Social, ecological and economic factors in evaluating the energy efficiency in housing construction

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Abstract. Mass housing does not satisfy energy efficiency. This article proposes a system of social ecological economic factors in assessing the housing construction energy efficiency. A performance evaluation criteria list has been developed. This toolkit consists of 4 groups. The authors of the given work have made an attempt to develop an inventory for evaluating the energy efficiency projects. The social ecological economic factors are taken into account in opposition of other assessment systems. The housing construction projects evaluation is based on the costs spent during the building life cycle. This criterion can be considered by the construction investors when making the projects decisions.

Introduction
The increase in the construction enterprises activity scale adversely affects the environment in nowadays conditions, as the resources consumption increases and the ecosystem is gradually destroyed. The statistic data analysis shows that the existing buildings and structures in the world consume about 40% of the world’s primary energy, 67% of electricity, 40% of raw materials, 14% of total drinking water, while they produce about 35% of the world’s carbon dioxide emissions, about 50% of solid municipal waste [7]. In this situation, the tasks of energy efficiency and energy saving in housing construction become especially acute [3].

The trends in the domestic construction industry analysis allowed to identify the promising research areas for the innovative and sustainable technologies development in housing construction: the innovative building materials and structures licencing organization; methods and tools for marketing the construction enterprises needs, the residential real estate consumers; R & D programs development; subjects interaction models in the innovation process; mechanisms for innovation at the regional level; mechanisms for the creation of innovative and sustainable development type consortia; business functions in innovative environmentally-oriented processes, etc.

The first substantial national “green” construction standard in Russia was the System of Voluntary Certification of Real Estate “Green Standards” [8]. As a shortcoming of the domestic standard, it is possible to note the economic criteria lack for energy efficiency [2]. In addition, the adopted normative documents and government programs implementation results in the field of energy conservation at the federal and regional levels do not allow the transition to a program-targeted management method and do not provide an investment resources increase in the budgetary sphere.

Approaches to assessing the investment projects’ economic efficiency, including construction, are now developed in detail [1]. The investment decisions effectiveness criteria are widely known and used in modern practice.
Goal, tasks, methods of study
However, the specifics of the “green technologies” development and the task of improving the investment management and construction projects for environmental housing causes green the construction projects evaluation methodological development at the pre-investment stage with a view to their selection and subsequent implementation [5].

In our opinion, when developing an investment projects methodology for assessing the effectiveness in the sphere of “green” housing construction, it is necessary to take into account the ecological, social and economic components that should pay attention to the tasks:
- the criteria list formation that characterizing the preferences and capabilities of consumers and housing consumer properties;
- the expected results comparison and costs taking into account the time factor;
- the facility construction life cycle’s all stages coverage;
- taking into account the risk factors for the green buildings’ construction;
- the collected information completeness, reliability and timeliness;
- the indicators transparency, independence and complementarity;
- gathering information about changing public opinion.

In our opinion, it is the innovative technologies application at all stages of the residential real estate life cycle (including the stage of operation, which accounts for up to 80% of total costs) will provide the citizens of the Russian Federation with affordable and comfortable housing [10].

Currently, the integrated approach lack to the innovations’ application has led to the fact that the optimal choice of environmentally friendly and resource-saving materials, products and technologies depends on the designers’ responsibility degree.

Formation of methodological tools for assessing the social ecological economic efficiency of housing projects
As a result, we have summarized the methodological tools for assessing the social environmental and economic efficiency of green construction projects, which includes a system of several indicators:

1. Indicators for assessing the housing quality as the main parameter for improving the residential building consumer properties, taking into account the environmental and social components, paying attention to the residential environment consumer properties, the consumer differentiation in terms of income level: functional properties, ergonomic properties, engineering properties, environmental properties, aesthetic properties.

2. The project commercial efficiency indicators from the position of potential investors on the residential facility life cycle length basis and the discount factor, including:

   2.1. The project economic efficiency international indicators system based on discounting

   Indicators for assessing the effectiveness of investment in environmental and energy-efficient housing construction are: net discounted income (NDI) and profitability index (PI). The methodology is used to evaluate the large energy saving projects with heterogeneous flow of costs and revenues throughout the building life cycle [9].

