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FOREIGN AND RUSSIAN EXPERIENCE CONDUCTING MAJOR REPAIRS OF HOUSING FUND TAKING INTO ACCOUNT ENERGY-EFFICIENT MEASURES

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Statement of the problem. Perform a comparative analysis of foreign and Russian experience in major repairs of housing stock taking into account energy efficiency measures. To consider and identify the most effective financing mechanisms, energy efficiency measures during the overhaul.

Results. When performing the comparative analysis, the most acceptable model for sustainable financing of capital repairs and energy efficiency of residential buildings in the Russian Federation was identified, and an effective list of measures carried out during major repairs was selected. Indicators were determined to assess the economic efficiency of energy modernization projects in apartment buildings.

Conclusions. Successful implementation of an energy-efficient overhaul requires motivation for all stakeholders, as well as financial support from the budget. Not a few important moments is the realization that the return on investment in energy-efficient overhaul will be effective in the long term.

Keywords: overhaul, repair and construction work, energy-efficient measures, apartment buildings.

Introduction. Housing privatization contributed to a dependent attitude of homeowners to their property. For most apartment buildings, the city council is responsible for operation and maintenance of residential buildings through communal housing and maintenance enterprises.

The quantity and quality of utilities that these companies provide are not always up to the high standards and requirements. Meanwhile, the cost of maintaining the housing stock is constantly growing, which has been causing citizens' concerns. It is also worth mentioning that the buildings have not been renovated for decades resulting in the deterioration of existing apartment buildings as no major repairs are performed. Renovation needs a great deal of finance.

To accommodate homeowners' needs, it is suggested that a mechanism is designed for major repairs of apartment buildings on a co-financing basis. Raising funds from the city budget should not only be aimed at increasing the financial ability to carry out repairs, but should also encourage residents to treat their common property, its maintenance and preservation responsibly.

Throughout the course of the analysis of the already completed projects for major repairs and reconstruction of high-rise residential apartment buildings in the Russian Federation and abroad, the main types of work were identified to prevent physical and moral deterioration of housing. These include major repairs and reconstruction of roofs; insulation and cladding of external walls; provision of fire safety measures; replacement of engineering equipment, etc.

Improving the quality of life in housing is the main objective of major repairs of high-rise apartment buildings. Outdated housing consumes a greater number of energy resources as opposed to newly-built housing complexes designed in compliance with modern energy-efficiency standards. While performing major repairs and choosing energy-saving measures to adopt, the main pressure is minimum investment with a maximum effect [9].

In [22] it was noted that during the operation of high-rise apartment buildings, most heat (40 %) is lost through walls, through windows — 18 %, through basements — 10 %, through roofs — 18 %, through ventilation — 14 %. In order to minimize heat loss, an integrated approach to energy conservation is necessary. It can include increasing heat transfer resistance of building envelopes, sealing cracks and joints employing metering devices and controlling consumption of thermal energy in houses, etc. [1, 4, 11, 13].

1. Major housing repairs in foreign countries. Based studies of foreign experiences [12, 21] in developed economies, it can be noted that there is a decrease in capital investment in the design of new high-rise apartment buildings. Major investments are made in major repairs and reconstruction of outdated housing. This is due to the fact that most of the EU housing is in need of major repairs and reconstruction. More than 40 % of housing was built before 1960, the remaining high-rise apartment buildings were built before 1999, and as little as 1 % of new housing is being used. The countries with the largest proportion of new housing (designed between 1990 and 2010) are Ireland, Spain, Poland, and Finland [7].

In a lot of EU countries, major repairs are funded by the state or municipality. Reconstruction and modernization of outdated housing takes place due to addition of floors, terraces, recessed balconies as well as use of energy-efficient materials [16].

In Germany, a managing company is in charge of major repairs. Their costs are calculated individually depending on the design features of a particular house and are paid for by the owners or loan programs [8].

