

The feasibility of energy efficiency class improving of a building from economic point

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Abstract. In this article 4 complexes energy efficiency measures for different energy efficiency classes are chosen, it is defined the thermal heating costs of the building during the heating period, it is defined the cost and the payback period of energy efficiency measures. The conclusion about the feasibility of capital repair of buildings by increasing energy efficiency class from an economic point of view is made.

1 Introduction

In Russia at the present time the potential of energy savings is 35 % to 45 % of total modern energy consumption, which 350-460 million tons is conditional fuel. Among the reasons indicated huge potential energy saving the main are technological imperfection of fixed assets, the traditional energy squandering and mismanagement, poorly managed and do not have modern technical means consumption of energy resources, lack of standardization and certification of energy consumption, lack of application of methods of energy management [1-3].

The most effective use of energy resources of the country for the revival and subsequent recovery and provide a decent life for the population declared main goal of the energy strategy of Russia since 1995. If we consider that the Russia total area of operated buildings is about 4.8 billion m² and heating annually is 400 million tons of fuel equivalent, or 25% of the annual energy countries, it is quite obvious priority role of energy efficiency measures [4, 5].

The efficiency of the economy is the key to sustainable economic development, preservation of the natural environment. Improving energy efficiency leads to energy savings, the cost to them. One of the possible ways of improving energy efficiency is a capital repair and modernization of existing buildings by improving energy efficiency measures [6, 7].

The purpose of this article is to analyze the feasibility of capital repair of buildings by improving energy efficiency class from an economic point of view.

2 Input data

For calculation and the analysis the building of preschool institution was taken.

Design conditions and heat energy parameters of the buildings for the climatic conditions of St. Petersburg adopted according to SNiP 23-01-99* are presented at Table 1.

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Table 1. The design conditions.

The characteristics	Symbol parameter	Unit of measure	Value
Design temperature of inside air	t_{int}	°C	-26
Design temperature of outdoor air	t_{ext}	°C	-0.9
The duration of the heating period	z	day/years	239
Heating degree day	D_d	°C·day/years	5473
Mean temperature of outdoor air	t	°C	22

Areas of external structure of building heated volume are presented at the table 2.

Table 2. Areas of external structure.

Type of structure	Areas of structure A_i , m ²
External structure A_s	807.2
Windows A_w	457.8
Entrance external doors A_d	50.7
The combined covering A_c	1218
The overlapping A_o	1186
The total area A_{tot}	3719.7

Design structure of the building is presented at table 3.

Table 3. Areas of external structure.

Type of structure	Characteristic	Materials			
		gypsum cement	slag brick	mortar	ceramic wall tile
External structure	δ , mm	0.005	0.51	0.02	0.01
	λ , (W/m ² ·°C)	0.35	0.58	0.3	1.7
Covering		rubberoid	mortar	foamed concrete	ferro-concrete
	δ , mm	0.02	0.02	0.125	0.18
	λ , (W/m ² ·°C)	0.17	1.2	0.3	1.7
Flooring		linoleum	floor batts	ferro-concrete	
	δ , mm	0.01	0.025	0.2	
	λ , (W/m ² ·°C)	0.33	0.041	1.7	
Door		wood door			
	λ , (W/m ² ·°C)	0.26			
Window		triple-pane glass			
	λ , (W/m ² ·°C)	0.3			

3 Thermotechnical calculation

By calculation we received:

$$Q_h = 3441704.09 \text{ (MJ)}$$

$$Q_{\text{int}} = 417390 \text{ (MJ)}$$

$$Q_s = 170739 \text{ (MJ)}$$

Then the amount used of energy on heating of buildings during heating season is calculated by formula 1.

$$Q_h^y = [Q_h - (Q_{\text{int}} + Q_s) \cdot \nu \cdot \xi] \cdot \beta_h \quad (1)$$

$$Q_h^y = 3324145.916 \text{ (MJ)}$$

Then the specific drain of energy on heating of building is calculated by formula 2.

$$q_h^{\text{des}} = \frac{10^3 \cdot Q_h^y}{V_h \cdot D_d} \quad (2)$$

$$q_h^{\text{des}} = 76,76 \text{ (kJ/(m}^3 \cdot \text{ }^\circ\text{C} \cdot \text{day))}$$

For the two-storeyed building of preschool institution required specific drain of energy on heating of building equal to= 38 kJ/ (m³·°C·day).

