Influence of thermal protection of residential buildings in rural settlements on the state of the environment

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Abstract. The state of the environment is most affected by the emission of greenhouse gases, in particular, carbon dioxide, which is formed during the combustion of fossil fuels. The main part of the energy resources that are consumed in rural areas, in addition to technological purposes, is fuel used for heating residential buildings. The article examines the state of thermal protection of residential buildings (individually defined buildings). During their construction in every region of a large country, they adhered to the established traditions, which changed slightly with the advent of new materials. Residential buildings built over a century ago are in operation in Russia. Local materials were mainly used in the construction of the walls. For a long time, state structures were not interested in the state of residential buildings, since there was no need for this due to the lack of a centralized fuel supply to villages. Gasification of rural settlements requires a revision of the attitude towards thermal protection of residential buildings. To solve the problem, state support will be required for the insulation of some of their external enclosing structures.

1. Introduction
The state of the environment is most affected by the emission of greenhouse gases, in particular, carbon dioxide, which is formed during the combustion of fossil fuels. The main part of the energy resources that are consumed in rural areas, in addition to technological purposes, is fuel used for heating residential buildings. The article examines the state of thermal protection of residential buildings (individually defined buildings). During their construction in every region of a large country, they adhered to the established traditions, which changed slightly with the advent of new materials. Residential buildings built over a century ago are in operation in Russia. Local materials were mainly used in the construction of the walls. For a long time, state structures were not interested in the state of residential buildings, since there was no need for this due to the lack of a centralized fuel supply to villages. Gasification of rural settlements requires a revision of the attitude towards thermal protection of residential buildings. To solve the problem, state support will be required for the insulation of some of their external enclosing structures.
2. Materials and methods

The state standard (GOST) of Russia refers to a building as a separate "object intended for permanent or temporary stay of people in it." From this category of objects, we single out a single-family residential building (an individually defined building), the construction of which, with rare exceptions, was not interested in the state either in Soviet times or later. In the Soviet Union, there was a restriction on his living space, in the Russian Federation, on the site of his personal local economy, it is allowed to build one, not divided into apartments, a house no higher than three floors, while the basement and attic floors are not taken into account, that is, in fact, it may turn out to be five-story.

Energy saving issues has been seriously dealt with in the capitalist countries since 1968 and in the states that were formed after the collapse of the USSR - twenty years later [1-2]. In all countries, special attention is paid to saving thermal energy for heating residential buildings of all types, significant success has been achieved [3-4], and very interesting projects are proposed [5-6]. There is no single definition of residential buildings, both in our country and in other countries; they are called either cottages or villas [7]. Economic measures are applied to carry out energy saving measures, for example, an energy certificate has been introduced in Ireland [8], energy saving measures is subsidized in New Zealand [9], as well as in the countries of the European Union [10].

In Russia, five years after the adoption of the law on energy saving in building regulations (SNiP), the chapter of SNiP 31-02-2001, dedicated to single-family residential buildings, appeared for the first time. Despite the fact that the document contained a section "energy saving", the compilers limited themselves to general instructions: to calculate the heating system and external enclosing structures in a residential building in such a way that, taking into account the construction area, they provide the GOST temperatures in the premises during the heating period. The adopted document did not contain instructions on how to determine the required resistance to heat transfer of enclosing structures, but there was a reference to the then existing SNiP II-3-79*, in which the minimum required values of the heat transfer resistance of enclosing structures were established for all buildings, except for buildings up to three storey’s high with walls made of small piece materials. In October 2003, SNiP II-3-79* was replaced by SNiP 23-02-2003, the effect of the latter extended, in particular, to the thermal protection of residential buildings (without specifying their status), a template of the building's energy passport was also presented there. The element-by-element control of the external enclosing structures was carried out, as before, by standardizing the temperature difference between the air and their surfaces in the room. A year earlier, the Code of Rules (SP) 31-105-2002 was put into effect, which concerned only single-family wooden frame houses, where there were instructions regarding the device of their thermal protection.

