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Environmental substantiation for the use of alternative energy sources

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Abstract. An overview of the substantiation of the relevance of the transition to mass ecological housing construction, which is determined by an acute shortage of housing and a high increase in the cost of electricity, is given. The development of an ecological substantiation of an energy-independent house using the example of a one-story house, taking into account natural and climatic conditions, is presented. The characteristics of the work of all utilized engineering systems are considered. It has been established that the housing and utilities sector, being one of the main sources of air and groundwater pollution, creates a large amount of household waste, which has a detrimental effect on the environmental situation. Renewable energy sources have an inexhaustible supply, since they are obtained from natural processes that will not be exhausted in the foreseeable future. Thus, the prospects for renewable energy sources are in considering them to replace fossil fuels. Economic efficiency is defined, which implies that the energy source is economical both in relation to the net cost of production and in relation to supply. The development of renewable energy sources will play an important role in the transformation and digitalization of the Russian power industry. Technologies of energy storage, intelligent systems for forecasting production and demand, predictive analytics of equipment condition, consumption management and many others will be developed.

1 Introduction

The need for the construction of residential buildings with low energy consumption entails a number of reasons [1]. As a result of environmental and energy reasons, there is an urgent need to protect natural resources [2].

In most cases, residential buildings were not erected in full, considering all the norms and requirements for the design of thermal insulation, taking into account the climatic features of the construction areas [3-5]. In the southern regions of Russia, new technological developments are rarely used, with the help of which it is possible to significantly reduce the cost of construction and operation of buildings [6]. The experimental construction of residential buildings with lower energy consumption was not taken into account [7]. In the aggregate, measures in the field of heat reuse technology, the

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implementation of thermal insulation, the correct orientation of buildings and the main ways to increase energy savings are not used. Accordingly, in our time, residential buildings in Russia consume energy 2.5-4.4 times more than residential buildings with low energy consumption built abroad [8-9].

By the end of the twentieth century, the concept of building solar houses was formed, and they were divided into active and passive methods of using solar energy. The use of alternative (renewable) energy sources in low-rise construction is closely related to the problems of energy conservation [10].

Experimental residential buildings with the use of alternative (renewable) energy sources are actively building in areas with a moderate continental and continental climate.

When building in the southern regions, developers of private houses often use solar collectors for hot water supply.

Apart from the construction of private houses, which are designed using renewable energy sources, projects for the construction of a number of ecological settlements have been introduced in Europe.

It follows from this that the eco-house should be equipped with heat, electricity, hot and cold water exclusively from internal sources and have an autonomous system of sewerage and disposal of household waste. Since direct pollution (the use of fossil fuels for domestic use) should also be excluded, the eco-house should be provided with energy only from alternative renewable sources - sun, wind, water, plants.

For low-rise construction, the use of renewable energy sources is essential:

- low-grade thermal energy (geothermal energy): reservoir,
- soil - and ground;
- solar energy;
- wind energy.

Low grade heat energy is the generation of energy from the environment. The heat pump uses geothermal energy and has the ability to use renewable low-temperature energy from the environment for heating and water heating needs.

Solar energy can provide heat to a home using solar collectors, and electricity using solar panels. A solar collector converts the sun's infrared energy into thermal energy.

Wind energy is used to generate electricity using wind turbines. The amount of energy contained in the wind is proportional to the air flow area and the wind speed cubed. In other words, if the wind speed doubles, then the amount of energy that can be obtained will increase 8 times.

2 Methods and materials

An energy-independent one-story house was taken as the object of the study. Like an old Russian hut, it has a solid volume, but in a modern interpretation, in which alternative energy sources are used, such as: solar panels and collectors, wind generators and heat pumps. The type of climate in the considered construction area is sharply continental.

The total duration of sunshine is 2198 hours, and, on average, 73 days without the sun per year. The wind speed, the frequency of exceeding which for this region is 5%, reaches 9 m/s, and 45 windless days per year.

The ecological house is designed taking into account climatic conditions. The house is oblong, its long side is oriented to the west-east, has an offset slope facing south, and is located not perpendicular to the south (north), but at an angle so that the winds from the east (west) side do not hit the wall, but flow around it. House area $S = 122\ m^2$.

