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# Green Energy Development in Russian Regions

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**ABSTRACT:** The analysis of the development of "green energy" in the regions of Russia is one of the pressing modern scientific issues. This article describes the general situation with carbon dioxide emissions in the atmosphere in the world and in Russia. It is shown that the Russian Federation is one of the world leaders in the volume of carbon dioxide emissions. Global and Russian trends in the development of renewable energy sources are considered. The spatial unevenness in the development of renewable energy sources in the regions of the Russian Federation is characterized. An econometric model is proposed, which investigates the influence of the production process (through such factors as gross regional product and electricity consumption) as well as the development of renewable energy sources on carbon dioxide emissions in Russian regions. The results show that gross regional product and regional electricity consumption have positive impact on increasing carbon dioxide emission while the increase of renewable energy sources has a negative impact on increasing carbon dioxide emission. At the present stage, Russian regions can face a number of problems and constraints of social and economic nature that may hinder the development of a "green economy".

**KEYWORDS:** Carbon dioxide emissions, Green energy, Renewable energy, Regional ecology, Sustainable development.

## INTRODUCTION

Economic development, expansion of the volume and range of goods and services produced in the global economic system for a long time has been associated with the use of traditional forms of energy, which inevitably led to an increase in carbon dioxide emissions into the atmosphere. As the results of numerous studies show, the described trend is still relevant, as the volume of carbon dioxide emissions has been steadily increasing over the past decades.

The gradual realization of the need to abandon traditional energy sources is expressed in a change in the development paradigm itself, which is associated with the spread of the concepts of "green economy", "blue economy", "green energy" and sustainable growth, which necessarily involves an assessment of the environmental aspects of development.

For a country with a vast territory such as the Russian Federation, the adoption of strategic decisions aimed at ensuring sustainable development at the federal level seems obviously an insufficient measure, since the development of the territories themselves is significantly differentiated and in each particular case a large number of factors, ranging from natural and climatic to social and economic, must be taken into account. That is why the study of peculiarities of "green energy" development in the regions of Russia seems to be an urgent scientific task.

Purpose of the research: to characterize the features and specifics of "green energy" development in the regions of Russia.

## DEVELOPMENT OF RENEWABLE ENERGY SOURCES

Globally, carbon dioxide emissions have been rising steadily. If we consider the dynamics of the values of this indicator from 2000 to 2020, we can note that the decrease in emissions was observed only in 2020, which is logical, taking into account the decline in the production of goods and services due to the pandemic coronavirus [7].

Figure 1 shows Top 5 countries by the volume of carbon dioxide emissions in 2020.

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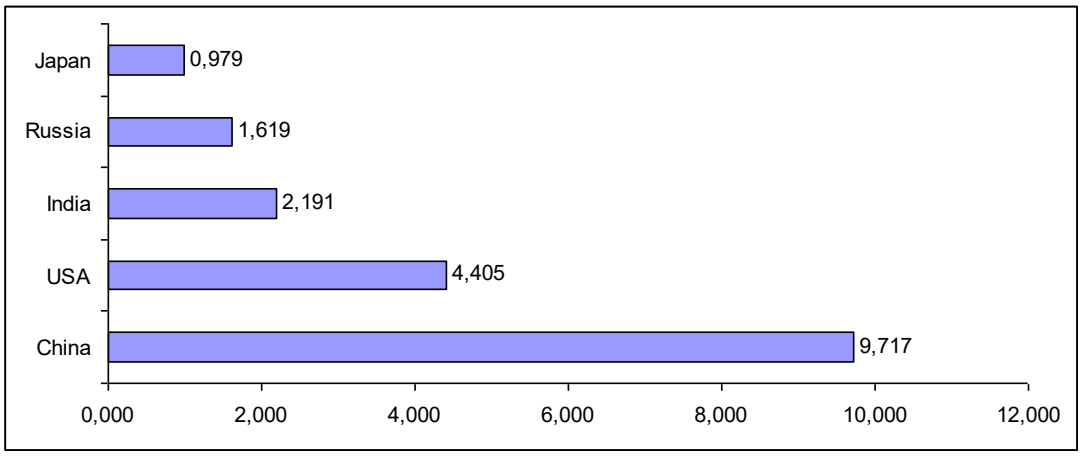


**Figure 1** - Top 5 countries by carbon dioxide emissions in 2020, million tons [8]

Thus, by the end of 2020, Russia ranks fourth in the world in terms of carbon dioxide emissions. And the value of this indicator, although fluctuating, shows an upward trend, as shown in Figure 2.

