 https://doi.org/10.1051/e3sconf/202236304008

Classification of the housing stock for the implementation of standard programs of energy-efficient capital repairs (case study of Arkhangelsk)

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Abstract. The purpose of the study is to analyze the energy efficiency class of the housing stock for the implementation of comprehensive energy-efficient capital repairs on houses of different construction series. Research objectives: - assessment of the feasibility of using the software product "ECR Assistant" to assess the energy efficiency class of the housing stock; - analysis of resource consumption and assessment of energy efficiency class depending on climatic factors; - assessment of the energy efficiency class of multi-apartment houses of the same series. According to the results of the study, it was revealed that the estimated energy efficiency class of a building varies depending on the average annual outdoor air temperatures. The main characteristics of buildings belonging to the same building series are not enough to classify objects in order to form programs for energy-efficient capital repairs. For qualitative organizational and technological design of restoration measures in the form of a capital repair, it is necessary to develop a fundamentally sound approach to the classification of the housing stock using modern methods for processing large amounts of data collected on the basis of continuous monitoring.

1 Introduction

The owner of the residential premises of an apartment building is responsible for the maintenance of the common property of the owners in an apartment building (Article 30 of the Housing Code of the Russian Federation). At the same time, in accordance with the requirements of the legislation of the Russian Federation, one of the main requirements for the maintenance of common property in an apartment building is compliance with the reliability and safety characteristics of an apartment building (Decree of the Government of the Russian Federation of August 13, 2006 N 491). The reliability and safety of the building is ensured by a complex of capital restoration measures that allow eliminating signs of physical wear and tear of structural elements of engineering systems.

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Most of the housing stock is in good and satisfactory condition (Analysis of the technical condition of apartment buildings (gosuslugi.ru)) with wear and tear of less than 40% (Fig. 1). Structural elements of buildings are generally suitable for operation, but require some major repairs, which are most appropriate at this stage.

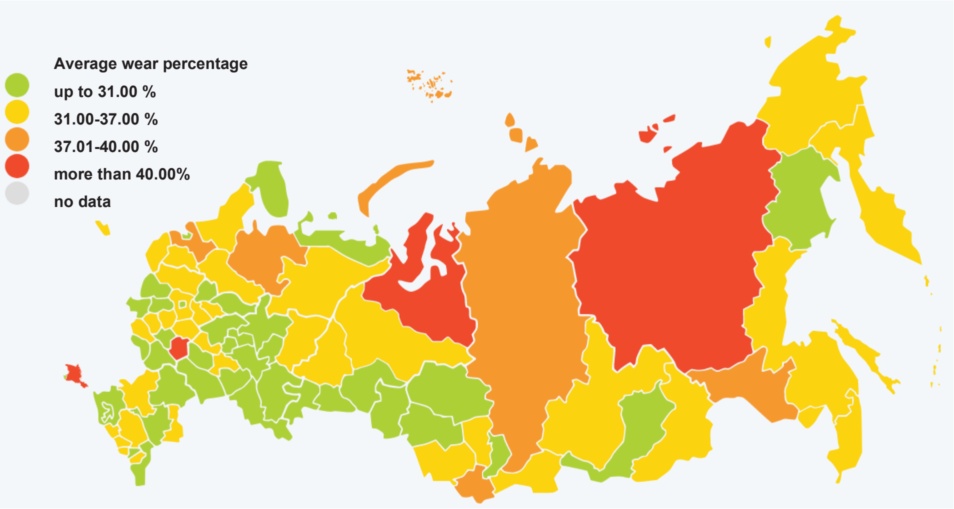

Fig. 1. Analysis of the technical condition of apartment buildings in the Russian Federation.