The south-facing slope plays an important role in the energy balance of the home and allows storing the energy of the sun thanks to strategically located roof windows, solar panels and collectors.

All windows are equipped with sun-protection elements (awnings), which, when opened, increase lighting and heating, or when closed, prevent overheating. Reinforced concrete foundation has the form of a slab. The enclosing structures and internal walls are presented in the form of a frame, as in the project "Active House" in Russia.

A frame house is a ready-made kit consisting of house building elements. The object we are considering is a wooden house in which the walls are formed by a wooden insulated frame.

3 Results

We have considered polycrystalline solar batteries with a rated voltage of 24 V and a maximum power of 230 W.

Two methods were used for the calculations. When calculating by the first method, the results showed that the use of the maximum value of the energy utilization factor and energy-saving lamps increases the costs of solar panels, and the number of solar panels is also high (25 pcs).

In the second calculation, the results showed a reduction in solar panel costs. The energy utilization rate was reduced and energy-saving lamps were replaced with LED ones. There were 11 solar panels (16.5 m^2).

Table 1. Calculation of the amount of energy generated by photocells.

Total energy consumption of a house, kWh/year	The amount of energy for the control period generated by photocells, kW/h	Total consumption for the control period, kW/h	Number of solar panels, pcs.	Occupied area S, m^2
21 870	4	44	11	17

The system of work of the wind generator is considered. One wind generator was selected with a generation capacity of 750 watts, a nominal voltage of 24 volts. The calculation determined that this wind generator provides electricity to 8% of consumers per year, depending on the power consumption. This includes all household appliances and lighting, except for the electric stove, washing machine and refrigerator.

Table 2. Calculation of the annual electricity generation by a wind generator.

Wind wheel swept area, m^2	Power generated by the wind turbine, W	Annual power generation, kW/h	Average annual electricity supply, %
5.86	726	1722.95	8

For the object under study, solar collectors are used for supplying the house with hot water. Our project uses a vacuum collector with thermal tubes, which works all year round: the aperture area is 1.972 m^2, the tank volume is 1.55 liters, the number of vacuum tubes is 15 pieces, the collector dimensions are 2020x1410x150 mm.

The calculations were carried out for the period with the lowest solar insolation indicators (from November to February). The calculation determined that seven solar collectors will be required during the study period.

But it is necessary to put an additional boiler in the winter (just in case). For the summer period (from May to August), the use of one collector will be sufficient.

Table 3. Calculation of the amount of energy for heating water by solar collectors and the number of solar collectors.

Calculation period	Receiving surface temperature, ^{0}K	Specific energy, MJ/m^2	The amount of energy for heating water, MJ	Solar collector area, m^2	Number of solar collectors, unit	Average number of collectors, unit
November	306	2.88	15.6	5.56	5	7
December	303	1.72	16.8	10.2	9	
January	301.5	2.1	17.6	8.4	7	
February	302	4.6	17.2	3.8	4	

And the last system for our facility was a heat pump designed to supply hot and/or chilled water to air handling units, fan coil units or underfloor heating systems. It is used with a boiler/dry cooler system and a geothermal circuit.

To heat our house, it is enough that a heat pump consumes electricity of power equal to 1.5 kW.

The underfloor heating system is connected to the heat pump for heating the house. The heated area of the house is S = 110 m^2, of which 12 m^2 is the north side of the house wall.

The costs are large compared to other systems, but quite justified, since the heat pump has a long service life - at least twenty years, the efficiency of heat pumps is 150-200%, they use 80% of the energy received. We will have to pay for the remaining 20%, which in our case will justify solar panels.

The last stage in the work on the project was the connection of the house to a smart home system, i.e. an autonomous house controlled by computer technology.

4 Discussion

The result of the work done is the assessment and substantiation of the use of alternative energy sources from the economic and environmental side:

1. After the inclusion of all engineering systems in our study object, the payback period of our house was 16 years, which does not look very good against the background of the economy of energy-independent houses. But it is necessary to take into account a stable increase in the cost of energy, resources, and at the same time, a decrease in the cost of engineering systems. It should be noted that in our project, we presented a comprehensive application of the entire engineering system using alternative energy sources, plus we include a smart home system, which also requires capital investments.

