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Technical solutions and technologies for energy-efficient overhaul of apartment buildings

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Abstract. The study presents a comparative analysis of technical solutions and technologies for energy-efficient capital repairs of apartment buildings. The purpose of the study is to determine the most effective ways to increase the energy efficiency of a residential building by carrying out repair work. The methodological approaches of the study are based on a statistical analysis of the data on the results of major repairs in the practice of world construction. According to the results of the study, it was found that when planning major repairs in order to reduce energy consumption, special attention should be paid to choosing a set of technical solutions that collectively contribute to improving the energy efficiency of a residential building. The analysis showed that with the introduction of modern energy-saving technologies, the overhaul of apartment buildings makes it possible to modernize each building, increasing its level of energy efficiency and prolong its service life for at least a quarter of a century, which as a result improves the quality of life of citizens and accelerates the economic growth of the country. In our opinion, taking into account the international experience of reducing heat losses and energy consumption in residential apartment buildings, it is necessary to adopt new rules establishing approaches to determining the energy efficiency class and appropriate labeling of construction products, with a transition from using a relative indicator (deviations of the actual or projected annual specific energy consumption from the normative value) to setting minimum and maximum values (ranges of values) of energy consumption in apartment buildings for each energy efficiency class.

Keywords: energy efficiency, major repairs, apartment buildings, technical solutions, technologies, translucent structures, enclosing structures, thermal conductivity, electricity

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1. INTRODUCTION

In the modern world, where environmental problems and climate change are becoming more and more urgent, the need to systematize the classification of construction products by energy efficiency classes comes to the fore. This concept not only meets the challenges of the time, but also serves as the basis for the sustainable development of the construction industry, ensuring the harmonious coexistence of man and nature.

First of all, it is worth noting that the construction industry is one of the main sources of negative environmental impact. The construction and operation of buildings require significant amounts of energy, which leads to high carbon emissions and depletion of natural resources. In the context of global climate change, it becomes critically important to minimize this negative effect [1-3].

Economic benefit also plays a key role in the need to systematize classification. Energy-efficient buildings require lower heating and air conditioning costs, which reduces operating costs. The classification allows consumers and developers to easily find profitable solutions, which makes real estate investments more attractive. In the context of rising energy prices and an unstable economic situation, such aspects are becoming especially important for end users [4-6].

The quality of life is another significant aspect that cannot be ignored. Energy-efficient buildings provide the best microclimate, which directly affects the comfort and health of their residents. The systematization of classification helps to choose materials and technologies that contribute to the creation of optimal living and working conditions. Thus, consumers get the opportunity not only to save money, but also to improve their quality of life [7, 8].

In addition, standardization and classification create a competitive environment for manufacturers of building materials. This stimulates the development of new solutions and technologies, which contributes to innovation in the industry. In a rapidly changing world where technology is developing at a tremendous rate, such dynamics are necessary to maintain competitiveness [9-11].

Equally important is compliance with the regulations and standards that are being introduced in various countries to improve the energy efficiency of buildings. The classification of construction products helps manufacturers meet these requirements, which avoids fines and problems with legislation. This is becoming especially relevant in the light of global initiatives to combat climate change [12-14].

Finally, the systematization of classification increases consumer awareness of the benefits of energy-efficient solutions. This contributes to a more responsible choice of materials and technologies, which ultimately leads to a more sustainable development of society as a whole. Informed consumers become active participants in the process, contributing to the formation of demand for environmentally friendly and energy-efficient solutions [15].

2. METHODS AND MATERIALS

The twentieth century has become an important stage in the practice of world construction. Rapid urbanization, economic changes and technological developments have defined many aspects of building design and construction.

