Directions for the development of renewable energy sources in Russia using information technologies during the formation of the climate crisis

E S Bogodukhova¹, V V Britvina¹, E O Bobrova¹,², G P Konyukhova³ and A V Altukhov²

¹Moscow Polytechnic University, 38, st. Bolshaya Semyonovskaya, Moscow, 107023, Russia
²Lomonosov Moscow State University, 1, Leninskie Gory, Moscow, 119991, Russia
³Moscow State Technical University "Stankin", 1, Vadkovsky per., Moscow, 127994, Russia

E-mail: bogodukhova_katerina@mail.ru

Abstract. This work is devoted to the study of the dynamics of the development of renewable energy (RES) in Russia; or rather, provides effective directions for overcoming the climate crisis using information technology. The aim of the work is to study the impact of green energy both on the situation in the global energy market and on the infrastructural connectivity of the regions, on the basis of which projects for the introduction of alternative energy are being implemented. A comparative analysis of several countries has shown the effectiveness of the introduction of renewable energy sources into energy systems. Territorial studies have made it possible to identify regions where a full or partial transition from traditional energy to alternative energy as a source of energy supply will increase financial sustainability and improve the ecological situation of the environment. Based on the results of the work carried out, the most pragmatic direction for the development of renewable energy sources for the Russian energy system was determined. The article is supplied with graphic materials and tables, as well as a detailed description of each stage of the study.

1. Introduction

To date, about 103 million cases of infection with the new coronavirus have been recorded, of which more than two million deaths and almost 57 million recoveries. The whole world is following the updating of these figures, but few people pay attention to the fact that about 6 million people die a year from the effects of burning fossil fuels and traditional biomass, due to atmospheric air pollution, of which more than 950 thousand from burning coal.

Ecosystems destroyed by humans have triggered a process of climate change that will not end by itself, but will only cause more and more major crises. This means that if the previous development trends persist, new pandemics are likely in the near future.

That is why; the article discusses the issue of the transition from traditional energy to renewable, based on alternative sources, on the territory of Russia. For an optimistic interpretation of trends in this area, it is necessary to study the development rates and growth potential of alternative energy in the global energy balance, consider several solutions to the climate crisis and, on their basis, determine the most pragmatic for the Russian energy system.
Over the past half century, burning fossil fuels has contributed more than 80% of all global greenhouse gas emissions, the accumulation of which in the atmosphere has caused climate change. The use of traditional energy for energy supply has led to the emergence of a climate crisis, the way out of which is due to the transition to nuclear or renewable energy [1-2].

2. Materials and methods
In many regions of the world, renewable energy is an established industry with a progressive development rate. The installed capacity of renewable energy plants in China is three times the capacity of the entire energy system of Russia. In Germany, the development trend of solar energy on an industrial scale is the leading energy trend.

In 2019, the total capacity of wind generation in the world has exceeded 651 gigawatts (2.5 times more than the total capacity of all Russian power generation), having increased by 10% over the year [1; 5]. The largest markets for onshore wind farms remain China and the United States - these countries accounted for more than 60% of the facilities put into operation [3-5]. At the same time, coastal wind generation is starting to play a more prominent role: in 2019, the capacity of this sector increased by 6.1 gigawatts [5].

By the end of 2019, the global installed solar capacity exceeded 630 gigawatts. The share of solar energy in the world's electricity generation is today about 2.6% [1]. In 2021, a global increase in solar energy is expected by 150 gigawatts and in 2024 already by 200 gigawatts. On the part of the industry, the possibility of such growth is provided today.

According to data for 2019, renewable energy sources generated more energy for 6 months than nuclear power plants and thermal power plants, their share was 47.3%, more than half - 24.5% fell on solar energy (figure 1, a), and 22.8% - wind (figure 1, b), biomass and water [8], and in 2020, wind and solar power plants provided 42% of electricity generation in Germany and 33% in the UK [5]. Leaders in these destinations are China, Japan, Germany, USA, Italy, India and UK.

![Wind power](image1.png) ![Solar energy](image2.png)

**Figure 1.** Renewable capacity statistics for 2019 in gigawatts: a – wind power; b – solar energy.

It can be seen that the share of electricity production (figure 2) from combusted fuels over 10 years has been decreasing with a certain frequency and had a trend line (4 continuously increasing and decreasing points), which characterizes the instability and variability of the traditional process of energy production, and from renewable sources it gradually increased, making process acceptable and stable for further operation. The success of renewables (over 5%) is partly due to a decrease in electricity consumption due to the COVID-19 pandemic (minus 4%). Despite the epidemiological
situation, the commissioning of new solar and wind generation capacities turned out to be surprisingly large-scale. The growth potential of renewable energy sources is colossal: in the global energy balance, alternative energy still accounts for only 10% of all energy production, but high export figures of more than two billion euros per year prove the economic profitability of this direction [2].