Then value of deflection calculated specific drain of energy on heating of building from standard requirements is equal 102 %. It means this building corresponds to a class E («very low»).

4 Improvement of building structures for the purpose of energy efficiency increase

We modernize the building characteristics; we will improve its class of energy efficiency by the way of selection necessary energy effective measures.

Advanced building structures are chosen to improve the building characteristics to class D:

- Add insulation for wall - Venti Batts, $\delta = 0.1\text{m}$, $\lambda = 0.04$
 - Add insulation for roofing - Roof Batts, $\delta = 0.1\text{m}$, $\lambda = 0.041$
 - Increase insulation for flooring - Floor Batts, $\delta = 0.05\text{m}$, $\lambda = 0.041$
 - Door is the same wood door
 - Change window construction to the glass cellular block 244x244x98mm, $\lambda = 0.33$
- Advanced building structures are chosen to improve the building characteristics to class C:
- Increase insulation for wall - Venti Batts, $\delta = 0.2\text{m}$, $\lambda = 0.04$
 - Increase insulation for roofing - Roof Batts, $\delta = 0.2\text{m}$, $\lambda = 0.041$
 - Increase insulation for flooring - Floor Batts, $\delta = 0.1\text{m}$, $\lambda = 0.041$
 - Change door construction to the plastic door with one chamber glass, $\lambda = 0.35$
 - Change window construction to the triple-pane glass in single transom of ordinary glass with 8mm distance between glass panes, $\lambda = 0.50$

Advanced building structures are chosen to improve the building characteristics to class B:

- Change the wall configuration is presented at table 4.
- Change insulation s for roofing - Polyurethane foam, $\delta = 0.15\text{m}$, $\lambda = 0.019$
- Change insulation for flooring - Polyurethane foam, $\delta = 0.15\text{m}$, $\lambda = 0.019$
- Change door construction to the plastic door with the triple-pane glass, $\lambda = 0.49$
- Change window construction to the two one-chamber glasses in twin sashes, $\lambda = 0.80$

Table 4. Construction of the new wall.

Material	λ , (W/m ² ·°C)	δ , mm
Plaster	0.9	0.01
Gas concrete	0.12	0.3
Polyurethane foam	0.019	0.15
Air gaps	0.022	0.05
Ceramic granite tile	0.2	0.07

5 The technical-economic analysis

5.1 The calculation of thermal energy cost

To similarly previous calculation thermal losses for each type of designs of a certain energy efficiency class were calculated and costs of the thermal energy for the heating during the heating period are defined. The costs of the construction are defined. Results are presented at Table 5.

Table 5. The annual thermal energy cost on building heating at the accounting of losses only through external enclosure structures.

Class of energy efficiency	Costs of the construction, millions	Cost of heating, millions/year
E	1.32	1.00
D	2.60	0.67
C	4.88	0.49
B	6.05	0.37

The change of construction characteristic and heating cost by energy efficiency class upgrade is presented at Figure 1. As a characteristic we choose transmission factor of heat transmission (Ktr). It depends on the construction layers and determinate by Russian standards. There is obvious fact than cost of the construction directly correlated with that factor. In case of cheaper structure it will be increasing of transmission factor and, accordingly, increasing heating cost [8-11].

Total costs of heating of the building and of a design taking into account growth of tariffs for each class on energy efficiency are presented at Figure 2. The minimum values for each year show the relevance of using the energy efficiency class for each period of time. Thus, during the first three years changing of class does not entail a sum cost benefit. In the span of 3-7 years, becoming the most profitable using of Class D [12, 13]. In considering the service life of more than 7 years it should be used a class B.