According to the Strategy for the Socio-Economic Development of the Russian Federation with Low Greenhouse Gas Emissions until 2050 (Decree of the Government of the Russian Federation of October 29, 2021 No. 3052-r), more than half of apartment buildings in the Russian Federation are energy inefficient and consume twice as much energy as their modern counterparts. High energy efficiency classes (A, B and C) have no more than 30 percent of the annually commissioned apartment buildings. A similar state is typical for public and administrative buildings. That is, most of the energy resources necessary for the operation of buildings are spent irrationally and are accompanied by excessive CO_2 emissions.

Thus, the expediency of using energy-efficient technologies during major repairs is obvious.

Energy-efficient repair technologies are currently being developed, researched and described in the works of many authors [1-16]. Presumably, the complex application of a combination of several technological solutions should give a synergistic effect. Packages of the most appropriate measures are proposed [17]. However, the impact of the use of a particular technology or their combination on the energy consumption of various objects has not been studied enough. Studies of the effectiveness of technological solutions for various types of buildings, building structures and their elements related to common property in apartment buildings are episodic and not structured.

The purpose of the study is to analyze the energy efficiency class of the housing stock for the implementation of comprehensive energy-efficient overhaul programs for houses of different construction series.

Research objectives:

- assessment of the feasibility of using the software product “ECR Assistant” to assess the energy efficiency class of the housing stock;
- analysis of resource consumption and assessment of energy efficiency class depending on climatic factors;
- assessment of the energy efficiency class of multi-apartment houses of the same series.

2 Materials and methods

2.1 Assessment of the applicability of the software product "ECR Assistant" for the purposes of the study

In the framework of this study, the software product "ECR Assistant" is used to calculate the predictive effectiveness of the implementation of energy-saving measures as part of a comprehensive overhaul.

ECR Assistant is a calculator for calculating the potential for saving utility resources in an apartment building. The application was developed on the basis of the Model Calculation Methodology for achieving savings in the consumption of public utilities from the implementation of energy-saving measures as part of capital repairs. The methodology was approved by the decision of the Board of the State Corporation – Fund for Assistance to the Reform of Housing and Communal Services.

The calculation method is performed in a MS Excel file.

Initially, the program was used to assess the effectiveness of the measures provided for in the List of works and services performed during the overhaul of common property in apartment buildings in accordance with Parts 1 and 2 of Article 166 of the Housing Code of the Russian Federation for those apartment buildings that applied for financial support. The list of works has been expanded in the new version of the ECR Assistant.

The program compares the energy consumption of apartment buildings with the base values of apartment buildings with the same number of storeys, located in the same weather conditions, based on a small set of data:

- data from metering devices according to the annual costs of energy resources for heating, hot water supply, ventilation and electricity as a share of the costs for general house needs;
- specific indicator of the area of the apartment building premises, not related to the common property;
- indicator of degree-day of the heating period [3];
- other parameters of the apartment building (Fig. 2)

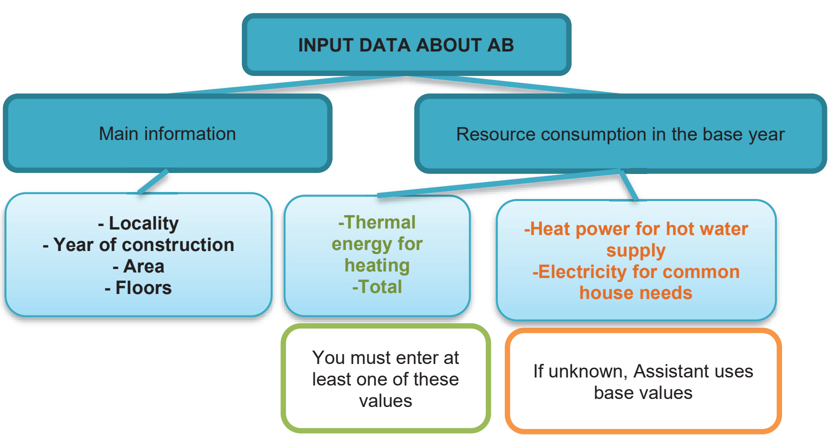

Fig. 2. Algorithm of the work of the user of "ECR Assistant" when entering the initial data.