Because of updating SNiP 31-02-2001, SP 55.13330.2016 appeared, in its section "Energy Saving" the reference essentially remained the same, but now it was SP 50.13330, which, in particular, applies to the design of thermal protection of residential buildings under construction or reconstructed with a total area of more than 50 m. For a full-fledged organization of thermal protection, a prerequisite is the simultaneous fulfillment of element-by-element, complex and sanitary and hygienic requirements: the reduced resistance to heat transfer of individual enclosing structures should be not less than the standardized values; the specific heat-shielding characteristic of the building should be no more than the standardized value; the temperature on the inner surfaces of the enclosing structures must not be lower than the minimum permissible values. Due to the occurrence of a short period after the adoption of this document and the lack of statistical data, it is impossible to determine to what extent its instructions are being fulfilled. The state supervisory authority, represented by the Bureau of Technical Inventory, did not impose any requirements for their thermal protection to single-family residential buildings commissioned before 2017.

3. Results

Here are some Rosstat data in the context of population and residential buildings in the country and federal districts as of January 1, 2019:
Population of 146.79 million people, of which in the federal districts: Central - 39.39, North-West - 13.97, South - 16.46, North Caucasian - 9.87, Privolzhsky - 29.40, Uralsky - 12.35, Siberian - 17.17, Far East - 8.19;

The rural population is 37.42 million people, of which in the federal districts: Central - 6.97, North-West - 6.97, South - 6.14, North-Caucasian - 4.95, Privolzhsky - 8.21, Ural - 2.28, Siberian - 4.41, Far East - 2.22;

The total area of the housing stock is 3,780 million $m^2$, including by federal districts: Central - 1063, North-West - 384, South - 407, North-Caucasian - 212, Privolzhsky - 785, Ural - 314, Siberian - 423, Far East - 192;

Total area of rural housing stock - 1004 million $m^2$;

The total area of residential premises, on average per person in the country is 25.8 $m^2$, and in the federal districts: Central - 27.0, North-West - 27.5, South - 24.7, North-Caucasian - 21, 5, Privolzhsky - 26.7, Siberian - 24.6, Ural - 25.4, Far East - 23.4;

The number of apartment buildings (MKD) - 2.704 million, residential buildings (individually defined buildings) - 18.123 million, total houses 20.827;

Number and share of residential buildings by years of construction, million (%): before 1920 - 0.722 (4.0), 1921-1945 - 1.599 (8.8), 1946-1970 - 7.226 (39.9), 1971-1995 - 4.935 (27.2), after 1995 - 3.641 (20.1);

The number and proportion, million (%), of residential buildings, the wall material of which: stone - 0.639 (3.5), brick - 4.013 (22.1), panels - 0.212 (1.2), blocks - 0.776 (3), wood - 9.408 (51.9), monolith - 0.645 (3.6), mixed materials - 1.274 (7.0), other materials - 1.156 (6.4).

Since there are no separate statistics on the areas of the housing stock of apartment buildings and residential buildings (individually defined buildings), some of their indicators can be assessed only indirectly.

Therefore, in another section of the same statistical collection it is indicated that in Russia there are apartments, with an average area of 55.7 $m^2$, only 66.9 million with a total area of 3723 $m^2$. Thus, in this case, all residential buildings were counted as apartments. If you subtract 18.123 million residential buildings from the total number of apartments, counted as apartments, then 48.777 million apartments will remain in 2.704 million apartment buildings. However, this is not quite true.

On the portal of the housing and communal services fund in the section my house, as of December 23, 2021; 1.008 million apartment blocks with a total area of 2,758 million $m^2$ were registered. Of course, among the registered apartment buildings, there are those that were put into operation in 2019-2020, some management companies did not manage to register, but the order of the numbers from the end of 2018, apparently, have not changed significantly, when the total number of apartment buildings was 2.704 million with a total area of the housing stock of 3723 million $m^2$. It turns out that in two years the number of apartment houses decreased by 1.696 million, that is, from 2.704 to 1.008. Most likely, this is the number of residential buildings located in cities that, in the statistical reports, for some reason unknown to us, were listed as apartment buildings in 2018. If this is the case, then 1.696 million former apartment houses will be transferred to the category of residential buildings, the number of which will increase from 18.123 to 19.819 million.

From the statistics it follows that as of the beginning of 2019, three quarters of the buildings of the housing stock in Russia were erected five years before the appearance in the regulatory documents of instructions on the thermal protection of residential buildings, therefore, by definition, they cannot be subject to any specific requirements heat losses. It is doubtful that during the construction after 1995 of the rest of the residential buildings, the normative requirements for their thermal protection in force now.

