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# Coordination of the Development of Renewable Energy and Small Business as a Mechanism for Ensuring the Sustainable Development of Russia

**Sergey Aleksandrovich Nekrasov**[1,*] and **Natalya Evgenievna Egorova**[1]

[1]*Central Economics and Mathematics Institute, Russia Federation*

**Abstract:** The article deals with the development of renewable energy in Russia, taking into account the coordination of this sector with small- and medium-sized businesses. The aim of the study is to theoretically substantiate the strategy for the transition to renewable energy based on small- and medium-sized businesses and to develop practical recommendations using the example of solar energy in Russia. The methodological basis of the article is the general organizational science of tectology A.A. Bogdanov, which was subsequently developed in the general theory of systems by L. von Bertalanffy. On the basis of a system analysis of a transformable energy complex, the authors carried out a theoretical justification for the emergence of synergy as a result of the involvement of small- and medium-sized businesses in the development of renewable energy. It is shown that the formation of new links between small- and medium-sized businesses and renewable energy has a positive effect, consisting in diversifying the country's fuel and energy balance and reducing the negative anthropogenic impact on nature without increasing electricity prices for end consumers. Using the example of installing solar panels on the vertical enclosing surfaces of buildings and structures with the involvement of small- and medium-sized businesses, the reserves currently not fully used for the development of solar energy, mainly in the northern and eastern regions of Russia, without withdrawing territories from economic circulation, have been identified. The information base of the study is the data of the International Energy Agency, IRENA, and the Photovoltaic Geographical Information System. A graphical method was used to determine the feasibility of installing solar panels in different regions, taking into account seasonal fluctuations in the intensity of insolation, as well as the dependence of the coefficient of conversion of sunlight energy into electricity on temperature and snow cover albedo. The results of the study can be recommended for countries with similar natural and environmental conditions to Russia.

**Keywords:** system analysis, renewable energy sources, small and medium business, synergy effect, structural stability

## 1. Introduction

Renewable energy has shown the highest growth rate among national economy of the advanced countries of the world. This trend is in full accordance with the Concept of sustainable development proposed in Rio de Janeiro in 1987 by the UN International Commission on the Environment and subsequently adopted in 1992: it satisfies the needs of the present without jeopardizing the ability of future generations to meet their needs (World Commission on Environment, 1987).

Recent decades have been characterized by higher rates of development of renewable energy compared to conventional energy. This trend continues despite the energy crisis that unfolded in 2022 in a number of European countries. Since 2000, the average annual growth rate in the renewable energy sector has been 3.2%, which is significantly higher than in the traditional energy sector (1.4%) (Table 1).

In the conditions of the large-scale transformation of the energy system taking place around the world, an increasingly urgent task is to form the main directions for the transition from energy supply using fossil fuels to energy supply that involves a combination of these sources using renewable energy sources. At the same time, a special role in the energy transformation belongs to distributed energy, which allows, firstly, to produce electricity near the end consumer, thereby increasing the reliability of energy supply, and, secondly, to attract capital from both small- and medium-sized businesses and the population.

However, many theoretical and practical issues of forming a strategy for the transformation of the energy complex are debatable and are solved for each country taking into account national characteristics.

The purpose of the article is to develop key theoretical and methodological principles for the formation of a sustainable development strategy for renewable energy sources in the context of using the opportunities of small- and medium-sized businesses and formulate recommendations for their implementation, taking into account the climatic features of Russian regions.

*Corresponding author: Nekrasov Sergey Aleksandrovich, Central Economics and Mathematics Institute, Russia Federation, Email: san693@mail.ru

**Table 1**
**Dynamics of production indicators in the global renewable energy sector**

| Years | Electricity generation, TW·h |
|---|---|
| 2000 | 2.8 |
| 2008 | 3.8 |
| 2018 | 6.7 |

Theoretical aspects of this problem are considered in the article from the standpoint of system analysis, as well as the study of global trends in the energy sector, and practical aspects – on the example of the solar energy industry in Russia using data from the Photovoltaic Geographical Information System. The formation of a strategy for the development of the renewable energy sector involves the substantiation of its rational structure, taking into account the natural and climatic conditions of the country. The prospects for the development of renewable energy in Russia are great as well. In this regard, this segment is given special attention in the work.