To date, there has been a sharp increase in the need to increase the energy efficiency of the enclosing structures of these buildings in order to improve their thermal performance and reduce operating costs. Measures taken to improve the energy efficiency of existing buildings will reduce the energy consumption of these buildings and certify them according to the energy efficiency category. Energy efficiency certification and classification (categories) of buildings by energy consumption is a statistical tool that creates a basis for evaluating and comparing energy costs and energy efficiency of apartment buildings in international rating systems for assessing the environmental friendliness of residential buildings [16].

Table 1. Classification of energy efficiency of residential apartment buildings.

Designation of the energy efciecy class of apartment buildings	The name of the energy efficiecy class of apartment buildings	The amount of deviation of the value of the actual specific annual consumption of energy resources from the base level on average, %	Oriented specific energy cosumtion per m^2 of the building, kWh per year to achieve the standard residential temperature	Recalculation – specific cosumtion per 50 m^2, kWh per year	Recalculation – specific energy consumption per 100 m^2, kWh per year
A++	Close to zero energy consumption	-75% inclusive and less	Less than 20	Less than 1000	Less than 1000
A+	The highest	From -60% to -75% inclusive	20-35	1000-1750	2000-3500
A	Very high	From -45% to -60% inclusive	35-50	1750-2500	3500-5000
B	High	From -30% to -45% inclusive	51-90	2550-4500	5100-9000
C	Elevated	From -15% to -30% inclusive	91-150	4500-7500	9100-15000
D	Normal	From 0% to -15% inclusive	151-230	7550-11500	15100-23000
E	Lowered	From +25% to 0% inclusive	231-330	11550-16500	23100-45000
F	Low	From +50% to +25% inclusive	331-450	16500-22500	33100-45000
G	Very low	More than +50%	More than 450	More than 22500	More than 45000

Energy efficiency in housing construction provides an integrated approach to measures to reduce the thermal energy consumed in a building, which is necessary to maintain the basic and mandatory parameters of the microclimate in buildings and maintain safety [17].

Modern lamps, which are installed in residential buildings as part of the overhaul, have a number of advantages. The first, of course, is energy efficiency. They consume significantly less energy and are equipped with opto-acoustic sensors that respond to movement. Residents can choose one of the existing modes: if there is no movement, then the light bulbs are not lit, or the light may be dimmed during rest, and light up when a person appears on the site. On average, three lighting fixtures are installed on one site. This number varies based on the area of the object.

In addition to the main lighting fixtures, any major repair project necessarily includes the installation of an emergency lighting group, which continues to function even if the entire house is de-energized. To do this, batteries are built into the devices, capable of maintaining autonomous operation for about six hours. The main task of emergency lighting is to accompany the escape routes and illuminate the main fire escape. The built-in sensors that respond to the absence of direct current are also responsible for timely activation of the battery.

Energy efficiency is the main, but far from the only indicator of high-quality equipment. The lighting device must be reliable, with a long service life or, in case of unforeseen circumstances, repairable. Based on international energy efficiency standards, lighting devices must have sufficient protection against the penetration of solid granule-like particles and the ability to withstand immersion in water for a short time without water penetrating into the interior in an amount that would have a harmful effect.

Let's consider the main measures to reduce the cost of electric energy for lighting residential premises.

According to the requirements of LEED certification, exceeding or underestimating the parameters of lighting installations leads to adverse consequences, decreased performance, fatigue, irritability, loss of visual acuity.

It is known that people sometimes tend to forget to turn off the light when leaving the room. Technical and economic comparison of the parameters of fluorescent lamps for a room-sized project 9*6*3,2 m in length, width and height, respectively, is shown in Table 2.

Table 2. Technical and economic comparison of the parameters of fluorescent lamps.