Comparing the requirements and the algorithm for determining the energy efficiency class of the apartment building in accordance with the Order of the Ministry of Construction and Housing and Utilities of the Russian Federation dated 06.06.2016 No. 399/pr (Chapter 1.2) and the program "ECR Assistant", we can conclude that the program is based on the Order. However, the ECR Assistant takes into account in the calculations not only the costs of heating, ventilation, hot water supply and electricity, but also the typical design features of the building (material of the external enclosing structures, features of engineering systems, etc.). The program allows you to make a forecast of resource consumption based on the possible characteristics of the building after a major overhaul, including energy-saving measures.

2.2 Selection of research objects and analysis of resource consumption (assessment of the energy efficiency class) depending on climatic factors

The objects of the study were the houses of the most common typical series of multi-apartment residential buildings in Arkhangelsk, for which there are data from heat energy meters for heating and hot water supply for 3 years: 93-012, I-447C, I-335A, A-1-464. Based on the archival data of the hydrometeorological center, the average monthly temperatures for 3 studied years (2017-2019) were determined.

Data on energy consumption are presented in table 1.

Table 1. Monthly consumption of thermal energy for heating and water supply of research objects for 2017–2019.

Year	Month	Average monthly temperature, °C	Consumption of thermal resources by addresses, Gkal					
			Gaidar st., 23	Voroninst., 43	Troickij, 157	Vybornov st., 3	Voronin st., 29/1	Vologodskaya, 26
			93-012	93-012	I-447C-12/31	1-447C-40	I-335A-I	A-1-464A
2017	Jan	-10	154.35	17.43	78.92	118.83	111.34	15.84
	Feb	-7.5	143.78	13.63	66.01	113.88	106.40	94.51
	Mar	-1.5	103.38	5.23	62.49	84.77	79.39	66.72
	Apr	-1	119.47	14.29	70.39	98.62	87.10	76.53
	May	3	112.16	13.15	63.03	92.99	80.11	72.62
	Jun	9.5	32.24	7.73	15.47	27.83	29.90	22.82
	Jul	17.5	18.50	13.27	0.01	5.39	8.86	14.41
	Aug	16	13.81	12.25	0.00	9.67	10.74	10.61
	Sep	8.5	39.89	36.33	23.33	19.33	32.77	25.43
	Oct	3	83.47	70.63	45.59	86.23	61.58	61.54
	Nov	-1	117.74	103.01	59.47	103.42	84.32	75.47
	Dec	-4	123.90	111.60	50.36	110.15	90.04	82.60
2018	Jan	-6	137.90	121.53	83.01	121.89	97.32	89.72
	Feb	-13.5	169.65	150.27	103.49	151.22	119.94	110.93
	Mar	-11.5	154.23	134.16	91.85	134.22	107.65	97.87
	Apr	1.5	119.05	98.99	69.60	103.15	80.05	76.53
	May	9	80.60	52.71	41.30	37.71	45.40	45.88
	Jun	12	16.75	13.80	10.95	11.49	14.97	11.45
	Jul	18.5	14.58	12.50	9.87	11.80	12.61	10.14
	Aug	15.5	13.46	6.93	8.28	9.67	8.09	8.83
	Sep	11.5	24.43	21.58	13.98	18.26	19.41	16.14
	Oct	4	94.08	86.95	52.15	104.53	67.39	60.80
	Nov	-1	118.33	99.69	67.90	123.77	79.01	75.35
	Dec	-8	140.57	118.41	81.43	156.77	92.61	91.69
2019	Jan	-13	164.60	128.69	88.27	141.84	101.12	107.77
	Feb	-7	146.60	121.18	83.33	128.38	89.00	95.71
	Mar	-4	113.00	103.48	69.60	103.05	74.07	75.94
	Apr	3	102.26	101.82	64.86	99.84	74.13	72.50
	May	8.5	56.19	54.61	38.81	52.64	40.14	40.42
	Jun	13.5	16.95	12.29	12.46	11.88	12.45	12.36