2. From an environmental point of view, it can be noted that the whole house is practically independent of the surrounding world. It is fully autonomous, provides itself with all energy resources and heat. No harmful emissions will be committed into the environment, since the house does not use natural gas, electricity is generated using a wind generator and solar panels, and there is no extraction and burning of natural resources somewhere to supply the house with energy. Accordingly, an ecological house has a healthy microclimate, which is ensured by the smart home system and the rational use of the building structure. The systems we use should ensure a reduction in atmospheric emissions (compared to a residential building of identical volumes and a traditional heating system): up to 5700 kilograms of CO_2, up to 185 kilograms of SO_2, up to 17.5 kilograms of NO_2, up to 17580 kilograms of polluted flue gases per year; reduce the consumption of atmospheric oxygen to 3690 kilograms per year; reduce the amount of waste to 1325 kg of ash per year.

The relevance of the transition to mass ecological housing construction is determined by an acute shortage of housing and a high rise in the cost of electricity. The housing and communal sector, being one of the main sources of air and groundwater pollution, creates a large amount of household waste, which has a detrimental effect on the environmental situation.

5 Conclusions

Nowadays, the main area of global energy development is the transition to the widespread use of renewable energy sources. All over the world, the main trend in energy policy is the transition from non-environmentally friendly fuels (oil and coal) to cleaner ones - renewable energy sources and natural gas.

This is especially important in the face of climate change, low air quality, especially in large cities with local air pollution. It is expected that,RES will become the leaders in electricity generation in the world by 2030.

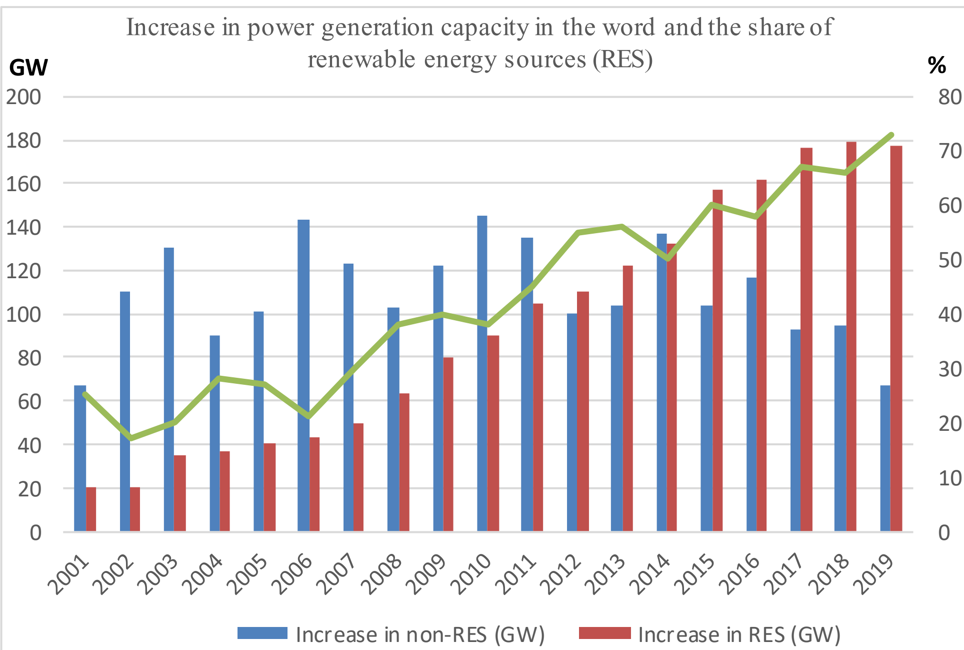

Fig. 1. Increase in power generation capacity in the world and the share of renewable energy sources (RES).

In Russia, the main areas of state policy in the field of using alternative energy sources have already been outlined. In the long term, they will ensure the achievement of 4.5% of the production and consumption of electric energy using RES until 2024.

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