№	The model of a fluorescent lamp	E	P, W	ΣP, kW	Energy saving
1	LPO46-2x36-604 with EmPRA	416	88	0.88	0%
2	LPO46-2x36-614 with EPR	488	72	0.72	18%
3	LPO46-2x28-614	435	60	0.6	32%
4	LPO46-2x35-614	451	72	0.576	35%
5	DPO12-38-101	477	38	0.38	57%

At present, many energy-saving design standards have improved the transparent part of the exterior fence, that is, the heat transfer performance of exterior doors and windows, and reduced heat transfer to improve their thermal insulation performance. Thus, one of the ways for the window industry to meet the new standard is to switch to triple-layered double-glazed windows, which are thicker, heavier and more expensive than modern double-glazed windows filled with argon. To achieve an energy-saving effect, multilayer glass laying technology can be used, but carbon dioxide emissions from the material itself are also high. The use of vacuum technology to improve the thermal performance of exterior doors and windows to a very high level. This brand new window can be used both as thermal insulation and as a wall. The excess heat lost by modern windows can be saved (Fig. 1).

Fig. 1. Heat loss through translucent structures in a residential apartment building.

At present, many energy-saving design standards have improved the transparent part of the exterior fence, that is, the heat transfer performance of exterior doors and windows, and reduced heat transfer to improve their thermal insulation performance. Thus, one of the ways for the window industry to meet the new standard is to switch to triple-layered double-glazed windows, which are thicker, heavier and more expensive than modern double-glazed windows filled with argon. To achieve an energy-saving effect, multilayer glass laying technology can be used, but carbon dioxide emissions from the material itself are also high. The use of vacuum technology to improve the thermal performance of exterior doors and windows to a very high level. This brand new window can be used both as thermal insulation and as a wall. The excess heat lost by modern windows can be saved.

Table 3. The annual consumption of heat energy losses through the external enclosing structures of the building during the heating period.

Calculation results that meet the requirements of the standards	Annual consumption of thermal energy through external translucent structures		
	kWh/year	MJ/year	gCal/year
Double-glazed window 32 mm 4M1-10-4M1-10-4M1	9 386 890.5	33 792 805.8	8 072.7
Double-glazed window 40mm 4M1-14-4M1-14-4M1	8 665 207.1	31 194 745.6	7 452.1
Double-glazed window 40mm 4M 1-14P(Ar)-4 M 1-14P(Ar)-4 And	5 591 287.1	20 128 633.6	4 808.5

3. RESULTS AND DISCUSSION

Based on the research and calculation of the transmission loss of buildings that use three types of translucent structures-two standard double-glazed windows and a double-glazed window with a soft emission coating and fill the space between floors with argon, the advantages of using energy-saving windows have become obvious: the heat loss during a heating period is reduced by nearly 2 times, which also greatly reduces the economic cost of heating residential buildings [18].