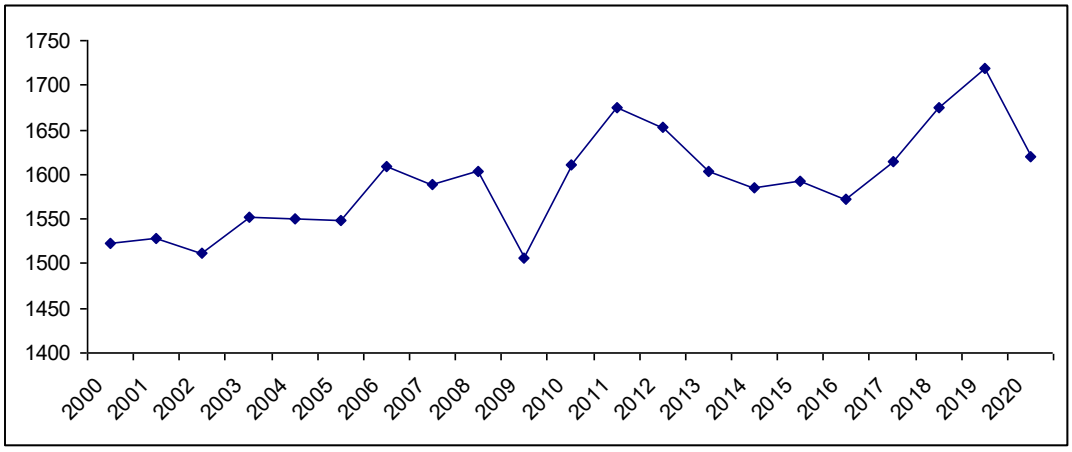


**Figure 2** - Dynamics of carbon dioxide emissions in Russia in 2000-2020. [8]

One of the significant indicators of green energy development is the share of renewable sources in electricity generation. In 2020, the value of this indicator was 28%, as shown in Figure 3.

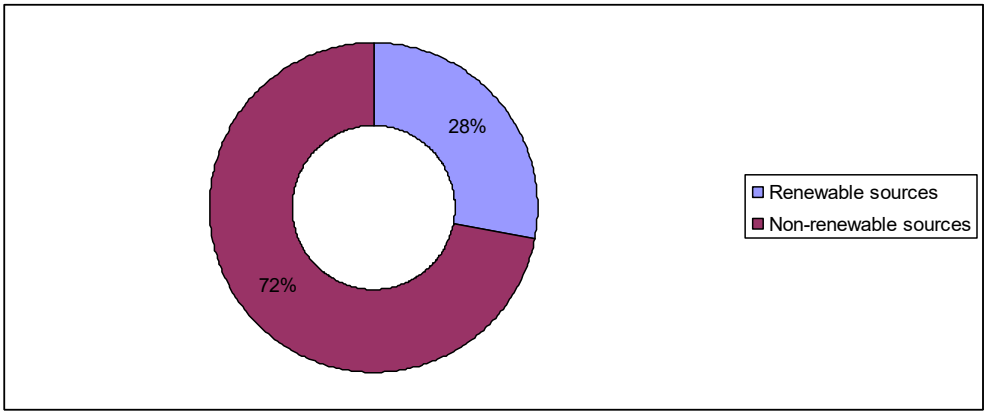


**Figure 3** - Share of renewable sources in electricity production in the world in 2020, % [8]

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It is important to note that the value of this indicator is quite differentiated and varies from 0.2 per cent in Saudi Arabia to 98.4 per cent in Norway (all data are given as of 2020). Figure 4 shows the top five countries in terms of the share of renewables in electricity generation in 2020.