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	Jul	13	13.99	13.04	11.71	9.53	12.80	10.69
	Aug	11.5	13.05	1.06	11.19	10.15	1.00	9.00
	Sep	9.8	77.53	38.14	24.44	31.59	29.72	27.76
	Oct	2	102.05	81.59	63.81	83.51	68.33	61.07
	Nov	-3	128.04	102.36	75.18	100.81	81.71	78.28
	Dec	-4	121.49	95.89	72.83	164.27	73.44	73.76

The data obtained were processed in the ECR Assistant program, and an energy efficiency class was determined for each considered apartment building in each period under study.

2.3. Assessment of the energy efficiency class of multi-apartment houses of the same series

At the next stage of the study, an assessment of the energy efficiency class for 2 series of houses I-447C-12/31 (brick walls) and 93-012, 84 (panel walls), which are common in Arkhangelsk, was made in the same time period to exclude climate impact on the results.

Main characteristics of the I-447C-12/31 series:
- year of construction: 1964–1965;
- number of floors: 5 floors;
- consumption of thermal resources: from 400 to 780 Gkal per year;
- load-bearing wall material: brick;
- floor type: reinforced concrete.

Main characteristics of series 93-012, 84:
- year of construction: 1961–1964;
- number of floors: 5 floors;
- consumption of thermal resources: from 600 to 1200 Gkal per year;
- material of load-bearing walls: panel;
- floor type: reinforced concrete.

Data on energy consumption are presented in tables 2 and 3.

Table 2. Consumption of thermal energy for heating and water supply of the studied apartment buildings of series I-447C-12/31 for 2019.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly outdoor air temperature, °C	-13	-7	-4	3	8.5	13.5	13	11.5	9.8	2	-3	-4
Troickij pr., 159	68.85	75.92	56.78	55.52	47.19	22.18	6.74	5.44	6.25	21.86	45.84	49.62
Troickij pr., 182	55.97	60.03	48.11	47.70	40.81	22.14	9.65	7.80	7.27	20.91	40.83	42.87
Troickij pr., 157	88.27	83.33	69.60	64.86	38.81	12.46	11.71	11.19	24.44	63.81	75.18	72.83
Gagarin st., 9	91.67	81.43	64.07	58.97	27.20	8.92	6.56	7.66	24.08	49.73	68.33	68.54
Roza Shanina st., 6	116.71	127.34	96.25	97.95	87.46	50.18	14.81	20.45	14.81	43.73	87.51	97.38

Table 3. Consumption of thermal energy for heating and water supply of the studied apartment buildings of series 93-012, 84 for 2018.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly outdoor air temperature, °C	-6	-13.5	-11.5	1.5	9	12	18.5	15.5	11.5	4	-1	-8
Sadovaya st., d.2, bldg. 1	87.92	111.40	101.28	76.49	43.18	7.33	8.70	6.73	16.12	75.57	67.67	86.44

Suvorova st., 16	78.29	96.36	86.36	65.33	34.70	9.33	7.53	7.37	11.82	54.90	66.03	80.86
Sadovaya st., 12	167.64	209.33	184.59	141.72	79.12	24.30	34.13	19.40	32.27	118.56	138.37	175.35
Troickij pr., 166	114.70	140.10	125.29	94.50	52.73	13.45	11.61	11.77	18.28	76.86	89.72	109.46
Vologodskay a st., 1	132.26	155.63	141.25	108.75	61.84	17.66	15.77	17.76	22.79	90.16	104.65	126.99

3 Results and discussion

The results of the assessment and analysis of the energy efficiency class of the series of apartment buildings common in Arkhangelsk, depending on climatic factors, were summarized in a general diagram of the dependence of heat resource consumption on climatic factors (see Figure 3).