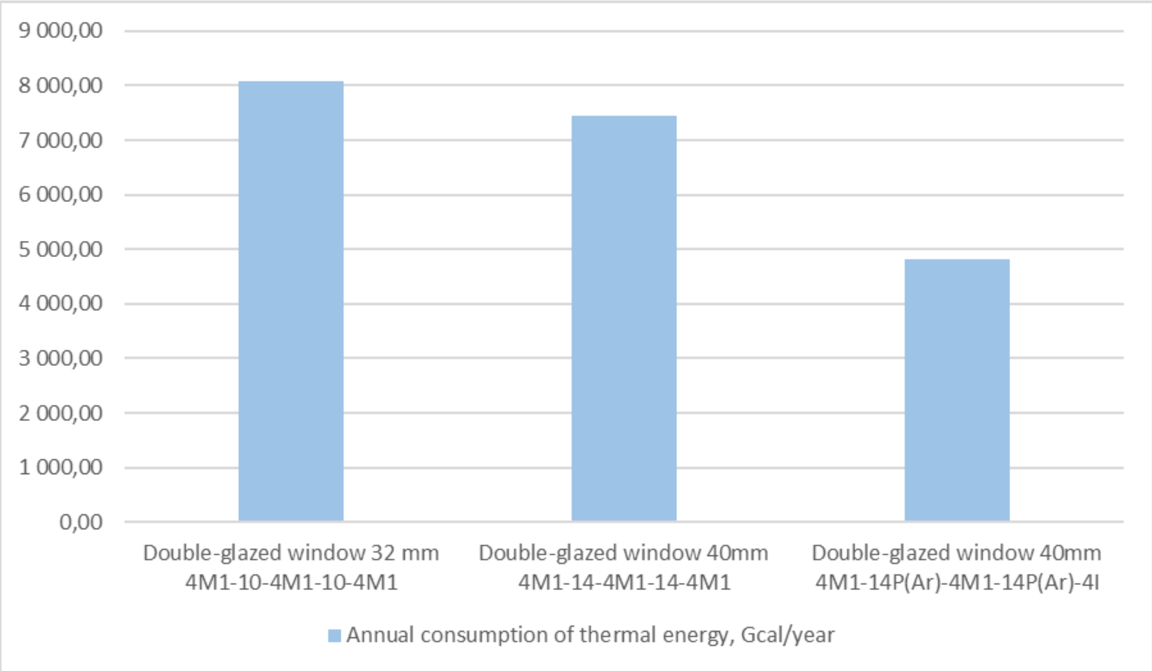
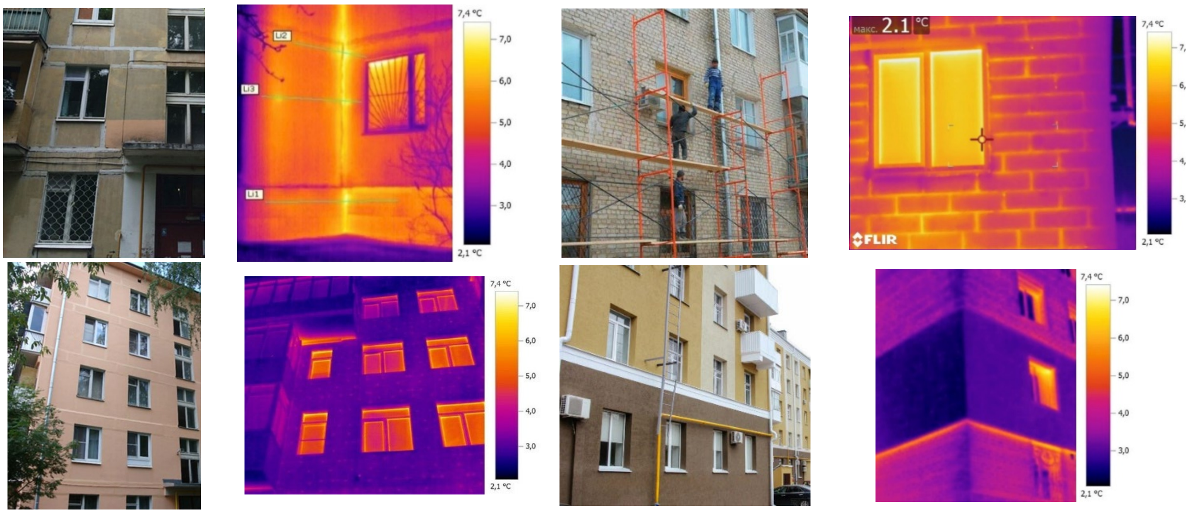


Fig. 2. Comparison of annual thermal energy costs based on the calculation results.

To assess the effectiveness of insulation and identify places with high transmission losses, it is advisable to use thermal imaging diagnostics [19]. Thermal imagers allow you to visualize temperature fields on the surface of buildings, identifying areas where heat leakage occurs, which allows you not only to identify problem areas, but also to evaluate the effectiveness of the insulation work carried out after major repairs (Fig. 3).



a) panel residential building b) a brick residential building

Fig. 3. Heat loss of enclosing structures of an apartment building during thermal imaging inspection before and after carrying out energy–efficient capital repairs.