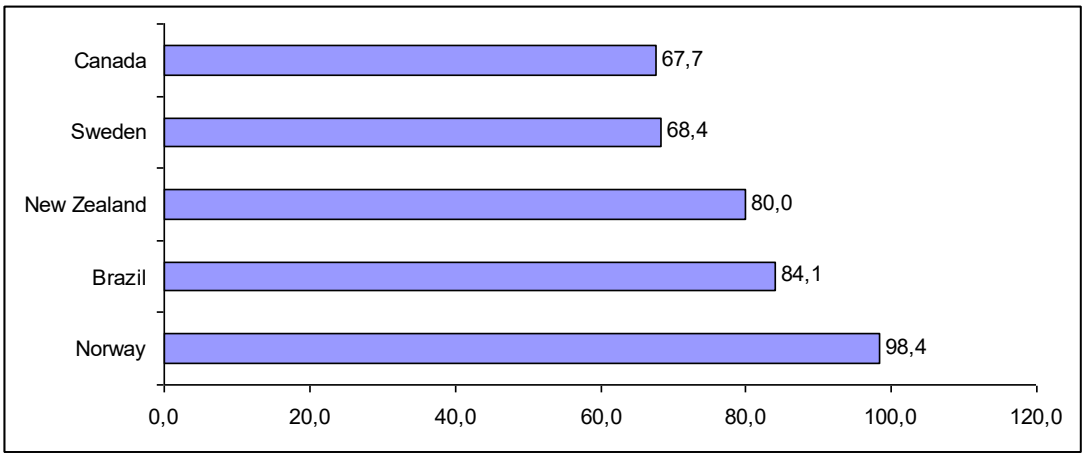


**Figure 4** - Top 5 countries by the share of renewable sources in electricity generation in 2020, % [8]

If we consider the level of development of renewable energy sources in different countries, it is worth mentioning that, as of 2020, only a few countries in the world had more than sixty per cent of their electricity production from renewable sources in 2020 - in addition to the top five countries, these include Colombia and Venezuela. It is important to emphasize that in South America, the use of renewable sources in electricity generation is a significant trend. Table 1 shows the share of renewable sources in electricity production in the world's largest macro-regions over the period 2000-2020.

**Table 1.** Share of renewable sources in electricity production in the largest macro-regions of the world in 2000-2020. [8]

| *No.* | *2000* | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|---|
| **1. Europe** | **20,1** | **19,8** | **25,2** | **33,6** | **42,8** |
| **2. CIS** | **17,9** | **17,9** | **16,3** | **15,6** | **19,6** |
| **3. North America** | **15,5** | **15,5** | **16,7** | **20,3** | **26,1** |
| **4. South America** | **61,6** | **58,8** | **57,3** | **51,7** | **57,6** |
| **5. Asia** | **13,4** | **13,7** | **15,7** | **19,8** | **25,0** |
| **6. Africa** | **17,8** | **17,6** | **17,0** | **17,9** | **21,1** |

In general, the analysis of the data shown in Table 1 shows that throughout the period under study, there has been an upward trend in the share of renewable sources in electricity generation in the largest macro-regions of the world. Figure 5 traces the change in the share of renewable sources in electricity generation in Russia in 2000-2020.

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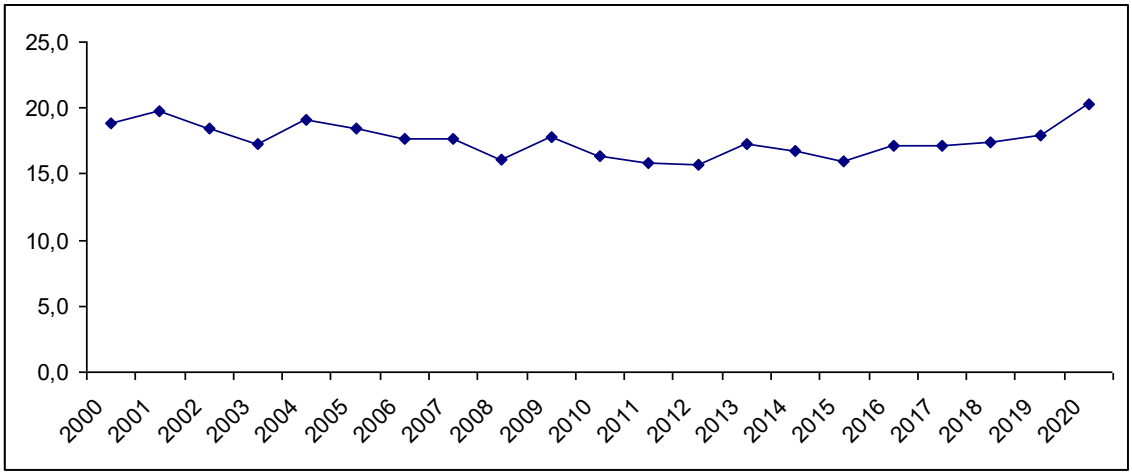