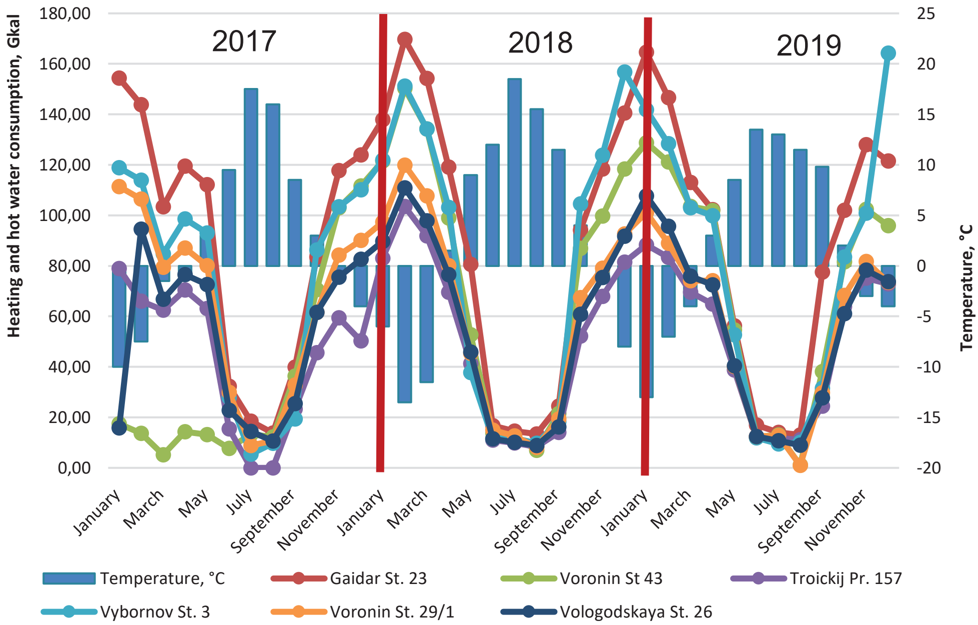

Fig. 3. Consumption of thermal resources in relation to climatic factors for various series of apartment buildings in Arkhangelsk.

Figure 4 shows the dynamics of changes in the energy efficiency class according to the calculated data.

According to the results of the calculation using the software product "ECR Assistant", it was revealed that the energy efficiency class of the studied apartment buildings changes (varies) from year to year depending on the change in the average monthly outdoor temperature (other climatic parameters were not taken into account in the calculations - temperature drops, precipitation, speed wind, etc.). Presumably, this can be caused by a change in the volume of the supplied resource, depending on weather conditions. In addition, many of the city's housing stock put into operation before 2000 do not have individual heat points and weather control systems that help reduce the consumption of heat resources.

The results of the assessment and analysis of the energy efficiency class for multi-apartment buildings of the same series in a given time period also showed conflicting results. Diagrams of consumption of thermal resources are presented in Figures 5 and 6. Diagrams of distribution of apartment buildings by energy efficiency classes are presented in Figures 7 and 8.

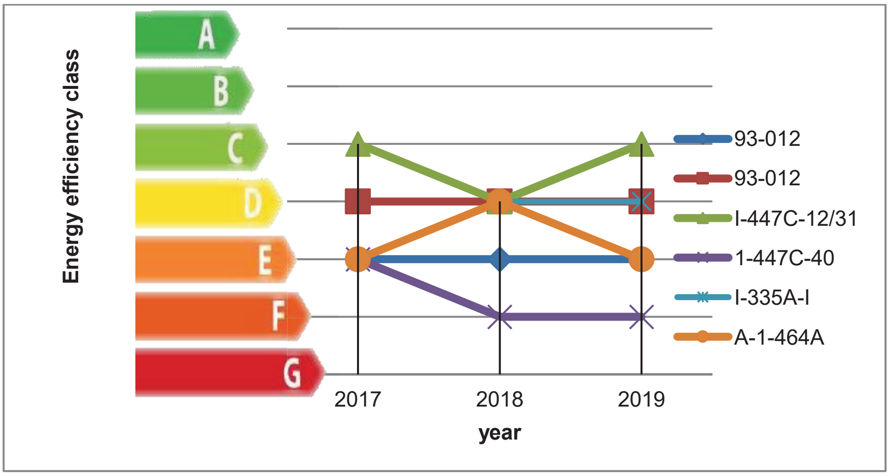

Fig. 4. Energy efficiency class of buildings depending on climatic conditions.