In terms of thermal engineering qualities, currently about half of all energy consumption is accounted for residential and civil buildings, since most of these buildings were built according to building standards of the last century and, accordingly, have low thermal protection properties. At the same time, the main reserve of energy saving is laid down in buildings built without taking into account the requirements for energy efficiency of buildings [20-22]. This is due to the fact that until now, the main focus in construction practice has been on minimizing one-time costs, and the operating costs associated with heating and air conditioning of buildings have been practically ignored due to the relatively low cost of fuel and energy resources. For various structural characteristics of buildings, the energy efficiency class of apartment buildings during major building repairs is shown in the Table 4.

Table 4. Assessment of the energy efficiency class of apartment buildings with various design features by carrying out capital repairs.

Type of external enclosing structure	Material	Layer thickness δ, mm	Coefficient of thermal conductivity λ_A, W/(m · ^{0}C)
Exterior walls (ventilated facade)	Granite slabs	12	0.31
	The air layer	60	0.18
	Insulation PIR-plate	100	0.023
Windows, balcony doors and stained glass windows	Four-chamber double-glazed window with I-glass Veka Proline	70	-
	The light-transparent facade of ALUTECH	60-80	0.65
Exterior entrance doors	«Warm" ALT 65 door series ALNEO	65	-
Green roof coating	Plant substrate	250	1.21
	The fixing layer of the soil	150	0.47
	Expanded clay gravel (500 kg/m3)	40	0.15
	XS TECHNONICOL CARBON	100	0.032
	Ondulin layer	36	0.20
	Monolithic reinforced concrete slab	200	1.92

Continuation of Table 4

An overlap over an unheated basement	Quartz Vinyl SPC Tile	5	0.14
	Floorwood	1.5	0.44
	The substrate for the floor	50	0.76
	CPS reinforced	50	0.032
	XS TECHNONICOL CARBON	4	0.17
	Roll-up waterproofing of the TECHNONICOL floor	20	0.76
	CPS leveling	200	1.92

Based on studies of the thermal conductivity of building materials and structures, it is advisable to systematize the data obtained by introducing a classification of construction products by energy efficiency [23]. An example of performing some energy-efficient facade overhaul and window replacement work is shown in the figure.

A study was conducted for major renovation of apartment buildings built in 5 different regions of the country in the 70s, 80s, 90s and 2000s with different climatic and structural features (Table 5).

Table 5. Assessment of the energy efficiency class of apartment buildings with various design features by carrying out capital repairs.

Example No.	Energy efficiency class before overhaul	The amount of deviation of the value of the actual specific anual consumption of energy resources from the base level on average, %	Oriented specific energy cosumption per 50 m2 of builing, kWh per year to achieve the standard residential temperture	Energy efficiency class after mjor repairs	The amount of deviation of the value of the actual specific anual consumption of energy rsources from the base level on average, %	Oriented specific energy cosumption per 50 m2 of builing, kWh per year to achieve the standard residential temperture
1	D	From 0% to -15% inclusive	7550-11500	A+	From -60% to -75% inclusive	1000-1750
2	E	From +25% to 0% inclusive	11550-16500	A+	From -60% to -75% inclusive	1000-1750
3	E	From +25% to 0% inclusive	11550-16500	A	From -45% to -60% inclusive	1750-2500
4	E	From +25% to 0% inclusive	11550-16500	A	From -45% to -60% inclusive	1750-2500
5	F	From +50% to +25% inclusive	16500-22500	B	From -30% to -45% inclusive	2550-4500

Example №1: Marine climate. Block walls, 10 floors. The year of construction is 1978. The total area is 9,745.9 m^2. The indicator of savings in utility costs is 33.45%. Due to the measures, the calculated energy efficiency class has increased from D to A+.

Example №2: Continental climate, the average temperature in January is -15 degrees. The warmest month of the year is July, with an average temperature of +19 degrees. The savings rate for utility bills amounted to 32.34%. Due to the measures, the calculated energy efficiency class has increased from E to A+.