In Sweden, the Sustainable Built Environment Research (SBER) is engaged in a project to develop a robust methodology for the economic analysis of energy-efficiency measures for buildings from the 1970s and to examine the cost-effectiveness of related integrated measures. These reconstruction measures include additional insulation of a basement, exterior walls and roof; the use of energy-efficient appliances and lighting; exhaust air heat recovery unit. This project is aimed at investigating indicators during major repairs and related economic parameters for energy sustainability in existing buildings in need of reconstruction [24].

In the United Kingdom since 1979, a change reform has been focused on reconstruction with active participation of residents to carry out repairs and construction without resettling them thus increasing their speed. Major repairs and reconstruction were funded by loans adding to the market value of new housing and tax rates [3].

2. European LEAF project for addressing energy efficiency of high-rise apartment buildings. One of the leading energy efficiency projects is Low Energy Apartment Futures (LEAF). This is a three-year project for improving energy efficiency of high-rise apartment residential buildings by means bridging the barriers that emerge in the process of housing modernization. It was funded by the European Union's Intelligent Energy Europe (IEE) program and by local organizations in each participant country. The project involved 8 partner organizations from 6 European countries: Austria, France, Germany, Hungary, Sweden, and the United Kingdom. The LEAF project included fundamental research, development of interactive and technical tools to facilitate the modernization of high-rise apartment buildings.

The EU Energy Union strategy launched in February 2015 had five major targets with “Energy efficiency To Help Reduce Demand” as one of them. According to the strategy, energy efficiency is vital. The 2010 Energy Performance of Buildings Directive (EPBD) and the 2012 Energy Efficiency Directive (EED) are the main EU legislative regulations regarding energy consumption in buildings. The key areas of legislation addressed in each of these Directives are summarized in Figure 1 [23].

Energy-Efficiency Directive of Buildings	Energy-Efficiency Directive
— Certification of energy-efficiency of buildings — Inspection of heating and ventilation systems — Target characteristics for all newly-built housing by the end of 2020 — "almost net-zero houses" — Identification of minimum operational requirements — Mechanisms of financial support for improving energy-efficiency of buildings	— Energy-efficient improvements in a minimum of 3 % of state-owned and private buildings — Energy-efficiency is a top priority for state purchasing — Long-term national strategies for reconstruction of buildings will be developed in the framework of national energy-efficiency action plan

Fig. 1. Principle underlying the EU legislation regarding the energy characteristics of buildings [23]

Implementation of the above policies as well as their improvement provides an opportunity to facilitate the modernization of high-rise apartment buildings. As a result of extensive policy research, a practical retrospective analysis of buildings and stakeholder engagement, a series of recommendations were developed at the EU and national levels [18, 20].

Based on the results [20, 23], it can be noted that in order to increase the energy efficiency of housing, it is necessary to provide incentives for every individual involved in organizing and funding major repairs. The state is interested in improving the energy efficiency of housing, since this has to do with general economic sustainability, rational use of energy resources and addressing environmental concerns.

3. Structural analysis of available models for funding major repairs and improving energy efficiency in high-rise residential buildings in the Russian Federation. Studies of best international practices in organizing and funding major repairs as well as improving the energy efficiency of high-rise residential buildings reveal a number of common structural elements characteristic of the Russian Federation:

a) importance of a clear and consistent public policy;

b) importance of federal, regional and municipal government, both in terms of regulation and direct financial engagement;

c) importance of an effective regulatory framework and of striking a balance between the regulation of civil rights and market incentives;

d) need for specialized state-run institutions to promote and support public policy;

e) need for appropriate forms of financial and tax incentives from the government to encourage property owners for modernization;

f) need for a clear legal definition of the duties and responsibilities of property owners and mechanisms that facilitate collective management during maintenance, modernization and repairs;

g) importance of accessing funding (loans) for owners in funding repairs and modernization of their high-rise residential buildings on reasonable terms.

4. Mechanism for funding major repairs and improving energy-efficiency of apartment buildings. The analysis [5, 19] shows that the most acceptable model for sustainable funding of major repairs and improving the energy-efficiency of residential buildings in the Russian Fede-ration in the medium term could be a combination of various elements as shown in Fig. 2.