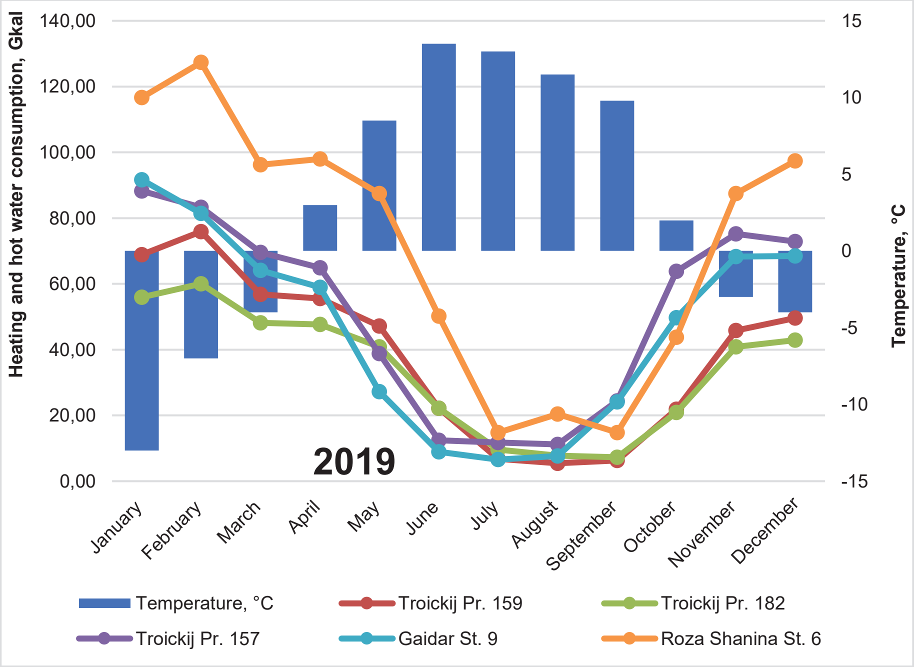

Fig. 5. Resource consumption of the apartment buildings, series I-447C-1231 (brick) in 2019.

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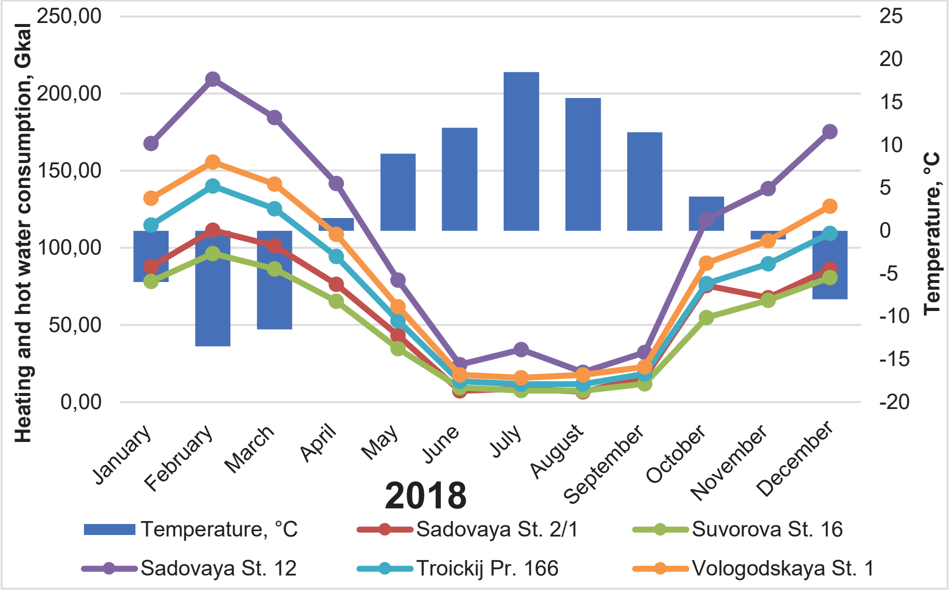

