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Ekaterina Sharovarova ✉; Vladimir Alekhin; Sergei Shcheklein; Nina Novoselova

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The Use of Renewable Energy Sources in Energy Efficient Buildings

Ekaterina Sharovarova[1, a)], Vladimir Alekhin[1, 3, b)],
Sergei Shcheklein[2, c)] and Nina Novoselova[3, d)]

[1]*Institute of Civil Engineering and Architecture, Ural Federal University, Ekaterinburg, Russia.*
[2]*Ural Power Engineering Institute, Ural Federal University, Ekaterinburg, Russia.*
[3]*Ural State University of Architecture and Art, Ekaterinburg, Russia.*

[a)] *Corresponding author: sharovarovakatya@mail.ru*
[b)] *referetsf@yandex.ru*
[c)] *s.e.shcheklein@urfu.ru*
[d)] *deal.so21@gmail.com*

Abstract. This article is concerned with the problem of the development of renewable energy in the world. The paper presents the efficient potential of solar and geothermal energy in Russia. The advantages of using renewable energy technologies in buildings are presented. Examples of the introduction of renewable power plants into the building envelope are considered. A comparative analysis of the efficiency of solar facade power plants with thin-film panels is given on the example of a three-story residential building in two cities of Russia. The methods of regulation of state policy in relation to renewable energy in a number of countries are considered. The article provides comparable data on the percent of renewable energy sources in the total energy balance of European Union and Russia.

INTRODUCTION

Solar and geothermal energy account for a large proportion of the energy in the geosphere. The economically efficient potential of solar energy in the Russian Federation is estimated at 12.5 million tons of fuel equivalent. The resource potential of geothermal energy is recognized to be as inexhaustible as that of solar energy. There are estimates according to which the potential of geothermal energy in Russia exceeds the reserves of fossil fuel by more than 10 times. The development of technologies in the field of solar energy and construction makes it possible to create enclosing structures that simultaneously perform heat-shielding and energy-generating functions. In this regard, buildings with a complex of renewable energy sources are acquiring considerable relevance. High efficiency of the use of renewable energy sources in buildings is achieved in the case of the use of enclosing structures with high thermal insulation characteristics. Since the contribution of renewable energy is often limited for various reasons, the building should have the least energy loss [1-4].

The use of renewable energy sources that do not require fuel consumption - such as wind, sun and water - themselves increase efficiency by eliminating the need for thermal conversion. Decentralized energy production from renewable sources, coupled with energy efficiency improvements, reduces the maximum demand for electricity while reducing transmission losses.

Construction and operation of buildings and structures consume up to half of all generated energy in the world. The efficiency of the enclosing structures significantly affects the energy saving of buildings and forms up to 30% of heat losses. The use of renewable energy sources in buildings is effective when building envelopes with high thermal insulation characteristics.

An integrated approach to the implementation of energy installations based on renewable energy sources in buildings will significantly reduce energy consumption and increase their energy efficiency. The territories of the

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Russian Federation with decentralized energy supply, characterized by low consumer capacity, lack of access to power grids, lack of fuel, severe climatic conditions, and low population density, have a huge potential for the development of buildings with a complex of renewable energy sources [5-12].

The power industry in the European Union has undergone a change of leadership: renewable energy has become the largest electricity producer. In 2020, the 27 countries of the European Union received more electricity from renewable sources than from fossil fuels for the first time. The share of coal, gas and oil fell to 37%, while wind, solar, hydropower and biomass accounted for 38% of total EU generation. The amount of electricity generation with the use of renewable energy in the EU increased by 4% last year.

At the same time, the rapid decline in electricity production at coal-fired power plants continued. In 2020 alone, it fell by 20%, and compared to 2015, it decreased by half. As a result, the share of hard coal and lignite in electricity generation in the EU decreased by 13% [13].

METHODS

Implementation of the Renewable Energy Systems into Buildings

The use of alternative energy resources is one of the main ways to solve the problem of improving the energy efficiency of buildings and structures. In this regard, the architect is faced with the task of ensuring the expressiveness of energy-active buildings using renewable energy sources and the development of artistic techniques for integrating alternative energy objects into architecture.

The effective development of the consumer's energy supply is based on the scheme of its own generation, that is, to combine the consumer and the source of energy generation into one system. Such a scheme will reduce to a minimum the need for power lines and large substations, and megalopolises and other settlements will be freed from the consequences of power outages due to natural disasters and other unforeseen circumstances. Natural disasters in recent years in the United States, Europe, the East and Russia have shown the complete failure of the centralized power supply scheme, which is especially dangerous in the peripheral regions of our country and in other countries. Any technical or natural accident leads to high financial costs. The best energy efficiency is achieved when a separate building or an entire district is self-sufficient with renewable energy. For example, in wind power, energy efficient technologies make it possible to almost universally use the energy of an air stream, even with a low energy potential. In this case, energy storage devices or other types of generators are connected. And the use of a combination of all power plants according to the scheme of "centrifugal self-supply" of the consumer can change the economy of cities and villages. Some wind turbines can be installed in decorative architectural elements of buildings, in technical floors or on outriggers and pylons [14].