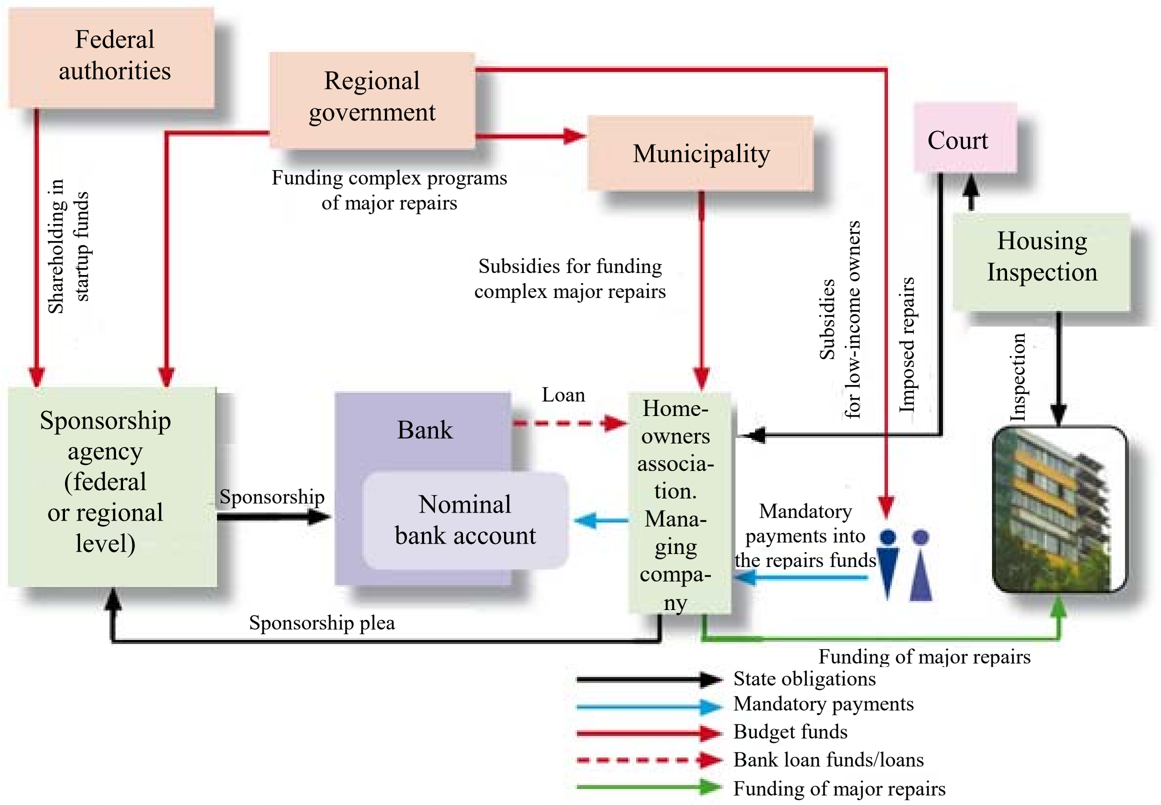

Fig. 2. Combined model of funding major repairs for improving the energy-efficiency of high-rise residential buildings [19]

A key feature of the above model is availability of three sources of funding for major repairs and improving the energy efficiency of high-rise residential buildings:

— owners' funds generated from contributions to the major repairs fund;

— loans and borrowings by commercial banks;

— government support.

In the medium term, this model might cause major repairs of Russia’s housing to be financed without co-financing from budget funds (except some social groups).

The “combined model” has the following key features:

a) mandatory creation of a collective major repairs fund;

b) establishment of requirements for a minimum contribution identified by the regional or municipal government as a condition for receiving state support (subsidies) or obtaining guarantees from the Sponsorship Agency on behalf of property owners;

c) assets accumulated in such a collective fund are considered to belong to all members of the corresponding representative organization (Homeowners association, housing cooperative, etc.), and are also accumulated and stored on the nominal account of this organization;

d) conditions for granting loans are considered by commercial banks.