Nuclear power cannot be considered as a solution to the climate crisis, since it is extremely vulnerable to climate change, and its use is associated with the risks of accidents and radioactive contamination. Due to global warming: the number of floods in coastal zones will increase, which will create a risk of accidents at nuclear power plants, and excessively heated water will impede daily cooling of the reactors [4]. In the past hot summer in France, reactors had to be shut down because of this, which led to a decrease in the output of nuclear power plants by 10%, and in Germany, according to the legislative form, all nuclear reactors must be closed by the end of 2022 (table 1) [6].

In anticipation of serious environmental consequences in many developed countries, an economic strategy has been developed that applies not only to energy, but also to other sectors of production and consumption of resources that can harm the environment. This strategy provides for the leading role of the state in solving environmental problems. An example of stimulating the development of energy from renewable sources is the German "Law on the Priority of the Use of Renewable Energy Sources". In Russia, such laws are not of such importance, and, therefore, the development of RES will require a structural approach [9] with partial implementation ("islands") in certain regions to control and systematize the energy supply process.

Currently, renewable energy sources, excluding large hydroelectric power plants, which have many environmental disadvantages, provide only 0.24% of all electricity production in Russia. By 2020, it was planned to bring the value of this indicator to 4.5%, but the percentage of the planned share of RES was reduced to 2.5% [3, 4]. With this percentage, the integral effect for the Russian economy from the development of renewable energy by 2024 will be about 170 billion rubles, export earnings will be more than 85 billion rubles, and environmental costs will be reduced by 20 billion rubles [10]. For the exponential growth of these indicators, it is necessary to increase the share of RES in the country. Table 2 shows a comparison of the use of RES resources in Russia with world indicators [7].
Table 1. The state of nuclear power in the leading countries.

| Country | Motivation for the development of nuclear energy | Prospects |
|---------|-----------------------------------------------|-----------|
| USA | There is no motivation. Nuclear energy is not competitive compared to fossil fuel energy. Nuclear energy is impossible without state support. The country is choking on emissions from coal-fired power plants. The task of a nuclear power plant is to reduce environmental pollution. | Decrease the share of nuclear power plants in electricity generation. |
| China | Energy independence. | Increase in the share of heavy power plants in electricity generation. |
| France | Energy independence. There is no motivation. It is required to increase the share of alternative energy sources in the energy balance. Coal and gas power plants provide Electricity needs. | Maintaining a high share of nuclear power plants in electricity generation. |
| Germany | Nuclear energy is impossible without state support. Nuclear energy is seen as a tool to influence international politics. | Elimination of nuclear energy. |

Table 2. RES resources in the world and in Russia.

| Energy type | Theoretical resources, mln., T.e. | Technical resources, mln., T.f. |
|-------------|----------------------------------|---------------------------------|
|             | Peace   | Russia | Peace  | Russia   |
| Energy of sun | 1.3·10⁸  | 2.3·10⁸ | 5.3·10⁴  | 2.3·10⁴  |
| Wind energy  | 2.5·10⁵  | 2.6·10⁴ | 2.2·10⁴  | 2.0·10³   |
| Geothermal energy (up to a depth of 10 km) | 4.8·10⁹  | -      | 1.7·10⁵  | 1.0·10²   |
| Energy of the World Ocean | 2.5·10⁵  | -      | -       | -        |
| Biomass energy | 9.9·10⁴  | 1⁴     | 9.5·10³  | 53       |
| Hydropower   | 5.0·10³  | 3.6·10² | 1.7·10³  | 1.2·10²   |

3. Results
Based on the data obtained during the study, it can be distinguished that 4 types of renewable energy are inherent in Russia, two of which are the most promising for use in Russia (see table 2). Wind power is viewed primarily as the most commercially viable area. Currently, this energy resource is mainly used in remote areas with a low population density, where access to the main sources of electricity is limited [12]. The installed capacity of wind energy in the country is only 0.06% of the capacity of power plants in the energy system [7; 12], but by the end of 2021 it is planned to commission about 30 small wind power plants with a capacity of 760 MW and localize the production of wind power plants by 68% [12]. Despite the potential increase in wind power plants in the country, Russia's entry into the world wind energy market [12] is associated with certain difficulties, since the commissioning of onshore wind turbines with a small installed capacity from an economic point of view is not quite...
cost-effective without mass production, as is the achievement of grid parity. Therefore, in order to take its place in an already existing niche with high competition, it is necessary both a total expansion of the construction of wind turbines [12] in the country, and collaboration with other energy sources.