**Figure 5** - Share of renewable sources in electricity production in Russia in 2000-2020. [8]

As Figure 5 shows, the share of renewable sources in electricity production in Russia in 2000-2020 is characterized by unstable dynamics, but since 2015, the value of this indicator is increasing, reaching a maximum of 20.3 per cent in 2020 [14].
In the Russian Federation, the development of renewable energy sources is carried out, among other things, in accordance with the federal program. At the same time, regional legislation plays an important role, since within each region priorities for renewable energy development are determined, as well as a set of necessary measures of stimulating nature aimed at attracting investment in this industry [9]. As a rule, regional authorities are ultimately responsible for creating the necessary investment climate and, ultimately, for the development of renewable energy sources within the boundaries of a particular territory. This thesis is confirmed, in particular, if we analyse the distribution of renewable energy sources in the regions. The results of this analysis are reflected in Table 2.

**Table 2** Distribution of renewable energy sources in Russian regions in 2022 [6]

| *Region* | *Numbers of projects* | *Types of renewable energy sources* |
|---|---|---|
| **Chukotka Autonomous Area** | **1** | **WPP** |
| **Kamchatka Territory** | **8** | **WPP, SHPP, GTPP** |
| **Sakhalin Region** | **3** | **WPP, GTPP** |
| **Republic of Sakha (Yakutia)** | **2** | **SPP, WPP** |
| **Trans-Baikal Territory** | **3** | **SPP** |
| **Republic of Buryatia** | **6** | **SPP** |
| **Krasnoyarsk Territory** | **1** | **SHPP** |
| **Republic of Khakassia** | **1** | **SPP** |
| **Tomsk Region** | **1** | **SHPP** |
| **The Republic of Altai** | **8** | **SPP, SHPP** |
| **Omsk Region** | **2** | **SPP** |
| **Sverdlovsk Region** | **1** | **SHPP** |
| **Orenburg Region** | **13** | **SPP, WPP** |

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| | | |
|---|---|---|
| **Republic of Bashkortostan** | **8** | **SHPP, SPP, WPP** |
| **Samara Region** | **1** | **SPP** |
| **Ulyanovsk Region** | **3** | **WPP, SHPP** |
| **Saratov Region** | **4** | **SPP** |
| **Astrakhan Region** | **12** | **SPP, WPP** |
| **Volgograd Region** | **8** | **SHPP, SPP, WPP** |
| **Republic of Kalmykia** | **6** | **SPP, WPP** |
| **Republic of Dagestan** | **8** | **SPP, SHPP** |
| **Chechen Republic** | **2** | **SPP, SHPP** |
| **Republic of North Ossetia-Alania** | **6** | **SHPP** |
| **Kabardino-Balkarian Republic** | **5** | **SHPP** |
| **Karachayevo-Circassian Republic** | **5** | **SHPP** |
| **Stavropol Territory** | **9** | **SHPP, SPP, WPP** |
| **Republic of Adygeya** | **4** | **SHPP, SPP, WPP** |
| **Krasnodar Territory** | **1** | **SHPP** |
| **Rostov Region** | **6** | **WPP** |
| **Belgorod Region** | **3** | **WPP, SPP** |
| **Moscow Region** | **11** | **SHPP, SPP** |
| **Pskov Region** | **2** | **SHPP** |
| **Republic of Crimea** | **11** | **WPP, SPP** |
| **Murmansk Region** | **4** | **TPP, SHPP** |
| **Republic of Karelia** | **9** | **SHPP** |

The following symbols are used in Table 2:
WPP - wind farms;
SPP - solar power plants;
TPP- tidal power plants;
SHPP - small hydroelectric power plants;
GTPP - geothermal power plants.

It is important to emphasize that solar and wind power plants prevail in Russian regions quantitatively. At the same time, the share of wind and solar energy in the country's electricity production in 2020 was only 0.3 per cent [4]. Thus, it is appropriate to say that the main volume of electricity produced by renewable energy sources is obtained as a result of small hydropower plants, which is confirmed by research results.