5. Recommended energy-efficient measures during the overhaul in apartment buildings (high-rise residential buildings). In order to improve the quality of life of owners and to increase the market value of residential and commercial premises in high-rise residential buildings, major repairs are required considering increased energy-efficiency. In this case, major repairs of high-rise residential buildings provide not only the restoration of the design characteristics of a house but also bring them into line with latest standards.

The decree of the Ministry of Construction and Housing and Public Utilities of the Russian Federation from February 15, 2017 № 98/пр contains a recommended list of measures that contribute to improving energy-efficiency of high-rise residential buildings. This list of measures during major repairs of high-rise residential buildings is shown in the Table.

According to the list, heat conservation can be classified as a priority. This is due to the fact that thermal energy is one of the most costly energy resources [14, 25].

Table

Recommended list of energy-efficient measures

№	Energy-efficient measures	
	Major measures	Additional measures
Enclosing structures	— compaction of outer entrance doors in the entrances with closers; — increasing heat engineering uniformity of external enclosing structures; — increasing thermal insulation of external walls, roof, balcony and window door blocks, attic floor up to the current stan-dards	— increasing the thermal insulation of floor, basement walls up to the current standards; — increasing heat engineering uniformity of the external enclosing structures, glazing of balconies and recessed balconies; — additional splitting of entrance vestibules

End of Table

№	Energy-efficient measures	
	Major measures	Additional measures
Heating and hot-water systems (HWS)	— Installation of common house meters for thermal energy, hot water; — installation of an individual heat point with a heat exchanger and heating control equipment (the parameters of the coolant are configured in the heating system depending on changes in the outdoor air temperature); — installation of an individual heat point with a replaceable hot water heat exchanger (hot water system) and HWS control equipment; — Installation of linear balancing valves and balancing of the heating system	— Installation of temperature regulators on heating devices; — thermal insulation of the internal house engineering networks of heat supply and HWS in the basement and (or) in the attic, pipelines of the heating system, pipelines of the HWS; — ensuring water recirculation in the domestic HWS
Energy supply system	— Installation of a common house meter for electric energy; — replacement of lighting in common areas by energy-efficient lamps; — installation of equipment with automatic regulation of lighting in public places (turning on / off lighting, responsive to movement (sound))	— Modernization of electric engines; — installation of variable frequency drives in the elevator system
Use of non-traditional energy sources	–	— Installation of the 1st stage of the preparation of hot water using heat pumps; — installation of the 1st stage of hot water preparation due to heat recovery from ventilation emissions; — device of a hybrid hot water supply system with heat storage and heat pumps using the heat of the soil and the heat of ventilation emissions; — device of a hybrid HWS system using solar water collectors

In order to reduce heat loss, V. M. Tsygankov [16] considered the increase in the energy-efficiency of a building by means of insulation of facades. The scholar suggested considering heat losses through a building envelope considering climatic features of a region. For effective implementation of the measures constituting major repairs, the most promising combination of measures and their sequence has to be chosen. Applying the shortest path search algorithm could be an option for this [12, 17].

6. Evaluation of economic efficiency of investments. Economic efficiency of energy-saving projects is evaluated using the following indicators: profit, profitability, capital recovery period and reduced costs. In order to determine the profit from the implementation of energy-saving measures $P_{ен}$, the proportion of the profit that changes in the course of an energy-saving project is extracted from the total value:

$$P_{ен} = P_t - P_{0t}, \quad (1)$$

where P_t and P_{0t} are profit indicators in the t-th year with and without the implementation of an energy-saving project.