## 2. Literature Review

The problems of renewable energy development are widely covered in the scientific literature. A study (World Energy Transitions, 2022), based on a comparison of technological solutions in the field of renewable energy sources, concluded that its fastest-growing segment is solar energy. Worldwide increase in the capacity of solar power plants for 2015–2020 was twice as large as the entire capacity of the Unified Energy System of Russia. It is predicted that for 2021–2026, global commissioning of new capacities that convert solar energy into electricity will exceed 1000 GW (The International Energy Agency, 2021). Theoretical and methodological issues of sustainable solar energy are presented in works (Akinyele et al., 2015; Barros et al., 2017; Philipps & Warmuth, 2023). A comparative analysis of various technologies in solar energy is carried out in the works (Jäger-Waldau, 2021; Kopecek & Libal, 2021; Zhang & Park, 2022). Studies have shown that large solar power plants with an installed capacity of hundreds of megawatts demonstrate the lowest costs for electricity generation. But along with this, projects of power plants with a capacity of tens, and sometimes even units of kilowatts, are becoming more widespread. Changes in cost parameters in the field of small solar power plants in relation to the costs of installing solar panels are considered in Werner (2022). The social aspects of development in this industry are explored in Barros et al. (2017).

Much attention is also paid by the scientific community to the development of small- and medium-sized businesses. This is due to the fact that this segment is the basis of the market economy of most developed countries and performs a wide range of socio-economic functions in developing new innovative niches, solving employment problems, and maintaining sustainable economic growth rates as a whole (Bosareva, 2017; Mesoeconomics, 2022; Smirnova, 2021; World Bank, 2021).

A significant part of the publications is devoted to the study of the functional and sectoral structure of the small- and medium-sized business sector, which ensures its sustainable development (Egorova et al., 2020; Egorova & Koroleva, 2021). At the same time, most studies conclude that, thanks to the comprehensive support of the state, the decline in the sector of small- and medium-sized businesses was not as significant as it could have been. Thus, in Russia, the share of this sector in GDP, calculated according to a methodology that allows for inter-sectoral comparisons (the methodology of the Organization for the Economic Commonwealth and Development), amounted to 20% in 2019–2022, 39% (Barinova & Zeltsov, 2019). This indicator approaches the critical economic indicator set by the World Bank for the development of this sector for market countries, which indicates the ability of Russian small- and medium-sized businesses to meet the challenges of state economic policy.

The review of the literature indicates that, despite the presence of a significant number of publications on the problems of renewable energy and the development of small- and medium-sized businesses, the issue of coordinating these sectors and implementing renewable energy projects based on small firms is in the background. This makes the research presented in this article relevant.

## 3. Methodology and Analysis

The methodological basis of the study is the general theory of systems, which studies the patterns of transformation of system objects, as well as an economic analysis of the problems of the development of the energy complex, which includes the renewable energy sector. These challenges include potential synergies between the renewable energy sectors and small- and medium-sized businesses; prospects for the development of distributed energy; and specifics of renewable energy development.

### 3.1. The main provisions of the theory of systems in the context of the transformation of the energy complex

The large-scale transformation of the energy complex makes it necessary to provide conditions for the continuation of its sustainable development. The need to solve this problem is due to a number of factors. The most significant of them is the fact that any transformational processes are always accompanied by a decrease in the stability of the system. No less significant is the need to coordinate the demand for electricity with the flow of renewable energy, which is increasing every year (Table 1) and depending on weather conditions. The reaction of any system to an increase in the impact of the external environment is to compensate for the additional load in order to maintain the ability to continue functioning in changed conditions.