When analysing the data presented in Table 2, it is important to note that renewable energy sources are distributed very unevenly across the country. In particular, the vast majority of them are concentrated in the territories that are located, conventionally speaking, in the southern part of the country. At the same time, the northern territories actually have no such sources. It is also interesting that in the central European part of the country, renewable energy sources are also almost completely absent. The aforementioned trends are graphically depicted in Figure 6.

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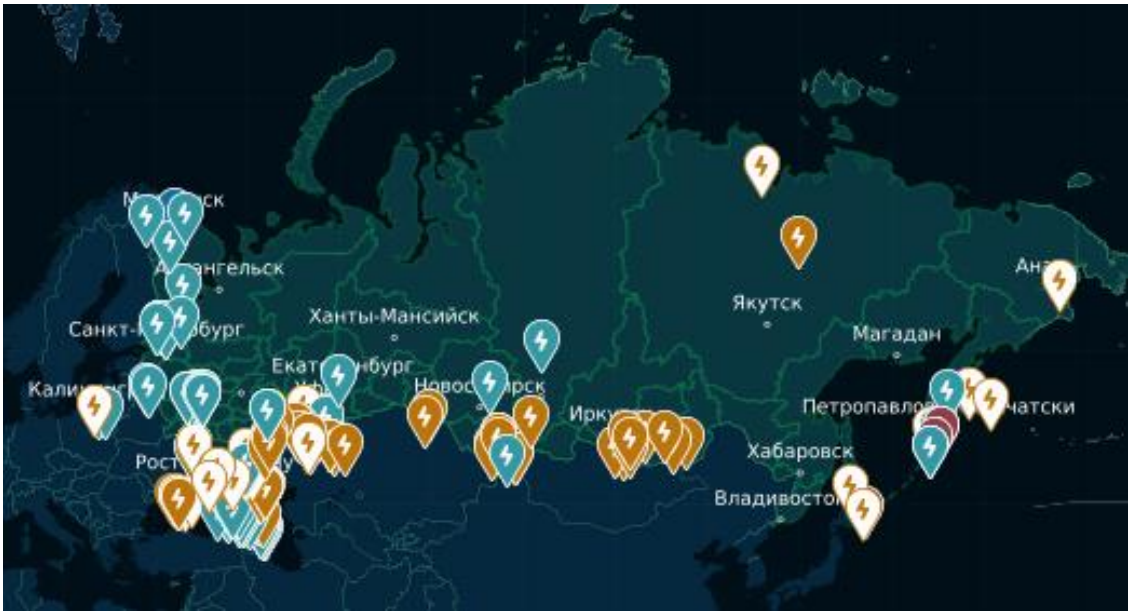


**Figure 6** - Distribution of Renewable Energy Sources in Russian Regions [6]

It should be emphasized that many of those territories in which renewable energy sources are not currently represented, or their number is insignificant, also have quite significant potential for their development in the near future. For example, the development of wind power plants is promising not only for the southern territories, where their number is already significant, but also for the northern regions, including those located above the Arctic Circle.

The southern regions and some parts of Western and Eastern Siberia and the Russian Far East have potential for solar power development. Small hydropower plants will work better where there are many small rivers - in the Siberian, Far Eastern, Northwestern, Southern, Urals and North Caucasus Federal Districts.

Speaking about the development of "green energy" in certain regions, it should be noted that first of all, of course, it is necessary to consider not only the natural, geographical features and characteristics of the territories, but also the current specifics of the development of various industries. For example, in the Vologda Region the use of wind and solar energy is significantly hampered by the fact that there are not enough natural capacities for this purpose, and the payback period of the corresponding types of power plants when put into operation will be unreasonably long. At the same time, the development of biofuel production in the region indicates the potential possibility of using this source of energy as much more environmentally friendly than the currently used for this purpose peat.

In 2020, for the first time, the Russian Federation formed a rating of regions in terms of their investment attractiveness for the development of renewable energy sources. Based on the calculation of several (in total - about ten) complex indicators, the regions were assigned appropriate ranks, according to which the first five with the maximum number of points included the regions of southern Russia: Rostov Region (71 points), Stavropol Territory (60 points), Astrakhan Region (57 points), Republic of Kalmykia (56 points), Volgograd Region (56 points) [9].