The profitability of an energy-saving project R (a simple rate of return) characterizes the return on the investment monetary unit and is the ratio of the current annual income $P_{ен}$ due to the implementation of an energy-saving project to the amount of capital investments (CI) for implementing it:

$$R = P_{ен} / CI. \quad (2)$$

The profitability indicator is used for assessing economic efficiency of implementation of energy-saving projects with a short construction period (1—2 years) and a constant annual profit, expenses and income. The payback period of an energy-saving project in its economic sense is the time when funds on its implementation are reimbursed by obtaining additional profit from saving fuel and energy resources. The payback period $T_{ок}$ is as follows:

$$T_{ок} = 1 / R. \quad (3)$$

According to the Belarusian methodology [15], for assessment of economic efficiency of energy-saving measures among indicators with no consideration of time only a simple payback period is calculated:

$$T_n = I / E_{year}, \quad (4)$$

where I are capital investments (or investments) in the implementation of energy-saving measures (from all funding sources); E_{year} is the annual saving of fuel and energy resources from the implementation of an energy-saving measure (in monetary terms).

The reduced costs B_n are the sum of the annual expenses (costs) and the standard profit from an energy-saving project, i.e., they characterize the lowest cost limit where an investment in it is an equal investment alternative with a standard efficiency ratio with no consideration of time:

$$B_n = E_н \cdot CI + B, \quad (5)$$

where CI are capital investments; B are current annual expenses (including depreciation charges for renovation); $E_н$ is the normative efficiency coefficient.

The calculation of the indicators of the second group was first described in the Guidelines for Project Evaluation (UNIDO, 1978) and is now commonly used by economists around the world. According to the theory, calculation of the criteria for evaluation of investment projects relies on the following principles:

1) invested capital is evaluated based on a cash flow indicator consisting of the amount of net profit and depreciation deductions during the operation of an investment project;

2) the value of both invested capital and cash flow is reduced to its present value, or discounted. Reduction of a value down to the present one occurs by means of multiplying the corresponding value of a cash flow or the amount of capital invested over a corresponding time period (month, year) by a corresponding discount coefficient given by the formula:

$$\alpha = 1 / (1 + i)^n, \tag{6}$$

where α is the discount coefficient; i is the the discount rate determined in compliance with an average deposit rate, inflation rate, risk premium, premium for low liquidity; n is the serial number of a period the calculation corresponds to, from the outset of the project;

3) a differential rate is selected in the process of discounting cash flows for different investment projects;

4) a base for setting a discount rate is chosen in compliance with the objectives of an evaluation.

The traditional indicators for evaluating the economic efficiency of investments considering time are Net Present Value (*NPV*), Internal Rate of Return (of Profitability) (*IRR*), Profitability Ratio (*PI*) and Payback Period considering time (discounted payback period, discounted payback period) (*DPP*). Net present value (*NPV*) is given by the formula:

$$NVP = \sum_{k=1}^{n} \frac{CF_k}{(1+r_k)^k} - \sum_{j=1}^{m} \frac{I_j}{(1+i_j)^j}, \tag{7}$$

where n is a prediction period; CF_k is a net input cash flow (income) per year, k; r_k is the annual discount rate per year, k; m is the number of years when project investments are planned; I_j are investments (costs) per year, j; i_j is a projected inflation rate per year, j.

Internal rate of return (IRR) is determined using the ratio:

$$\sum_{k=1}^{n} \frac{CF_k}{(1+IRR)^k} = I_0, \tag{8}$$

where *IRR* is such a value of the discount rate when the current value of investments (expenses) equals the current value of cash flows (income) from investments, or the value of the discount indicator when a zero value of a net current value of investments is provided; CF_k is an input cash flow (income) per year, k; I_0 is the current value of the investment. *IRR* is determined by means of the iteration-selection method.

A discounted payback period (*DPP*) is a period from the beginning of investment to the moment when *NPV* becomes positive.

A profitability index (*PI*) is determined using the formula:

$$PI = \sum\nolimits_{k=1}^{n} \frac{CF_k}{(1+r_k)^k} / \sum\nolimits_{j=1}^{m} \frac{I_j}{(1+i_j)^j}. \quad (9)$$

According to the method [2], all four indicators *NPV*, *IRR*, *DPP* and *PI* are calculated.