4. Discussion
In Russia, more than half of residential buildings are houses with wooden walls. If we add 0.987 million apartment buildings of the same type to them, then their total number will be 10.395 million.
with an area of 656.114 million m\(^2\), which corresponds to 17.4% of the country's housing stock. Thus, the average area of a residential building with wooden walls is less than 63.1 m\(^2\), and assuming that the area of one apartment building with wooden walls is equal to the area of four residential buildings made of the same material; this figure will decrease to 49.1 m\(^2\).

The choice of material for the walls during the construction of a residential building mainly depended on the area of residence of a person. On the territory of the South and North Caucasian Federal Districts, where there are few forests, there are no houses with wooden walls, there earlier, in the pre-war and post-war years, walls were erected of stone, adobe, or they were made turluchny. In places where there were forests, in which pines and spruces grew, wood was used as a wall material. Bricks and blocks for the construction of residential buildings began to be widely used around the mid-70s of the last century, when there were more building materials and the living standards of the population increased.

As for the thermal characteristics of the materials from which the walls of residential buildings were built, first of all, one should consider the thermal conductivity coefficient, for each of them, W/(m\(^2\) · °C): granite - 3.5, limestone - 0.58-1.2, tuff - 0.29-1.1, brick - 0.8, adobe - 0.6-0.8, pine and spruce across the portage - 0.18.

Granite has the highest thermal conductivity. As a material for the construction of walls, it was used earlier in the mountain gorges of the North Caucasus when necessary. Granite hardly lends itself to manual processing. It is much easier to process tuff and limestone, in which the thermal conductivity coefficient is related to density. The thermal conductivity of concrete blocks depends on the filler. As for adobe and bricks, from a heat engineering point of view there is not much difference between them. Pine or spruce wood, which is most often used in the construction of wooden houses, has a very low coefficient of thermal conductivity compared to other wall materials.

However, the resistance to heat transfer depends not only on the value of the thermal conductivity coefficient, but also on the thickness of the enclosing structure, in particular the outer wall. The thickness of adobe, brick, tuff and block walls of residential buildings, excluding plaster, was usually within 0.4 m. When stones are laid dry, the minimum wall thickness will always be more than 0.4 m. The thickness of a wall made of logs used to depend on the diameter trees in the forest nearest to the construction site. Now, when distance is not a problem for delivery, logs with a diameter of 0.24 to 0.28 m are considered the most common for the construction of a traditional log house, the minimum wall thickness, determined by the width of the laying groove, for them, respectively, ranges from 0.12 to 0.14 m. The reduced wall thickness (the ratio between its volume and area) depends on the degree to which the logs are hewn.

The thermal conductivity resistance of a pine log 0.12 m thick is 0.667 m\(^2\) · °C/W, which is equivalent to 0.83 m thick masonry made of solid ordinary bricks on a cement-sand mortar.

Regardless of the material of the walls, there are no significant differences between the materials and devices of the remaining external enclosing structures of residential buildings - windows, floors, attic floors. The floors of most of them are planks on logs without an insulating layer or on the ground, and the attic floors do not have modern thermal insulation. A mixture of clay-sand mortar with straw is used as thermal insulation, which is applied to the ceiling, where it dries and hardens. Plank ceilings, except for wooden houses, are plastered over shingles. Concrete floors have been used in recent decades in the construction of modern houses from bricks, blocks and tuff. Wooden windows are being changed everywhere for plastic ones with single-chamber double-glazed windows. Their heat transfer resistance is approximately equal, but plastic has a number of other advantages.

5. Conclusion
In general, that part of the housing stock that is formed by residential buildings located in rural settlements cannot meet modern requirements for thermal protection of buildings, which significantly affects the ecological state of the country.

Fuel consumption for heating and ventilation of residential buildings is significant; therefore, its reduction is becoming a state matter. The adult population has a very vague idea of the thermal
protection of a residential building. The average homeowner, even if she wants to, is not able to assess the thermal condition of her home and take the right direction of action. A specialist can only give the necessary recommendations after the initial examination of the object. Therefore, there should be a state program for the organization of thermal protection of existing residential buildings with the subsequent issuance of an energy passport based on the actual data of metering devices. Such a program will start working only if the state takes on compensation for part of the cost of insulating residential buildings after the completion of the work, while establishing a specific rate of heat loss. Energy service companies or other highly specialized organizations should carry out all work, taking into account foreign experience. It is necessary to learn a lesson from the general energy certification of buildings of budgetary institutions, when non-specialists, because of which money was spent, and the program, in fact, mainly did this failed.

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