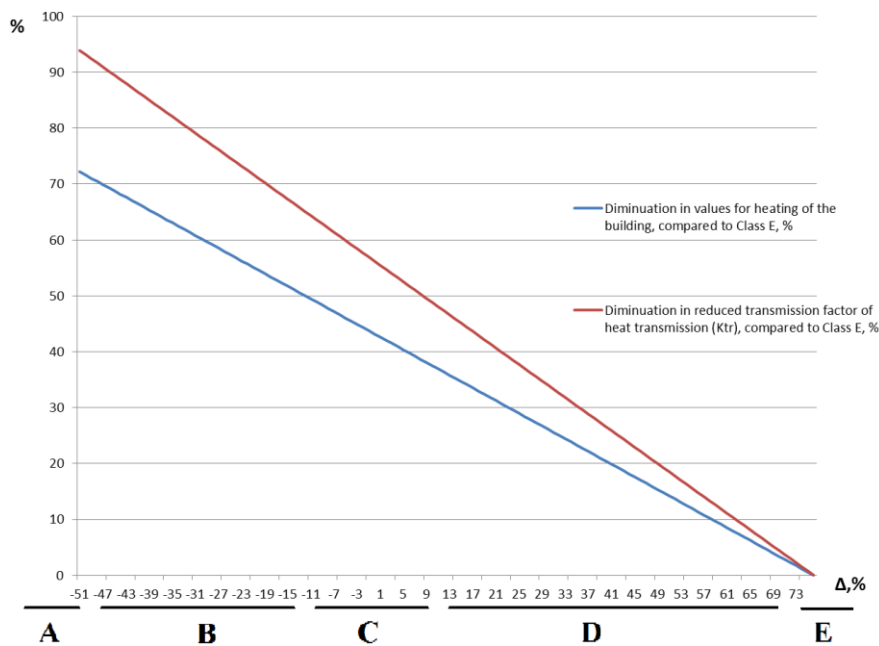


Figure 1. The schedule of change of construction characteristic and heating cost by energy efficiency class upgrade.

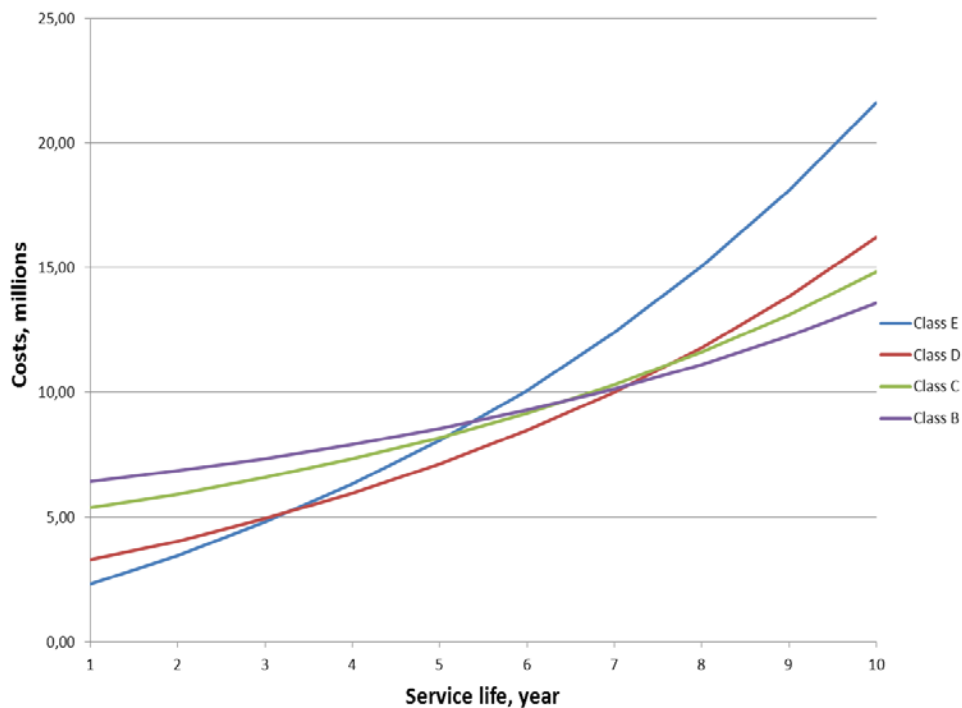


Figure 2. The dependence of total costs from service life.