   2.2. The procedure for calculating the life cycle of a residential building taking into account the total costs [4]:

   \[
   LC = Z_1 \times E_k \times R + Z_2 \times G_k \times T \times K \times R,
   \]

   \(LC\) – is the life cycle costs; \(Z_1\) – is one-time costs amount for design, production (construction), commissioning and decommissioning (disposal); \(Z_2\) – defines the amount of periodic expenses during the planned period of operation for resources, maintenance, current and capital repairs, consumables, management and labor payment; \(E_k\) – is the coefficient of accounting for energy efficiency class of the building; \(G_k\) is the greenness coefficient; \(T\) – is the equipment repairs and replacement periods number during the planned service life (life cycle) for each calculation element; \(K\) – is the correction factor, taking into account seasonality, and / or deviation from standards; \(R\) – defines the discounting factor.
3. Indicators for the analysis of the investment situation by the financing integration of private and public sources.

The affordability factor \( D \) of purchasing eco-housing, which determines the income ratio \( S \) and the housing cost \( P \) in a particular region:

\[
D = \frac{S}{P}
\]

It shows how many years it will take a typical family of 3 people to purchase housing at the existing income level.

4. Indicators for assessing social ecological and economic risk as a measure of compliance with the quality level of a residential facility in accordance with ISO 9000-2001.

Normative model of integral risk assessment \( R \) of social ecological economic system:

\[
R = 1 - \prod_{i=1}^{n} \left( 1 - r_i \right)^{\lambda_i}
\]

\( r_i \) - partial risk, \( \lambda_i \) - weighting coefficient of the partial estimates \( r_i, \Sigma \lambda_i = 1 \).

The private risk \( r_i \) determines the relative level of the quality of the social ecological and economic system and can be interpreted as a measure of the compliance of the achieved quality level \( x_i \) to the requirements \( r_i \), which is governed by the provisions of ISO 9000-2001 [6].

The proposed methodology feature is a systematic approach to the most significant economic, social and environmental performance indicators of a residential facility. As a result, it becomes possible to direct the limited resources of the investment and construction project for their priority mobilization with a view to creating “green” facilities.

**Experimental part**

As an illustration of the implementation of the investment and construction project for ecological housing, let us consider an example of calculating the proposed methodology for 12 apartment energy-efficient apartment buildings economy class with a level of energy consumption reduction in class “A”. This residential property characteristics are presented in Table 1.

| Name                                      | Value       |
|-------------------------------------------|-------------|
| The total area of the house, \([\text{m}^2]\) | 858.3       |
| Land area, \([\text{m}^2]\)              | 1847        |
| Number of apartments, including:         | 12          |
| 1-room - 8 units, ranging from 32.9 to 36.2 \([\text{m}^2]\) |             |
| 2-room - 4 units., ranging from 48.7 to 54.3 \([\text{m}^2]\) |             |
| Number of residents, people              | 28          |
| Number of floors                         | 2           |
| Energy efficiency class                  | B           |
| Wall material: heat-efficient masonry, prefabricated concrete blocks for basement walls with insulation to the depth of frost penetration | multi-layered |
| Overlap material: wooden structures with effective mineral wool insulation, reinforced concrete hollow slabs with mineral wool insulation | compound |
| Foundation type: tape reinforced concrete | monolithic  |
| Roof type: on the truss wooden structure  | pitched     |

The complex measures carried out on energy efficiency consist of the following units:
- passive energy efficiency (improvement of thermal resistance of walls, installation of 2-chambered double-glazed windows with special energy-saving spraying, meridional orientation of the object taking into account maximum solar activity);
- application of modern energy-efficient engineering systems (heat and cooling system based on heat pump, solar system on the basis of solar collectors, photovoltaic system for the needs of refreshment of common areas, apartment ventilation systems with heat recovery);
- saving and accounting of energy resources (lighting fixtures with motion sensors and with photosensors, etc.).

1. Indicators for assessing the quality of a residential property

The projected residential building is a low-rise economy class building, which architectural and artistic solution is based on the cheap environmentally friendly building materials use taking into account the overall urban situation. The project implemented the building maximum energy efficiency and functionality principles: glazing large areas are excluded; rounded corners of the building; technical underworld, unheated attic space, non-heating of staircases and corridors between apartments; conditions for guest accessibility of disabled people and low mobility groups.