There are many solutions of the use of renewable energy systems for the enclosing structures in buildings. As an example of the passive use of solar energy should be noted the Felix Trombus solar wall, which is a massive stone structure installed on the south side of the building behind a glazed façade fence. The wall can be covered with absorbent foil or painted black. Such a wall structure allows to accumulate solar energy, and then gives the thermal energy to the room at night. Douglas Balcomb's solar home concept uses the principle of residential heating using a double-height solar greenhouse on the south side.

Swedish architect Bengt Varna came up with the idea of creating a greenhouse built inside a transparent glass or polycarbonate case. Reduction of wind load and the air gap between the facades allows you to reduce the temperature difference between the premises and the street.

The use of renewable energy sources in high-rise construction is quite wide. In high-rise buildings, wind generators, solar batteries, hydropower plants, and devices accumulating energy of the earth and biomass are used. One of the existing high-rise buildings, illustrating the relevance of the use of non-conventional sources energy in construction is Burj Khalifa in Dubai. Burj Khalifa is the tallest building in the world. The height is 828 m. The tower is only partially covers its own need for energy. To achieve this, in the steeple of the object there is a wind turbine with a diameter of 61 m, as well as part of the facade of the building lined with solar panels, the area of which is 15 thousand sq. m. At the same time, they are able to convert sunlight into energy, maintaining transparency and reflecting excess heat to reduce consumption energy for space cooling [15, 16].

The Relevance and Availability of Solar Energy in Russia

The State Program of the Russian Federation "Energy Saving and Increasing Energy Efficiency for the Period up to 2030", approved by the Government of the Russian Federation in 2009, is aimed at improving the regulatory framework and implementing mechanisms for increasing energy efficiency, increasing environmental safety, reducing the specific energy intensity of the gross domestic product more than doubled since 2005.

Despite the fact that Russia is provided with its own reserves of traditional fuel and energy resources, the development of renewable energy sources (RES) is an extremely important strategic direction of the future energy. The development of renewable energy sources in Russia should be considered as an important factor in the modernization of the economy, including those associated with the development of innovative industries, new technologies, the development of small and medium-sized businesses, the creation of new jobs, the improvement of the environment, etc.

The development of solar energy has contributed to the reduction of the cost of producing solar panels and increase their efficiency. There are several generations of photovoltaic (PV) converters, depending on the material, design and production method:

- PV panels of the first generation based on crystalline silicon wafers (monocrystalline silicon (mc-Si), polycrystalline silicon (m-Si), based on gallium arsenide (GaAs));
- PV panels of the second generation based on thin films (amorphous silicon (a-Si), micro- and nanosilicon (μc-Si/ nc-Si), silicon on glass (CSG), cadmium telluride (CdTe), (di) copper selenide (indium) -gallium (CI (G) S));
- PV panels of the third generation based on cheap and recyclable polymers and electrolytes.

The use of PV panels, integrated into the facades of buildings, is now becoming more and more actual. For example, in 2015 the Finnish company Ruukki developed a special building cladding system that uses built-in solar panels. The plates used in the energy storage system of the façade consist of a film with a glossy black surface. Such panels are capable of capturing even diffuse radiation, which makes it possible to use facades also in cloudy conditions [17, 18].

Low cost (from $ 0.25 per 1 W), efficiency of 12-20% of third-generation modules and high performance in diffused light in comparison with crystalline analogs make it advisable to use them, including in the Ural region, with mostly cloudy weather. Some types of modules are produced with a transparency of up to 20%, which makes it possible to use such thin-film batteries on translucent structures. The most common are thin-film batteries based on amorphous silicon with an efficiency of no more than 12%. Currently, thin-film solar cells based on indium, selenium and copper with an efficiency of about 20% are the most effective [19].

The Evaluation of the Effectiveness of the Use of Thin-film Panels for the Facades of Buildings for Two Cities

To assess the effectiveness of the use of thin-film solar panels on the facades of buildings, research was carried out for two cities: Yekaterinburg (Sverdlovsk region) and Sevastopol (Republic of Crimea). The study is carried out for a three-storey residential building (Fig. 1) with dimensions in the axes of 18x24 m. The facade in the axes A-G, oriented to the south, is faced with thin-film panels. On the ground floor there are 3 apartments: 2-room, 3-room and 4-room. The second and third once also have 3 apartments: two 3-room and 4-room. The estimated number of people living in the building is 29 people.