Given the current moment, characterized by a revision of Russia's national priorities, it is appropriate to turn to the origins, to the roots of system theory. The patterns that occur in systems that change over time are the subject of study of a general organizational science – tectology [1], largely underestimated by compatriots, and subsequently developed in the works of Ludwig von Bertalanffy on general systems theory. A.A. Bogdanov introduced the concept of structural stability – the ability of a system to perform its functions under the influence of various external and internal factors (Bogdanov, 1989).

[1]Tectology (from Greek – the science of construction) is a general theory of the organization and structure of systems, which is based (according to A. Bogdanov) on the position that the laws of organization of systems are the same for any objects, which makes it possible to study them in a generalized form. The term "tectology" was introduced by E. Haeckel, who designated him a discipline that studies the principles of the structure of living organisms. Tectology A.A. Bogdanov (developed by him in the 1920s) anticipated the cybernetics of N. Wiener and the general theory of systems of L. Bertalanffy (Bogdanov A., 1989; ru.m.wikipedia.org).

According to A.A. Bogdanov, in the course of the evolution of any system, ingressions and disingressions occur in it. If the transformation of the system is carried out by forming new connections of the system (with its elements or systems external to it at this stage), and their subsequent unification, then such a process is called ingression. If the modified system, which includes previously independently functioning systems, ensures the performance of its functions in a wider range of external influences; in other words, it has greater stability, then such a transformation is preserved. Otherwise, the ingression is not fixed, and the system, continuing to evolve in the direction of increasing its structural stability, passes through the separation of its parts (disingression). In the general case, newly formed systems may not coincide with the original systems previously combined into a single whole.

With disingression (which is inevitable in transformational processes), the old connections of the system are destroyed or it breaks up into its component parts (other systems). Thus, the purposeful transformation of the system involves promoting sustainable ingressions and counteracting those disingressions that are accompanied by a decrease in its structural stability.

In the context of energy development, these processes are characterized by a set of indicators that are in a certain range, beyond which the system is not able to fully perform its functions and loses its structural stability.

Among such indicators for the energy complex, which includes renewable energy, are the following: (1) change in the power of peak energy sources that compensate for the impact of stochastic natural factors caused by the use of solar energy, wind energy, etc.; (2) the ability to manage the demand of consumers of energy resources; (3) the ratio of prices for electricity produced by traditional and renewable energy (as a motivational aspect of the development of RES), etc. It is also important that the placement of RES in the energy facilities of end energy consumers, using the consumer's ability to regulate his schedule of demand for electricity, is a mechanism for compensating for uneven electricity production from renewable sources under changing weather conditions (Nekrasov, 2021).

Table 2 (The International Energy Agency, 2021) shows the average data on the decline in electricity prices in the most promising RES segments: onshore wind farms and solar panels, confirming the long-term trend of increasing the competitiveness of renewable energy. As a result, for 2010–2020, average world electricity prices for onshore wind farms fell by 48%, and for solar power plants – by 85%. The range of costs for electricity generation from fossil fuels varied depending on the country and type of fuel, but in general was in the range from 5.5 to 14.8 US cents per kWh (The International Energy Agency, 2021), which was a powerful driver for the sustainable development of renewable energy. And the rise in energy prices in 2021–2022 created additional prerequisites for increasing the cost of electricity production from traditional sources. The result was an increase in the share of RES in the total capacity of commissioned power plants. If in 2011 this Figure reached 50%, then in 2021 it has already exceeded 83% (The International Energy Agency, 2021). Under these conditions, in an increasing number of countries, the further sustainable development of RES no longer implied the subsidized support required at the initial stages of their formation.

A direct comparison of the costs of energy production from RES and fossil fuels is a rather conditional issue. Coal is traditionally considered a cheap fuel (the price of electricity produced from coal mined in China's new coal mines of electricity is 5.5 US cents per 1 kWh). However, the cost of restoring people's health, damaged as a result of microdust emissions in mines and coal combustion, as well as environmental damage, expressed in pollution of areas adjacent to production, are not taken into account in this price (IMF, 2019). From these positions, coal is the most expensive source of energy for society. These considerations have been decisive for formulating the concept of sustainable development and supporting renewable energy for decades in many countries, when the use of renewable energy sources was many times (and at the initial stages, an order of magnitude) more expensive than the energy of hydro and thermal power plants.