Solar energy accounts for only 0.55% of the total electricity generation in the structure of generating capacities [12], but the amount of solar radiation arriving in Russia in a few days exceeds the annual electricity production in the country [12]. In the south of Transbaikalia, the duration of the annual sunshine is more than 2500 hours, and in the city of Borzya, Borzinsky district, the average annual number of sunshine hours is 2797 (table 3) [11]. The development of solar energy in the Trans-Baikal Territory, where more than 60% of the terrain from the location of the Sun is above the horizon, using a structural approach to the systematization of the energy supply process [9], will reduce the cost of electricity and fuel consumption, thereby increasing the standard of living of the population: the resumption of urban planning, landscaping and infrastructure of cities on the territory of which solar power plants.

Table 3. Weather station readings: leading cities in terms of average annual sunshine duration

| Weather station | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|----------------|------|------|------|------|-----|------|------|------|-------|------|------|------|------|
| Borzya         | 152  | 203  | 264  | 267  | 304 | 303  | 276  | 270  | 231   | 226  | 162  | 140  | 2797 |
| Khabarovsk     | 146  | 184  | 233  | 213  | 242 | 261  | 248  | 217  | 213   | 189  | 159  | 146  | 2449 |
| Astrakhan      | 87   | 107  | 164  | 225  | 295 | 315  | 332  | 310  | 252   | 180  | 84   | 59   | 2410 |
| Nikohodca      | 203  | 212  | 210  | 202  | 205 | 178  | 167  | 187  | 208   | 213  | 191  | 192  | 2368 |

4. Discussion
When comparing foreign projects aimed at the development and introduction of renewable energy sources, it was determined that their practical application gives the regions advantages from their exploitation, profitability and stability of resources in the energy sector, and when studying the indicators (tables 1-3) pragmatic directions development for the power industry in Russia [12] during the formation of the climate crisis.

One of the development directions is the introduction of onshore wind turbines. In Russia, this direction is developing rapidly, but will it be able to compete with traditional methods of extracting energy resources, with an average wind speed of 4-5 meters per second, and an output of 1-3% of the nominal power, freezing of lubricant at negative temperatures (more than -10 °C) and the need for technical repairs on a mast with a height of more than 25 meters on 99% of the entire territory of Russia, the cost of which exceeds the cost of the wind generator [12] itself several times.

Another area is the introduction of photovoltaic converters in the eastern part of Russia, which is dominated by high solar activity. The construction of solar power plants in the steppe zone will reduce not only electricity tariffs, but also the consumption of diesel fuel, the savings of which will quickly pay off the solar cells, which will increase the growth of the district's financial stability and reduce the number of fires by concentrating energy on panels.
5. Conclusion
In conclusion, I would like to note that Russia is on the verge of producing its own renewable energy, the commissioning of which, regardless of the choice of development direction, will improve the environmental situation and energy security in the regions, and colossal territorial advantages, which in turn make alternative resources inexhaustible, will allow create favorable conditions for all segments of the population.

References
[1] Expert portal on energy supply Retrieved from: https://gisee.ru/
[2] The influence of the spread of renewable energy sources Retrieved from: https://renen.ru/influence-of-the-spread-of-res-on-the-national-economy/
[3] Renewable energy sources (RES) Retrieved from: https://www.popmech.ru/
[4] Development of RES in Russia Retrieved from: http://atomicexpert.com/page462647.html
[5] Development of wind power generation in Russia and the world Retrieved from: https://incrussia.ru/specials/energy-from-air/
[6] The Impact of Renewable Energy Sources on Nuclear Energy Outlook Retrieved from: https://atomicexpert.com/page1082260.html
[7] Comparison with foreign technologies Retrieved from: https://studbooks.net/1846854/matematika_himiya_fizika/sravnenie_zarubezhnymi_tehnologiyami
[8] Bogodukhova E S, Britvina V V and Konyukhova G P 2020 Renewable energy development trends in russia. Theory and practice of project education 2(14) 73-74
[9] Logachev M S, Voronin I V, Britvina V V, Tichtchenko S A and Altoukhov A V 2020 Local Area Network Monitoring: The Issue of Broadcast Storm. International Journal of Advanced Trends in Computer Science and Engineering 9 4216-4222
[10] Budylina E and Danilov A 2019 Methods to ensure the reliability of measurements in the age of Industry 4.0. Journal of Physics: Conference Series 1379 012063
[11] Climate of Russia Retrieved from: https://ru.wikipedia.org/wiki/
[12] Bogodukhova E S and Kucherenko N S 2019 Solar energy development trends in russia. Materials of the National Scientific and Practical Conference "Digit" - reality changing the world: readiness of the russian economy for new rules of the game" Moscow 125-127