The indicators on resource-saving water supply and sewage systems save water consumption from 30% to 50% (Table 2).

### Table 2. Water supply and sewage systems water consumption

| System Name          | Estimated water consumption (sewage disposal) |   |
|----------------------|---------------------------------------------|--|
|                      | [m³/day] | [m³/hour] | [l/s] |
| **Plumbing B1 (household drinking)** |          |          |      |
| Hot water            | 10.80    | 2.07      | 1.038 |
| Household sewage     | 3.36     | 1.16      | 0.60  |

The hot water is disassembled from the tanks, designed for a maximum hourly flow of hot water. If it is impossible to create a hot water temperature of +55 °C, reheating of the water takes place in the penthouse double-circuit boilers. To eliminate temperature fluctuations due to insufficient gas supply for heating water in boilers, a mixing valve is used to mix cold water automatically, using a diaphragm.

The project provides systems with the following parameters: floor heating system (main source) - \( T = 35-25 \, ^\circ \text{C} \); radiator heating system (auxiliary source) - \( T = 80-60 \, ^\circ \text{C} \); system of hot water supply - \( T = 55 \, ^\circ \text{C} \).

With the territorial improvement the following works are performed: the asphalt-concrete cover on the driveways and parking lots; pavement with tile coating; bicycle paths; arrangement of recreational areas for adults and children; sports grounds; placement of garbage containers with separate collection of garbage. The landscaping project involves the planting of trees, bushes and hedges, the arrangement of lawns. At the end of construction, the greenery layer is distributed over the landscaping areas.

2. Indicators of commercial efficiency

The methodology for calculating the residential building life cycle, taking into account total costs is presented in Table 3.

### Table 3. Consolidated calculation of the total costs for the period of the life cycle of the object being built, taking into account the time factor, thousand rubles

| Name                                               | Value       |
|----------------------------------------------------|-------------|
| Discount rate, [%]                                 | 8           |
| Average annual price growth rate (inflation) for the period, [%] | 4           |
| One-time costs total, thousand rubles, including:   | 39 231.73   |
| the cost of commissioning, thousand rubles         | 38 425.93   |
| disposal costs (demolition), thousand rubles       | 805.80      |
| Energy Efficiency Ratio (Ek)                        | 1.00        |
| Non-recurring costs, including amendments, RUB thousand | 39 231.73   |
Recurrent costs total, including: 83 844.43
Expenditure on utilities 29 582.90
Expenses for the overhaul of common property in the MFB (30 years), thousand rubles 6 077.60
The cost of the current (planned) repair of common property (30 years), thousand rubles 7 398.39
The cost of the maintenance of common property in the MKD, thousand rubles 40 785.54
Greenness coefficient (Gk) 0.58
Recurring costs as amended 48 629.77
Life Cycle Costs Amount without amendments 123 076.16
The sum of life cycle costs (SFCF), as amended 87 861.50
The duration of the forecast period (before the first overhaul), years 30
Average annual total life cycle costs, rub./year/object 2 928.72
Area of the building (common or useful), sq. m 858.3
Cumulative building life cycle costs (RUR), rub./sq.m./year 3.41

When calculating the project’s commercial efficiency, the present cost of owning an efficient residential house is determined to be 3410 rubles per m² in a year. According to the previous studies analysis, it can be concluded that this value is 1.3-1.5 times lower compared to the standard house.

3. Indicators for the investment situation analysis

The prospective investors composition and structure on the experience basis in the housing programs implementation involving financing the public and private sources depends on a specific investment and construction project. One-time costs for the commissioning of an energy-efficient residential building amount to 38,425,933 thousand rubles.

4. Indicators for assessing the social environmental and economic project risks

The risk management process is to optimally neutralize the adverse risk factors impact ensuring the successful project implementation. The investment projects risk management process includes the solution of functional problems: identification and classification of the assumed risks; risk assessment and analysis; choice of risk management methods; the effectiveness evaluation of the methods used.