Example №3: The climate is temperate continental. The year of construction is 1999. Panel house, 10 floors. The total area is 11,776.4 m^2. Due to the measures, the calculated energy efficiency class has increased from E to A.

Example №4: The climate is temperate. Panel walls, 6 floors. The climate in the area is continental. The year of construction is 1970. The total area is 6,143 m^2. The number of residents is 223 people. Due to the measures, the calculated energy efficiency class has increased from E to A.

Example №5: The climate is temperate. The building is a panel, 5-storey building. The year of construction is 1983, the total area is 3,815 m^2. The number of residents is 135 people. The savings rate for utility bills amounted to 26.67%. Due to the measures, the calculated energy efficiency class has increased from F to B.

The estimated energy efficiency of residential buildings for different types of climate and building type is shown in the graph (Fig. 4).

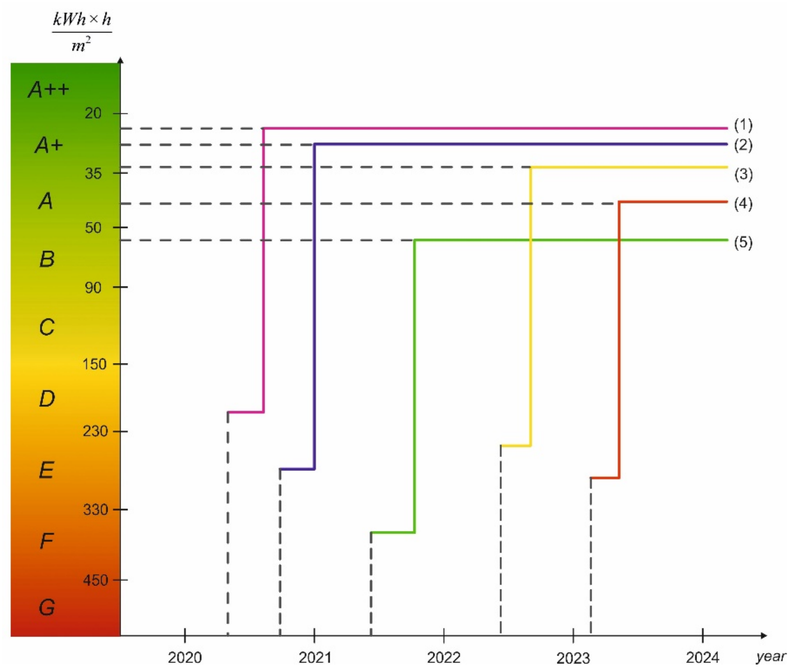


Fig. 4. A graph of the specific heat consumption of commissioned residential apartment buildings for heating, ventilation, hot water and electricity supply in accordance with the appropriate energy efficiency classes, where: 1 – example №1; 2 – example №2; 3 – example №3; 4 – example № 4; 5 – example №5.

4. CONCLUSIONS

This study compares and analyzes the technical solutions and technologies for energy-saving capital maintenance of apartment buildings. The purpose of this study is to determine the most effective way to improve the energy efficiency of residential buildings through maintenance work. The method of this research is based on the statistical analysis of the data of major overhaul results in world architectural practice.

According to the research results, it is found that when planning major repairs to reduce energy consumption, special attention should be paid to choosing a set of technical solutions that together help improve the energy efficiency of residential buildings. The analysis shows that with the introduction of modern energy-saving technologies, the overhaul of apartment buildings has made it possible to modernize each building, improve its energy efficiency level and extend its service life for at least a quarter of a century, thereby improving

We believe that taking into account the international experience in reducing heat loss and energy consumption in residential apartment buildings, it is necessary to adopt new rules to determine the energy efficiency levels and appropriate labels of building products, from the use of relative indicators (the deviation of actual or expected annual specific energy consumption from the normative value) to set the minimum and maximum values (range) of energy consumption in apartment buildings for each energy efficiency level.

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