## 3.2. Small business as a system interacting with the renewable energy sector

One of the features of the past two decades of the 21st century is the sustainable development of renewable generation based on small- and medium-sized businesses. Small enterprises take over the functions of generating electricity close to households and farms, as well as other market participants, which reduces losses in the transmission of energy to consumers. In addition, they:

- act as producers of renewable energy;
- are consumers of electricity, including RES energy;
- improve renewable energy technologies within innovation-oriented firms;
- provide innovative services to producers of renewable sources.

The features of interaction between small- and medium-sized businesses and renewable energy are determined not only by the level of development of small- and medium-sized businesses in different countries but also by the specifics of its structure. Small business is an important sector of the national economy of developed market countries. Its share in GDP is 40–60%. In Russia, a segmentation of small- and medium-sized businesses has developed according to the following quantitative indicators, similar to those in the United States and European countries:

- firms with a turnover of up to 120 million rubles (USD 1.621 million at the exchange rate as of February 15, 2023) per year and up to 15 employees – microbusiness;
- firms with a turnover of 120 million rubles per year and up to 800 million rubles (USD 10.811 million at the exchange rate as of February 15, 2023) and the number of employees from 16 to 100 people – small business;
- firms with a turnover of 800 million rubles up to 2 billion rubles (USD 27.027 million at the exchange rate as of February 15, 2023) per year, and the number of employees from 101 to 250 people is a medium-sized business.

At the same time, in different countries, small- and medium-sized businesses are heterogeneous and consist of various categories of small- and medium-sized enterprises that form its structure, which is homologous to small businesses. These categories are complementary, and the ratio between them determines the balance of small- and medium-sized businesses as a system as a whole. This fact is the basis for considering small- and medium-sized businesses as a heterogeneous system, in which the following categories are distinguished (Figure 1):

- "children" – new small businesses that grow as they develop into an "adult individual" and replenish large businesses;
- "genetic dwarfs" – small- and medium-sized businesses that do not have goals to transform into a large company. Given the availability of financial resources, they form networks of small firms and create integration either along a multi-profile type or on the principle of cooperation.

**Table 2**
**Change in electricity prices for onshore wind farms and solar panels, US cents/kWh**

| Years | Onshore wind farms | Solar panels |
|---|---|---|
| 2010 (Mean values) | 8.9 | 38.1 |
| 2020 (Mean values) | 3.9 | 5.7 |
| 2020 (Most successful locations) | less 3 | less 1.5 |

- transformers are the most flexible part of small- and medium-sized businesses, among which at least three varieties can be distinguished:
- “travelers” who easily move into market niches with higher profitability of economic activity;
- reorganizers changing the types of their activities as a result of significant transformations of the current business;
- imago – firms that temporarily do not carry out activities, but begin it in the event of a change in the external environment and the emergence of favorable conditions.

Figure 1 shows the system of feed-forwards and feedback arising from the interaction of the renewable energy sectors, small- and medium-sized businesses. In accordance with it, the growth in the number of small firms implementing renewable energy projects, on the one hand, ensures a more intensive development of the energy complex as a whole (due to the use of small-scale energy and microgeneration) in cases where the creation of powerful sources is not economically feasible. On the other hand, there is an increase in the number of small businesses migrating from old niches, within which their activities are no longer effective, to new, more promising niches.

In the conditions of Russia, the transformation of small- and medium-sized businesses as a result of their interaction with renewable energy is especially relevant. A distinctive feature of the Russian model for the development of small- and medium-sized businesses in comparison with foreign counterparts is a lower level of structural stability. An important aspect to be noted is the dominance of such a category of small business as “transformers and reorganizers”, which was formed mainly from small enterprises in the service and trade sectors. The share of industrial and innovation-oriented small firms, which form the composition of the most stable part of Russian small- and medium-sized businesses, is extremely insignificant (Egorova, 2021).