It is interesting to note that in the first two regions leading the rating, the share of renewable sources in the total energy balance of the territories is only five per cent, while in the Republic of Kalmykia, which is only on the fourth position, the value of the indicator reaches ninety-four per cent, and in the Volgograd region, which is closing the first five - only two per cent [5].

## RESEARCH METHOD

The study is based on the study of extensive scientific and statistical material on this issue. It should be noted that the regional aspect of "green energy" development has not been studied in sufficient detail so far. In particular, the development of "green energy" in the regions of the steppe zone of Russia is covered in [20]. The application of econometric methods to study the processes of development of "green economy" and "green energy" on the example of the European Union countries is considered in the works

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[18], [19]. At the same time, the studies of the impact on carbon dioxide emissions of various factors at the level of Russian regions using econometric methods have not been actually conducted so far.

The methods of economic and statistical analysis will be used in this study:

1. Dynamics analysis.
2. Structure analysis.
3. Correlation and regression analysis.

To describe the general trends in the development of "green energy" in the world and in Russia, it is planned to study the dynamics of carbon dioxide emissions, the dynamics and structure of the share of renewable energy sources in electricity generation, as well as the distribution of renewable energy sources in Russia at the present stage.

The working hypothesis of the study is that carbon dioxide emissions in the regions of the Russian Federation are directly influenced by the following factors:

1. Production of goods and services, which is expressed by the value of the gross regional product. It is assumed that the influence of this factor is negative, i.e., the volume of carbon dioxide emissions into the atmospheric air increases with the growth of the volume of production of the gross regional product.
2. Electricity consumption in Russian regions. It is assumed that the influence of this factor is negative, i.e., the volume of carbon dioxide emissions into the atmosphere increases with the growth of electricity consumption in Russia's regions.
3. The number of renewable energy sources in the region. It is assumed that the influence of this factor is positive, i.e. the volume of carbon dioxide emissions into the atmospheric air decreases with the growth of the volume of electricity consumption in the Russian regions.

In order to test the working hypothesis, the following Ordinary Least Squares regression (OLS) of CO2 is built:

$$CO2 = \beta_0 + \beta_1 GRP + \beta_2 ECR + \beta_3 SRS \quad (1)$$

Where

CO2 - carbon dioxide emissions in Russian regions (thousands of tons);
ECR - electricity consumption in the regions (million kilowatt-hours);
GRP - gross regional product (million rubles);
SRS - number of renewable energy sources in the region (units).

For construction of model of the correlation and regression analysis the data from open official statistical sources for 2020 [6], [15], [16], [17] were used.

The main calculations were carried out using R.

**RESULTS AND DISCUSSION**

As a result of the conducted calculations the following regression equation was obtained:

$$CO2 = 13{,}67 + 0{,}15 GRP + 0{,}001 ECR - 0{,}78 SRS$$

Interpreting the resulting equation, we can draw the following conclusions:

• The free term of the regression equation has no reasonable economic interpretation.

• The coefficient value with the gross regional product indicator, which is 0.15, shows that with the increase in the volume of gross regional product by 1 million rubles (that is, with the increase in the production volume of goods and services) the volume of carbon dioxide emissions into the atmosphere will increase by 0.15 thousand tons.

• The value of the coefficient with the indicator of electric power consumption in the regions, which is 0,001 shows that if the volume of electric power consumption in the regions increases by 1 million kilowatt-hours the volume of carbon dioxide emissions into the atmosphere will increase by 0.001 thousand tons.

• The coefficient value for the number of renewable sources of electricity production in the region, which is -0.78, shows that if the number of renewable sources of electricity production in the region increases by 1 unit, the volume of carbon dioxide emissions into the atmosphere will decrease by 0.78 thousand tons.

The main parameters of closeness and significance are presented in Table 3.

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**Table 3.** Main parameters of closeness and significance

| *Multiple R* | *R-square* | *F-test* | *t-test* |
|---|---|---|---|
| **0,747987808** | **0,559485761** | **33,02193** | **6,051545361** |

Interpreting the resulting equation of Table 3, we can draw the following conclusions:
• The value of the coefficient of determination obtained during the study shows that the change in the volume of carbon dioxide emissions into the atmosphere by 74.8 percent is due to changes in the factor attributes presented in the model.
• The value of the correlation coefficient obtained in the course of the study shows that the relationship between the factor and outcome attributes on the Cheddock scale is notable.
• Since the value of Fisher's F-test exceeds the critical value, the resulting regression equation is significant with 95 percent probability.
• Since the value of Student's t-test exceeds the critical value, the obtained correlation coefficient value is significant with 95 percent probability.
Thus, working hypothesis formulated before the study is fully confirmed empirically.