Table 4. The building energy-efficient housing social ecological and economic risk expert assessment [6]

| № | Name             | Risk level (r) | Value (significance) |
|---|------------------|----------------|----------------------|
|   | Economic risks   |                |                      |
| 1 | Financial risk   | 9              | 0.75                 |
| 2 | Project risk     | 9              | 0.63                 |
| 3 | Exploitation risk| 7              | 0.54                 |
|   | Social risks     |                |                      |
| 4 | Personnel risk   | 8              | 0.48                 |
| 5 | Demographic risk | 5              | 0.33                 |
| 6 | Cultural risk    | 2              | 0.21                 |
|   | Environmental risks |         |                      |
| 7 | Climate risk     | 6              | 0.19                 |
| 8 | Man-made risk    | 8              | 0.17                 |
| 9 | Urbanization risk| 4              | 0.11                 |

In general, the social ecological economic efficiency indicators calculation has shown that the project for the energy-efficient facilities creation is profitable both as demand housing and as a commercially profitable project.

Summary
Thus, the Russian economy outsider position in the field of energy conservation has led to a lag in energy efficiency compared with European countries, which is a powerful negative factor in economic development. The high economy energy intensity creates the conditions for a catastrophic decline in energy security and is the leading deterrent to economic growth. Under these conditions, the most important strategic task is the earliest possible reduction in the energy economic intensity, including the eco-efficient technologies introduction into housing construction.

The novelty of this work is to offer a methodological toolkit for assessing the housing projects’ social ecological and economic efficiency. This methodology is based on a systematic approach and makes it possible to assess the investment and construction project channeling limited resources possibility for their priority mobilization in order to create the green housing projects.

The theoretical significance of this article lies in the criteria system development allowing to take into account the socio-environmental and economic factors when evaluating the investment and construction projects during the residential facility entire life cycle. The practical significance of the proposed methodological toolkit is in its use by participants in the housing market when investing capital investments in green facilities in order to minimize costs and improve the construction quality.

References
[1] Vasilyeva A A 2015 “Green” construction as an innovative approach to the development of the construction industry in Russia (Bulletin of the Institute of Economics and Management of Novgorod State University, Yaroslav the Wise) 2 7-12.
[2] Zaguskin N N 2013 "Green" construction is the main direction of transformational changes in the investment and construction sphere (Problems of the modern economy) 4 (48) 314-319.
[3] Zelentsov L B, Mailyan L D, Shogenov M S Engineering management technologies of increasing energy efficiency processes in the investment and construction projects (IOP Conference Series: Earth and Environmental Science) 90 (1). Article no. 012037. Information on http://www.scopus.com/inward/record.uri?eid=2-s2.0-85035072916&doi=10.1088%2f1755-1315%2f90%2f1%2f012037&partnerID=40&md5=739af3a9f799b1d2a2bd028ee3781c0d
[4] The methodology for calculating the life cycle of a residential building, taking into account the cost of total costs 2014 (National Association of Designers. Moscow).
[5] Mishchenko V Ya, Sheina S G, Gorbaneva E P Increase of energy efficiency during overhaul of housing stock in Russian Federation (IOP Conference Series: Materials Science and Engineering) 481 (1) Article No.012031.
[6] Murzin A D, Kilafyan E A, Tsyayan Ye A 2012 Integral risk as a factor in the selection of investment and construction projects for the development of urbanized territories (Internet Journal of Science) 3 (12) 98.
[7] Nikitina O A 2006 To the problem of sustainable ecological and economic development of urban recreation (Progresses of modern natural science) 4 60.
[8] System of voluntary certification of real estate. Information on http://www.greenstand.ru (free access).
[9] Shvydenko N V 2010 Methodology for assessing the socio-economic efficiency of the construction of youth housing complexes (Engineering Bulletin of the Don) 4 (14) 170-180.
[10] Sheina S G, Minenko E N, Sakovskaya K A 2018 Complex assessment of resource-saving solutions efficiency for residential buildings based on sustainability theory (Materials Science Forum) 931 870-876. Information on http://www.scopus.com/inward/record.uri?eid=2-s2.0-85055928696&doi=10.4028%2fwww.scientific.net%2fMSF.931.870&partnerID=40&md5=99a3f170798eac82aa6d3d2d35c972fa.