As the transformation processes develop, the structure of Russian small- and medium-sized businesses will become more balanced due to an increase in the proportion of “children” gradually moving into big business, as well as “genetic dwarfs” who form its stable part, as well as a reduction in the number of adults and reorganizers. Thus, the result of the development of renewable energy based on small business will be an increase in the structural stability of small- and medium-sized businesses as a sector of the Russian economy. At the same time, the structure of the Russian energy complex will become more balanced. It will increase the share of renewable energy, which is currently insignificant compared to similar indicators in other countries.

**Figure 1**
**The scheme of direct and feedback links between the subjects of small and medium businesses and renewable in the process of transformation of the energy complex (SME-small and medium enterprises)**

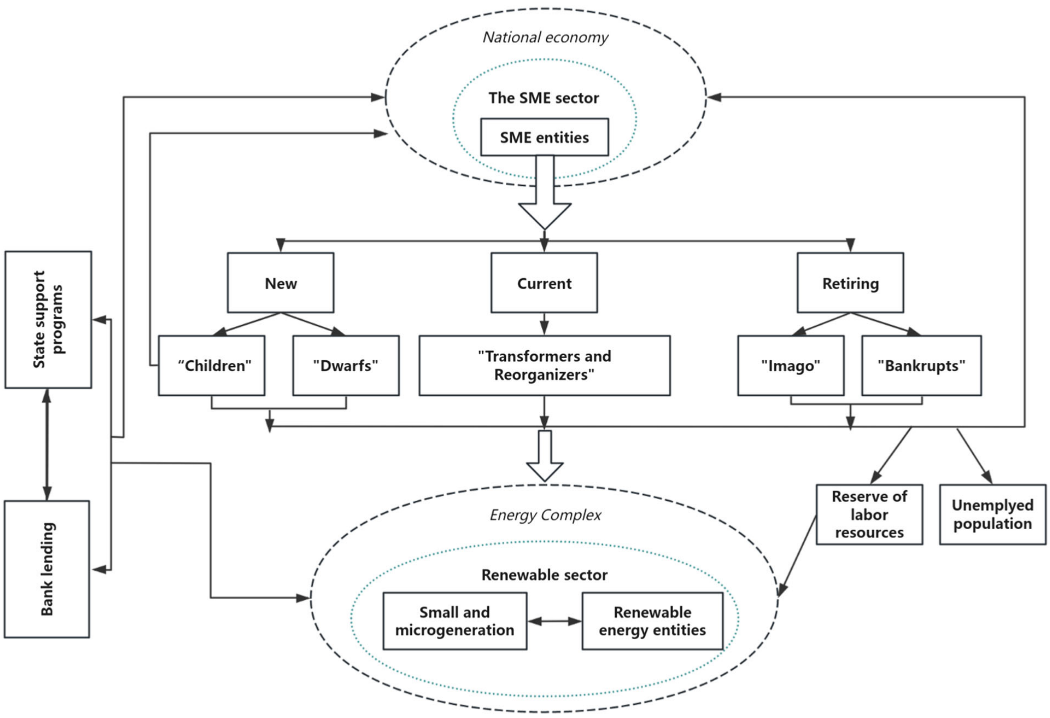
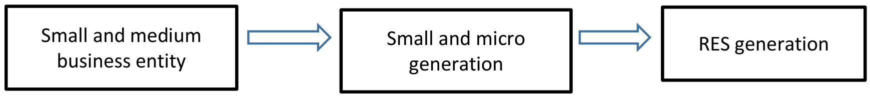


**Figure 2**
**Systemic connection between small- and medium-sized businesses and RES**




### 3.3. Prospects for the development of distributed energy based on small- and medium-sized businesses

An important point in analyzing the growth prospects of renewable energy is the possibility of attracting capital from small- and medium-sized businesses. To a large extent, this is determined, firstly, by the availability of the acquisition and subsequent installation by the entrepreneur (energy consumer and producer) of the relevant energy sources; secondly, by the possibility of ensuring their functioning in parallel with the power grid; thirdly, the scale of state support for regions with a low level of per capita electricity consumption (Nekrasov, 2022).