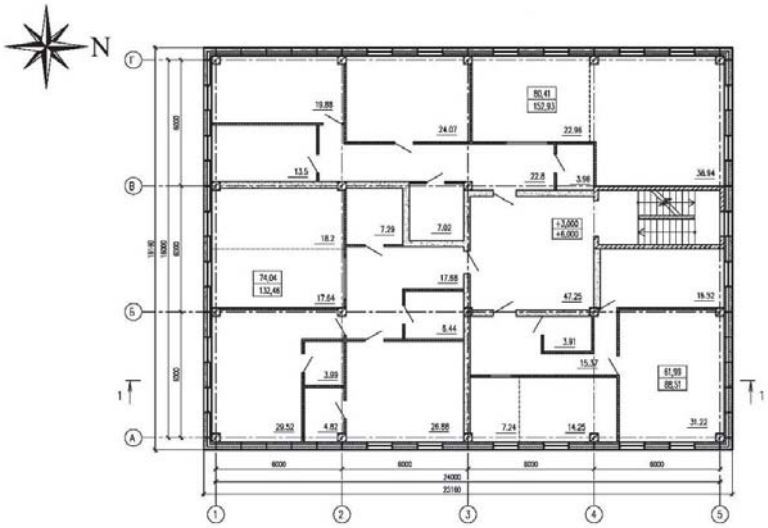

FIGURE 1. The plan of three-storey building.

Figure 2 shows a scheme of the connection of integrated solar panels to the city grid through a network sealed three-phase inverter with built-in MPPT controllers.

FIGURE 2. The scheme of the connection of integrated solar panels to the city grid.

In accordance with the standards for the consumption of utility services for electricity supply in residential premises for apartment buildings equipped with electric stoves, the consumption rate for 1 person per month (kWh) is for the Sverdlovsk region:

- 117 kWh for 2-room apartments;
- 99 kWh for 3-room apartments;
- 85 kWh for 4-room apartments.

The consumption rate of utility services for electricity supply for the Republic of Crimea is:

- 108 kWh for 2-room apartments;
- 91 kWh for 3-room apartments;
- 79 kWh for 4-room apartments.

The climatological data were used to determine the values of the total solar radiation (direct and scattered) with a cloudless sky on a vertical surface oriented to the south. Values are given for geographic latitudes for each month.

The coordinates of Yekaterinburg are 56 ° 50.3164 '0 "N (N), 60 ° 36.3308' 0" E. (E). The coordinates of Sevastopol are 44 ° 37.0012 '0 "N (N), 33 ° 31.5259' 0" E. (E).

Additionally, a coefficient was calculated equal to the ratio of the number of clear days in a year to the number of all days in a year. For Yekaterinburg, the number of clear days on average is 135 days, for Sevastopol - 300. The

total annual solar radiation, taking into account the adopted coefficient, for Yekaterinburg is 643.36 kWh / m2, for Sevastopol - 1218.62 kWh / m2.

TABLE 1. Power generation by solar panels with different efficiency

Value	Ekaterinburg	Sevastopol	The ratio of the energy generated by the solar panels to the energy consumption (%)	
			Ekaterinburg	Sevastopol
Annual total solar radiation Q, kWh/m2	657.47	1 479.19		
The value of the annual total solar radiation entering the façade, kWh	63 906.08	143 777.27		
Energy production by solar panels (with 10% efficiency)	6 390.60	14 377.70	19.4	47.37
Energy production by solar panels (with 15% efficiency)	9 585.91	21 566.55	29.19	71.06
Energy production by solar panels (with 20% efficiency)	12 781.20	28 755.40	38.88	94.75

Table 1 shows the generation of electricity by solar panels with different efficiency - 10%, 15% and 20%. With the area of the panels installed on the southern facade of the building equal to 137.8 m2 (excluding windows and doors), the energy generation by panels with an efficiency of 15% for the Sverdlovsk region is more than 40% of the total annual electricity consumption of residents, excluding electricity consumption for common buildings. For the Republic of Crimea, the production of panels with high efficiency is 83%.

RESULTS

The power of the facade PV power plant depends on the selected type of PV panel, the total power will be from 10 to 20 kW. In accordance with the adopted amendments to Federal Law No. 35 “On Electric Power Industry”, the concept of micro-generation was introduced - about private power plants with a capacity of up to 15 kW. In case when the capacity of power plant for the selected residential building is less than 15 kW, in summer period when there is more generated energy than their own consumption, energy supplying organizations are instructed to buy energy generated by microgenerating installations at the wholesale rate established in the given territory. The law does not contain a permit for offset compensation for electricity supplied to the grid, which significantly affects the stagnation in the development of renewable energy.