According to the methodology by the Ministry of Housing and Public Utilities of the Ukraine [10], the calculation of the discounted average annual return on investment R_d is additionally provided, which is the ratio of a discounted income P_{dt} to the amount of discounted investments in energy-saving measures.

The ABOK methodology [6] sets forth fundamentally different approaches to evaluating the economic efficiency of investments in energy-saving measures. The authors of the methodology note that the main economic indicator of the effectiveness of investments is the total (total) additional income *I* that can be obtained over the life of energy-saving measures $T_{сл}$. Depending on the way future income flows are utilized, they are either discounted or, if excluded from cash flow, are increased (capitalized).

As a result, the authors of [11] suggest the following system of indicators for assessing the economic efficiency of investments in energy-saving measures: net present value; a payback period of expenses calculated considering discounting or a payback period of expenses calculated considering build-up (capitalization); profitability index determined considering a discounting and profitability index identified considering capitalization.

A net accrued (capitalized) income I_c is determined using the formula:

$$P_k = \sum\nolimits_{t=1}^{T_{сл}} P_t (1+r)^{t-1} - K, \quad (10)$$

where $T_{сл}$ is a term of operation of energy-saving measures; P_t is income from the implementation of energy-saving measures in the period *t*; *r* is a capitalization rate.

A payback period of costs identified considering a discount when investments are one-off and occur in the first period of a project can be given by the formula:

$$C_{ок} = \frac{-\ln(1 - T_{ок} \cdot r)}{\ln(1+r)}, \quad (11)$$

$$C_{ок} = \frac{K}{\Delta P}, \quad (12)$$

where *K* are investments in energy-saving measures; ΔP is the annual additional income as a result of energy-saving measures.

A payback period of costs identified considering capitalization can be calculated using the formula:

$$C_{ок} = \frac{\ln(1 - T_{ок} \cdot r)}{\ln(1 + r)}. \tag{13}$$

A profitability index considering capitalization is determined using the formula:

$$PI_k = \frac{\sum_{t=1}^{T_{сл}} P_t (1 + r)^{t-1}}{K}. \tag{14}$$

In order to evaluate the economic efficiency of projects on energy modernization of high-rise residential buildings, the following indicators were selected:

1) without considering time:

— the total costs of a comprehensive energy modernization of a house;

— an income due to energy savings during the heating season with a decrease in heat loss following comprehensive energy modernization;

— an income due to energy savings while reducing heat loss following comprehensive energy modernization over the course of energy conservation measures;

— a profit from energy modernization during a period of energy-saving measures;

— a profitability index;

— a payback period;

2) considering time:

— a net present value (*NPV*);

— an internal rate of return (*IRR*);

— a payback period taking into account discounting (*DPP*);

— a profitability index considering discounting (*PI*);

— the total capitalized income from the reduction of heat loss during heating of a house following thermal rehabilitation;

— a capitalized profit;

— a profitability index taking into account capitalization;

— a payback period for energy modernization expenses taking into account capitalization.

Investments into energy-saving projects set the scene for effective development of a great number of energy-saving projects.

Evaluation of economic efficiency of investments should be prior to substantiating the criteria for investment efficiency (primarily economic ones), identifying funding sources and investigating the cost of equity.

Conclusions. Considering rising energy costs and a considerable energy intensity of modern industries, energy conservation and choice of investment priorities in order to improve energy efficiency of high-rise apartment buildings is a hot issue.

In the course of major repairs, considering energy-efficient measures, there are some obstacles that reduce their attractiveness. Thus, in order to increase energy efficiency in the construction sector, it is critical to find a way to address these obstacles and to develop methods for improving energy efficiency.

This study showed that there are certain conditions that must be met in order for energy-efficient major repairs to take place. First of all, all interested parties should be encouraged to participate, owners of buildings and managing companies should be informed on the benefits of major repairs with energy-efficient measures in mind. Second of all, it should be remembered that the return on investment in energy-efficient major repairs will operate in the long term. Thirdly, energy saving process needs to be evaluated in a comprehensive manner considering a whole range of all investment consequences: economic, technical, environmental, organizational, commercial ones, etc.

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