According to official documents, in the Russian energy sector, small power generation is distinguished separately – sources with a capacity of no more than 25 MW and microgeneration – sources up to 15 kW. An assessment of the financial performance of small-scale energy companies (120–750 million rubles/year) (1.621–10.135 million US dollars/year at the exchange rate as of February 15, 2023) allows them to be attributed to small- and medium-sized businesses.

Thus, the concepts of small and microgeneration represent a link between small- and medium-sized businesses and distributed energy. In the context of the study from the systemic standpoint of the interaction between small- and medium-sized businesses and RES, such a link allows you to form new links between them, aimed at their subsequent ingression (according to A.A. Bogdanov), which is schematically shown in Figure 2. The result is the transition of the system to a new qualitative state and increases its structural stability[2].

The peculiarity of the Russian distributed energy is that it is almost completely focused on the production of electricity from fossil fuels: primarily gas, and in its absence – diesel fuel, while abroad – on renewable energy projects. At the same time, in most remote regions of Russia, microgeneration is carried out mainly on imported diesel fuel. The need for such a method of energy production is determined exclusively by local conditions, since there are no other possibilities for energy supply. The costs of this method are extremely high due to the logistics costs for the delivery of fuel. In these cases, renewable energy generation may be a cost-effective addition to the existing energy supply. The experience of successful operation of solar panels of small capacities in Yakutia indicates that solar energy can be successfully developed in the most remote regions of Russia (Andronov, 2018).

Thus, the further development of Russian distributed energy with the participation of small- and medium-sized businesses and renewable energy projects will help reduce energy production costs, a more rational ratio of macro- and microgeneration, and also promote the development of remote areas.

[2] The ingression method according to A. Bogdanov is a way to create a stable connection between the elements under consideration by using something that has the properties of their connection (glue, when connecting pieces of wood; welding, when connecting metal objects, etc.). That is, what "enters" between organized objects. Hence the name – ingression (from lat. ingression – entry).

### 3.4. Features and prospects for the development of renewable energy in Russia

The share of RES in electricity generation in the world in 2021 reached 28.3% (Renewable Energy Policy Network for the 21st Century, 2021; The International Energy Agency, 2021). According to the forecast of the International Energy Agency, in 2022 the volume of electricity generation from RES will increase by 8.5%, which is due to the desire of most European countries to reduce dependence on natural gas consumption. The leaders in renewable energy are China, Denmark, Kenya, India, Iceland, and the United Arab Emirates. In Russia, the share of electricity produced using RES is much smaller. In 2021, this indicator was equal to 0.53%, but at the same time, by 2035, it is planned to significantly increase it.

Since it is necessary to solve the problem of using renewable energy in any case, it is important to substantiate the concept of the adopted strategy for the development of renewable energy. In most countries, this strategy is implemented mainly on the basis of large power plants: in solar energy, as well as in wind energy, there is an increase in their installed capacity. As a result, the unit power of some of them often exceeds 2 GW. The main contribution to the increase in the capacity of solar power plants is made by large facilities, the construction of which sometimes requires the alienation of large territories, which is not always rational.

The accelerated development of solar energy based on large facilities is typical for the United Arab Emirates, where economies of scale are used to the maximum to reduce prices for RES electricity. However, the capital-intensive Arab model of renewable energy development is not entirely suitable for Russia. This is determined by the current strategic priorities for the development of the Russian energy sector, as well as by the natural and climatic factors of the Russian regions.

