- The building service life *t*, years;
- The rate of investment capital *p* - 0 ... 20%;
- Specific fuel consumption *q*, kW per year/(m^2·year),

The mathematical model (2) allows to determine the economic feasibility of energy efficiency and passive houses, and also to assess the investment attractiveness of the various innovative energy-saving technologies in Ukraine. So it is necessary to compare housing projects versions, using, as a constraint optimization tasks, specific heat consumption q, kW*year/(m^2·year), which should be compared with control flow coefficients of heat energy:

- according to current standards $q \le E_{max}$, kW*year /(m^2·year);
- with the standards of a low-energy house $q \le 70$ kW per year/(m² year);
- with the standards of a passive house $q \le 15$ kW per year/(m² year).

The best option of an energy-efficient building is a rational combination of structural engineering and technological content of the building energy efficiency, which will provide the minimum total cost of the construction, operation and dismantling.

The offered method was used to solve the problem of finding the optimal alternative project of low-rise buildings for energy efficiency conditions of Ukraine.

Based on the main version (two-storey building with a wooden frame) seventeen versions of the building project have been designed and analyzed, they are different construction capital costs and thermal energy consumption in the facility operation (Table 1).

Table 1

Energy-efficient house varieties

varieties No.	Project Description	Capital construction Investments UAH. * (€)*	Specific Heat Consumption, $q_{буд}$, kW per year/m^2	Energy Efficiency Class	
				According to State Building Standards	European Classification
1	2	3	4	5	6
1	Basic version (insulation walls thickness – 100mm; attic floor – 200mm; ground floor – 50mm; windows – single-glass unit)	342 978,0 (32 054 €)	96,1	B	"New house" to 150 kW per year/m^2
2	Additional wall insulation by 50mm	352 804,8 (32 972 €)	87,5	B	"New house" to 150 kW per year/m^2
3	Additional wall insulation by 100mm	362 624,4 (33 890 €)	82,3	B	"New house" to 150 kW per year/m^2
4	Additional insulation in the attic floor by 50mm	346 324,8 (32 367 €)	94,2	B	"New house" to 150 kW per year/m^2
5	Additional insulation in the attic floor 100mm	349 664,4 (32 679 €)	92,9	B	"New house" to 150 kW per year/m^2
6	Additional floor insulation on the ground by 50mm	344 473,2 (32 194 €)	92,8	B	"New house" to 150 kW per year/m^2
7	Additional floor insulation on the ground by 100mm	345 960,0 (32 332 €)	90,9	B	"New house" to 150 kW per year/m^2

varieties No.	Project Description	Capital construction Investments UAH. * (€)*	Specific Heat Consumption, $q_{буд}$, kW per year/m^2	Energy Efficiency Class	
				According to State Building Standards	European Classification
8	Additional wall insulation by 50mm; attic floor by 50mm; ground floor by 50mm	357 632,4 (33 424 €)	82,3	B	"New house" to 150 kW per year/m^2
9	Additional wall insulation by 100mm; attic floor by 100mm; ground floor by 100mm	372 278,4 (34 792 €)	73,8	B	"New house" to 150 kW per year/m^2
10	Double- glass unit installation R=0,8 m^2*K/W	347 817,6 (32 506 €)	87,3	B	"New house" to 150 kW per year/m^2
11	Double- glass unit installation R=1,14 m^2*K/W	354 987,6 (33 176 €)	81,4	B	"New house" to 150 kW per year/m^2
12	Additional wall insulation by 50mm; attic floor by 50mm; ground floor by 50mm Double-glass unit installation R=0,8 m^2*K/W	362 472,0 (33 876 €)	73,4	B	"New house" to 150 kW per year/m^2
13	Additional wall insulation by 100mm; attic floor by 100mm; ground floor by 100mm Double--glass unit installation R=1,14 m^2*K/W	384 288,0 (35 915 €)	58,9	A	"Low power consumption house" to 70 kW per year/m^2
14	Installation of waste heat exchangers (recuperator)	372 034,8 (34 770 €)	65,9	B	"Low power consumption house" to 70 kW per year/m^2

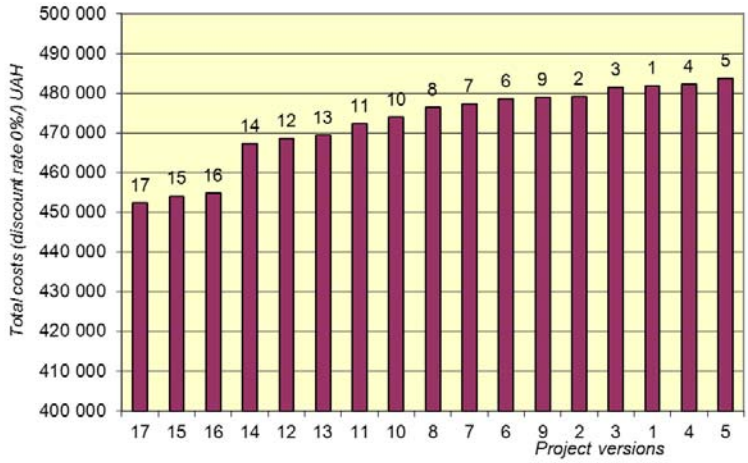
varieties No.	Project Description	Capital construction Investments UAH. * (€)*	Specific Heat Consumption, $q_{буд}$, kW per year/m^2	Energy Efficiency Class	
				According to State Building Standards	European Classification
15	Additional wall insulation by 50mm; attic floor by 50mm; ground floor by 50mm Double--glass unit installation R=0,8 m^2*K/W Installation of waste heat exchangers (recuperator)	391 528,8 (36 592 €)	43,3	A	"Low power consumption house" to 70 kW per year/m^2
16	Additional wall insulation by 100mm; attic floor by 100mm; ground floor by 100mm Multiple-glass unit installation R=1,14 m^2*K/W Installation of waste heat exchangers (recuperator)	413 344,8 (38 630 €)	28,7	A	"Low power consumption house" to 70 kW per year/m^2
17	Passive house	431 016,0 (40 282 €)	14,8	A	"Passive house" to 15 kW per year/m^2