5.2 The calculation of payback period

We will calculate a payback period of additional costs for a structure due to economy of thermal energy [14]. Additional costs are calculated as a difference between costs of construction (class E) and construction (other class). The economy of thermal energy is a difference between costs of the thermal energy used at application of construction (class E) and construction (other class). Costs of thermal energy are expressed in millions rubles. The payback period is calculated taking into account the average annual growth of tariffs 15% a year [15, 16]. Data for construction of a graph are presented in the Table 6.

Table 6. The annual thermal energy cost on building heating at the accounting of losses only through external enclosure structures.

Class of energy efficiency	Service life of the building , years/ Balance with accumulation, millions rub.							
	0	1	2	3	4	5	6	7
D	3.27	3.94	4.61	5.28	5.95	6.62	7.29	7.96
C	5.37	5.86	6.35	6.84	7.33	7.82	8.31	8.8
B	6.42	6.79	7.16	7.53	7.9	8.27	8.64	9.01

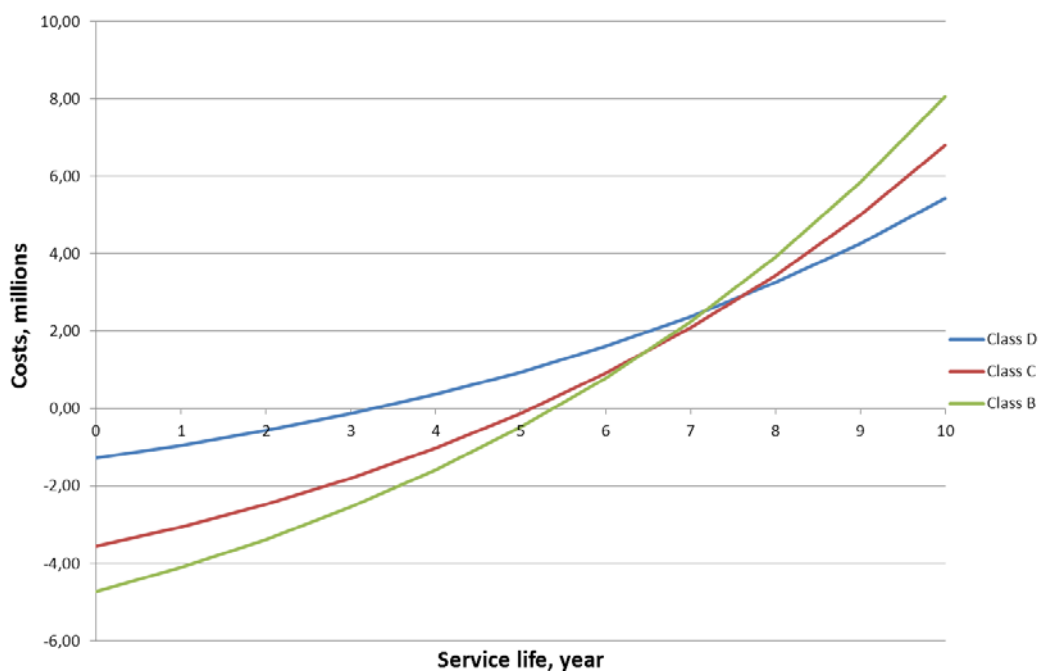


Figure 3. The schedule of payback period.

6 The conclusion

The thermal energy losses through the external structures of the building with the requirements of energy efficiency class C will be 33% less in comparison about the building constructed according to requirements of energy efficiency class E. And thermal energy costs will increase almost twice. The thermal energy losses through the external structures of the building with the requirements of energy efficiency class D will be 51% less in comparison about the building constructed according to requirements of energy efficiency class E. And thermal energy costs will increase to 3.5 times. The thermal energy losses through the external structures of the building with the requirements of energy efficiency class B will be 63% less in comparison about the building constructed according to requirements of energy efficiency class E. And thermal energy costs will increase to 4.5 times.

Modernization of the building by improve of a class of energy efficiency is expedient in case of long-term investment of capital. The payback period of the modernized designs due to economy of the thermal energy spent for heating of the building during the heating period at capital repairs of the building by improvement of a class with E on a class D makes 3 years, on a class C - 5 years, on B class - 6 years.

Using of a class C isn't relevance because the general costs of a class C aren't minimum in comparison with other classes for each year.

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