Fig. 6. Resource consumption of the apartment buildings, series 93-012 84 (panel) in 2018.

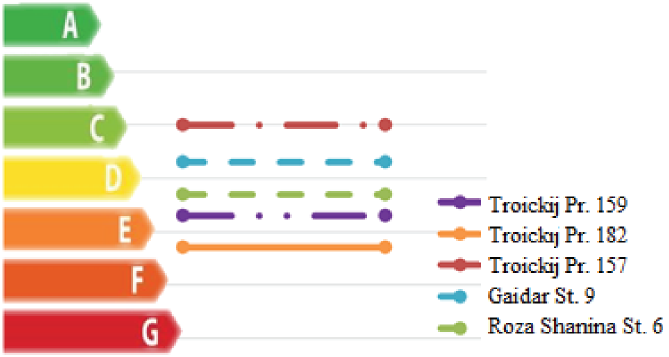

Fig. 7. Distribution of apartment buildings of series I-447C-1231 (brick) according to the energy efficiency scale.

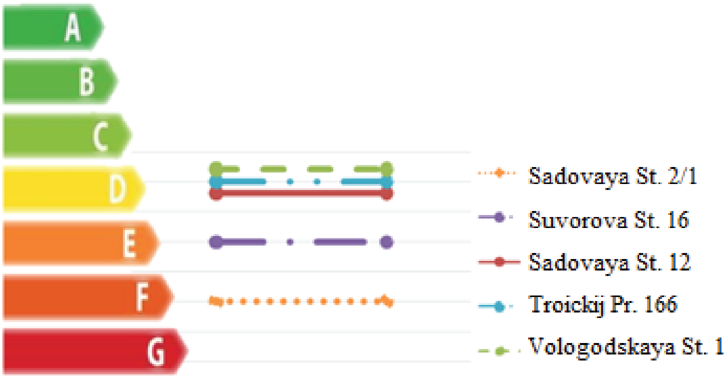

Fig. 8. Distribution of apartment buildings of series 93-012, 84 (panel) according to the energy efficiency scale.

For two series, there is a spread in energy efficiency classes, which indicates the impossibility of typing buildings for the purposes of energy-efficient overhaul, starting only from the series and year of commissioning. In this regard, it is assumed that a standard package of energy-saving measures selected in this way as part of the ongoing overhaul may not lead to the desired effect of saving resources.

4 Conclusions

The overhaul of the housing stock is one of the main restoring measures for construction projects. The amount of investments already accumulated in the regional capital repair funds exceeds 2 trillion rub., and the number of housing stock and its diversity is constantly growing. At the same time, signs of degradation are growing, expressed not only in the physical, but also in the moral obsolescence of housing. The main sign of such obsolescence is the low energy efficiency class of existing housing, which negatively affects not only the quality of life of citizens, but also the country's economy as a whole.

The formation of comprehensive programs for capital repairs should meet the modern requirements of organizational and technological design. The expediency of taking into account and improving the energy efficiency parameters of housing as part of capital repairs is obvious. However, the formation of effective programs for comprehensive overhaul without monitoring and typification of the housing stock is impossible.

Studies have shown that the characteristics of the housing stock are varied. Even serial buildings have a number of specific features that do not allow classification according to only one or two features. Thus, the formation of standard programs for the repair of buildings should be based on a fundamental methodological approach to the classification of objects based on multifactorial models using modern methods for processing large data arrays [18].

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