Note.
* - capital costs value for the construction of houses (including VAT) with no cost of engineering equipment and communications, excluding overhead and deductions, and net profit

These versions differ in the level of frame filling thermal protection and using a variety of energy-efficient engineering. All the versions, starting from the basic one, with a specific heat consumption 96.1 kW per year/ m^2, to the passive house ($q_{рік}$= 15 kW per year/ $м^2$), satisfy the requirements of the applicable building standards (efficiency classes - A and B). Maximum allowable regulatory heat for payment options is E_{max} =122 kW per year /m^2.

The data presented in Table 4 show that rising in price of the passive house (Variant 17) compared to the baseline (Variant 1) is 25,7%.

a)



b)

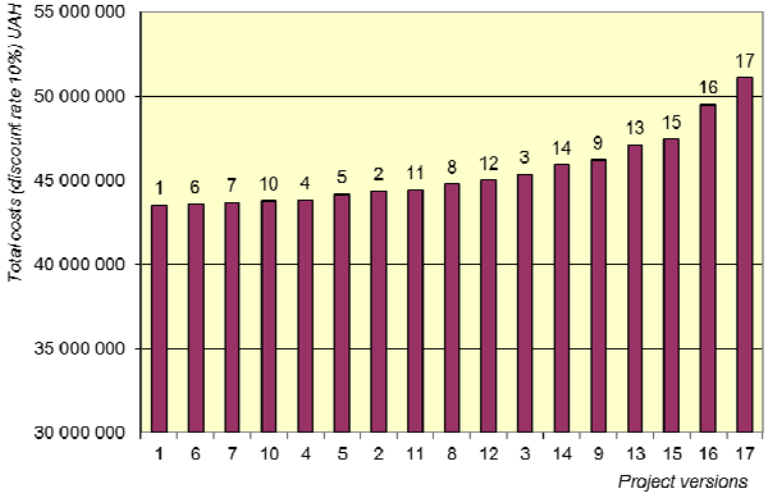


Fig. 1. Housing projects total cost of low-rise residential apartment building by the versions 1 … 17 for the conditions of Ukraine, at a discount rate: а) – 0%; б) – 10%; with the cost of heat energy - 268,74 UAH/Gcal (25 €/Gcal); service life - 50 years

The rational design problems have been set and solved in this work (the search for a rational project version of seventeen offered – see Table 1) with the following restrictions:

- the building service life is 50 years at the current cost of energy - 25 €/Gcal (a graphical result representation is shown in Fig. 1);
- the building service life is 50 years at various projected energy cost – 75 €/Gcal;
- the building service life is 20 years at the current energy cost.

Conclusions. The calculation results show that excluding changes in the value of money over time (discounting) the best option is the passive house. When taking into account changes in the value of money over time (discount rate 10%, 15%, 20%) - the best is the basic version (see Fig. 1). These calculations show that the introduction of passive housing in Ukraine today is economically feasible only in case of interest-free loans.

LIST OF APPLIED SOURCES

1 Коваль Е.А. Энергоэффективность архитектурно-конструктивных систем малоэтажных жилых зданий: Дис. канд. техн. наук: 05.23.01. / Коваль Е.А. – Днепропетровск, 2012. – 152с.

2 Савицкий Н.В. , Юрченко Е.Л. , Коваль Е.А. Совершенствование методики рационального проектирования малоэтажных жилых зданий с учетом их жизненного цикла / Н.В. Савицкий , Е.Л. Юрченко, Е.А. Коваль , Т.А. Ковтун-Горбачева // Theoretical foundations of civil engineering. – Warsaw: WUT, 2011. vol. №19/ – p. 307-312.

3 Савицький М.В. , Коваль О.О. , Юрченко Є.Л. Екологічне та енергоефективне малоповерхове будівництво / М.В. Савицький, О.О. Коваль, Є.Л. Юрченко, М.М. Бабенко, А.С. Коваль // Строительство, материаловедение, машиностроение. Дн-вск: ПГАСА, 2010. – Вып. №55 - С. 26 -31.

4 Коваль О.О., Лантух О.В. , Юрченко Є.Л. Стандартизація будівельних нормативів по підвищенню енергоефективності на Європейскому рівні / О.О. Коваль, О.В. Лантух, Є.Л. Юрченко, А.С. Коваль // Строительство, материаловедение, машиностроение. Дн-вск: ПГАСА, 2010. – Вип. №56 – С. 204-207.

5 Юрченко Є.Л., Коваль О.О. Проектування енергоефективних малоповерхових житлових будинків / Є.Л. Юрченко , О.О. Коваль // ЕКОінформ: 2011. - №5. – С.43.