For example, in Germany there is a law on renewable energy sources (EEG Renewable Energy Sources Act), which establishes the right to pay a premium for the supply of renewable energy from the lessor to the lessee, for solar installations with an installed capacity of up to 100 kW, which are installed in a residential building, provided that at least 40% of the building area is occupied by residential premises.

Also last year, the Berlin Senate approved the Action Plan for the development of solar energy in the capital of Germany (Masterplan Solarcity). According this, Berlin should reach 25% solar energy by 2050. Experts have calculated that for this, the city needs to install 4.4 GW of solar power plants. The Solar Energy Act is part of the implementation of the said plan. The regulation applies to roofs with an area of more than 50 m2, and the photovoltaic systems must cover at least 30% of the roof area. For residential buildings, the following minimum requirements were determined: for buildings with one or two apartments, these will be systems with a minimum power of 2 kW, for three to five apartments - 3 kW, and for buildings with six to ten apartments - 6 kW. Also, the text of the document provides for some special cases: for example, if the roof is facing north, or it is technically impossible to install the system on the roof. Then the solar station can be replaced with roofing thermal or facade photovoltaic systems. The Berlin House of Representatives has passed a solar energy law. According to the

document, from January 1, 2023, solar power plants should be installed on all new buildings, as well as roofs after major repairs in old buildings.

Government Promotion Policy for Renewable Energy Installations in Buildings

Incentive payments contribute to the development and diffusion of renewable energy sources. Under current law, power plant operators are compensated for 20 years for the renewable energy they generate and supply to the grid. The tariff is paid by the transmission system operator who sells the electricity on the exchange. The price they can get there is often below the flat rate of remuneration. The difference between labor costs and income from electricity sales is passed on to electricity consumers. The resulting figure is the payment for power plants based on RES.

Renewable energy has become the largest electricity producer in the European Union's electricity sector. In 2020, the 27 countries of the European Union received more electricity from renewable sources than from fossil fuels for the first time. The share of coal, gas and oil fell to 37%, while wind, solar, hydropower and biomass accounted for 38% of total EU generation, increasing production by 10% [20-24].

The percent of renewable energy sources in the total energy balance of Russia is only about 0.2%. Changes in the federal law in favor of renewable energy, the establishment of a procedure for incentive payments to operators of power plants can significantly affect the development of renewable energy sources in the Russian Federation.

DISCUSSION

The development of renewable energy is the most efficient and easily accessible way to first stop the growth of CO2 emissions into the atmosphere, and then drastically reduce them in order to ensure a safe climate future. In addition, the development of renewable energy sources will contribute to the growth of employment on the planet.

The increase in the share of renewable energy in world electricity production has a significant impact on many aspects of the economies of countries, since it changes the volume of consumption of fossil fuels and changes the structure of industrial production. Power plants based on renewable energy sources also have a significant impact on the modes of operation of power systems. Therefore, the question of the pace of transition to renewable energy seems to be very relevant.

The desire of national and international institutions to develop various kinds of measures to reduce greenhouse gas emissions has led to the formation of an explosive demand for carbon-free renewable energy technologies. The result was continuous improvement of technological solutions, reduction of equipment and construction costs due to high competition and achievement of economies of scale. Solar and wind energy in a number of countries has become cheaper than traditional generation, which will inevitably happen in the future in Russia.

Most of the promising areas for the development of renewable energy in Russia are at an early stage, and the scale of projects being implemented is very small. So, according to 2020, the share of wind and solar electricity in the balance of the UES of Russia amounted to only 1%. with a favorable forecast, the share of renewable energy sources could grow to 5% by 2035.

The most important goal for Russia is to rapidly reduce the cost of green electricity. Renewable energy produced with imported equipment will soon compete with electricity generated using Russian equipment for traditional generation. In the absence of its own technologies for power engineering for renewable energy sources, this will lead to dependence on imported technological solutions.

CONCLUSIONS

World experience shows that the renewable energy industry works most effectively if there is a formed technological cluster in the state, consisting of four basic elements: generation, production, research and education. The presence of all four elements is its important property, since the loss of at least one of them makes the entire system unstable. The applied solutions must correspond to the best technological practices, and the price characteristics must correspond to the world level, and, of course, the cluster must have a stable export potential.

Changes in the legislative framework of the Russian Federation in order to stimulate the use of green energy technologies in construction could significantly contribute to the widespread introduction of renewable energy sources in existing and projected buildings. The development and cheapening of solar energy technologies leads to the fact that every year the equipment for solar power plants becomes more and more accessible. The facade solar power plants considered in the article in dense urban development are especially relevant.

Successful development of renewable energy, stated in the Energy Strategy of Russia for the period up to 2030, is impossible without the dynamics of the main economic parameters of the production of renewable energy.

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