Considering further prospects for the development of "green energy" in Russia, it is worth noting that major projects in the field of creating renewable energy sources have been implemented, primarily due to significant support from the state. Thus, after the relevant state support program began to be implemented, about seventy solar power plants and over twenty wind power plants were created in the regions. Overall, according to the targets set out in the program, the total capacity of "green energy" should increase fivefold compared to when the program was launched [12].
On the one hand, government support is largely becoming a driver for the growth of renewable energy sources, but on the other hand, subsidizing those sources that still remain traditional (nuclear power and energy based on the use of fossil fuels) which leads to the fact that its cost to consumers at the moment is still lower and therefore - more attractive. In recent years, however, the cost gap has been narrowing, and in the end, energy from wind power plants is becoming cheaper than that from conventional methods. All this serves as unconditional proof of the promise of renewable energy sources not only in terms of their greater environmental friendliness, but also in terms of the resulting economic effect, and this parameter is certainly a key one for both users and potential investors.
When researching the prospects for the development of renewable energy sources in Russian regions, many analysts point out that in the very near future "green energy" will be able to fully cover the need for electricity generation, thereby replacing traditional energy. At the same time, there are certain social and economic risks [2]. It is very important to correctly assess the impact of the current situation in Ukraine on the further development of "green energy" in Russia. It is possible that the difficulties encountered, in particular, related to the partial oil embargo, in practice will lead to the fact that some of the extracted resources will simply be used within the country in a larger volume than it happened before, which can lead to the curtailment of some environmental programs, including those that are directly or indirectly connected with the development of renewable energy sources [11].
Another restraining economic factor may be the fact that for many domestic companies, especially for large ones, until recently, it was profitable to adhere to the policy of implementing various "green" projects, as it affects, among other things, the stock exchange quotations of such companies. Now, in view of the already imposed and ever-expanding restrictions on Russian business representatives, this agenda may become less relevant [10].
Finally, another economic constraint is the fact that the crisis caused by economic sanctions will inevitably cause problems with the implementation of policies to attract investment in the field of renewable energy and its development. In such a situation, it is likely that the main source of funding will continue to be the system of state support, which may not have the best effect on the development of "green energy" in the regions. In addition, there was a fairly strong interest in the development of "green energy" in the regions on the part of foreign investors. Many of those who were planning to implement such projects in the near future either suspended their activities in the Russian Federation or stopped them completely. Those companies that continue to operate in the country are unlikely to consider such projects in the foreseeable future due to the need to solve completely different problems [3].

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## CONCLUSION

The results of the conducted study demonstrate quite clearly that at the present stage the development of "green energy" both internationally and in the context of individual countries and regions becomes particularly acute due to the fact that the emissions of pollutants, in particular - carbon dioxide, are increasing due to the expansion of economic activity.

Through the application of correlation and regression analysis, the hypothesis is confirmed, according to which the volume of carbon dioxide emissions in Russian regions is influenced by the scale of economic activity, characterized by such indicators as gross regional product and electricity consumption, as well as the availability of renewable energy sources. All the theoretical provisions formulated at the beginning of the work are fully confirmed by empirical data.

As noted in the paper, at the present stage Russian regions may face a number of problems and constraints of social and economic nature, which may hinder the development of "green economy". In this regard, it is possible to identify a number of promising areas for research in this subject area:

1. Deepening research into issues of renewable energy development in individual regions, which will contribute to a better understanding of the measures that are being implemented locally to develop the "green energy".
2. Assessing the risks associated with "green energy" development in Russia's regions.
3. Examining the problems and factors that limit companies' investment activity in the context of developing renewable energy sources [13].
4. Study of the prospects for interaction with foreign partners in the context of using renewable energy sources [1].

Thus, it can be said, that there is the presence of a number of problem areas that require proper study and reflection in the framework of further research on the problems of "green economy" development in the Russian regions.

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