According to the authors, a more acceptable option for Russia is the Australian model of RES development, which takes into account the territorial extent and the need to develop the country's weakly energy-equipped regions. In Australia, the pace of development of small-scale generation using renewable energy is significantly ahead of that of large power plants. In particular, in 2017–2018, the annual increase in the capacity of solar energy from large sources was 45%, and from individual sources, more than 130% (AST, 2018). In 2021 alone, the increase in the capacity of small solar power plants reached 3.24 GW or 10% per year. As a result, more than 3 million small solar power plants were installed in the country by the beginning of 2022 in households and service industries (The Guardian, 2022). At the same time, the growth of renewable sources is largely provided by the investments of small- and medium-sized businesses. Russia also has underutilized reserves based on the combination of renewable energy technologies with the SME sector, especially in the field of solar energy.

The following is an example of the use of solar energy, illustrating the systemic connection presented in Figure 2 and implemented between small- and medium-sized enterprises and renewable energy facilities.

## 4. Results of the Study: Analysis of the Opportunities for the Development of Russian Solar Energy Based on Small- and Medium-Sized Businesses

Until recently, the prospects for the development of solar energy in Russia were assessed as insignificant. It was traditionally believed that its natural and climatic conditions are characterized by relatively low average insolation. However, the use of special technical solutions that make it possible to convert not only direct solar radiation but also diffused sunlight into electricity in conditions of high albedo in regions with a long period of snow cover makes it possible to correct this established point of view.

As the latitude of the location of the solar power plant in the northern hemisphere increases, both a decrease in electricity production per 1 kW of installed solar panel capacity and a reduction in differences with their vertical and optimal inclination are expected. But the greater efficiency of vertical arrangement of solar panels as longitude increases, for example, between Khabarovsk and Munich (Table 3, regions arranged as longitude decreases) is a much less obvious phenomenon. Despite the fact that both of these locations are located at 48 latitude, insolation in the first case is 24% higher with the optimal arrangement of solar panels and more than a third (34.8%) with their vertical arrangement. The reason for the increase in the efficiency of using solar panels with their vertical arrangement as they move eastward in Eurasia is the albedo effect (higher scattering power of the surface – snow cover), which enhances insolation. As the study conducted by the authors shows, the increase in the efficiency of using solar panels in the case of more northern locations not only compensates but in some cases even covers the decrease in their efficiency in comparison with the option of placing at the optimal angle of inclination. This phenomenon occurs as a result of the absence of snow cover formation on the panels themselves when they are vertically located and the reduction in the operating costs of solar power plants by the amount of snow and ice removal costs. Thus, the natural and climatic conditions of Russia are being transformed from a factor that hinders the spread of solar energy (which is the snow cover and ice that forms on the panels), into a factor of more efficient use of solar radiation. At the same time, the efficiency of using solar panels in a number of Russian regions, despite their more northern location, turns out to be comparable, and in some cases exceeding that in Bavaria, where solar energy is developing most successfully among other German lands – a country that is not only European but also global leader in solar energy.

An important issue when using solar panels is the uniformity of the microgeneration process. It is investigated by a graphical method for a vertical fixed method of their installation, taking into account the specifics of the natural and climatic conditions of various Russian regions, based on the data of the Photovoltaic Geographical Information System.

Figure 3 shows the dynamics of electricity production by vertically installed solar panels by months of the year for four selected cities located at different latitudes (three Russian, one German), reflecting the unevenness of seasonal insolation in each of the considered cases. At the same time, the efficiency of using solar panels in the Russian regions turned out to be at least comparable to those in Bavaria throughout the year (with the exception of the fourth quarter for the case of Novosibirsk and Yakutsk), despite their much more northerly location.

It was found that the vertical placement of the panels provides more uniformity of power generation throughout the year in comparison with other methods of their installation. At the same time, the maximum productivity of solar panels is achieved in Siberia and Transbaikalia in the spring, which is explained by low temperatures and high albedo of unmelted snow cover with a

**Figure 3**
**Monthly electricity production of a 1kW vertical south-facing solar panel**

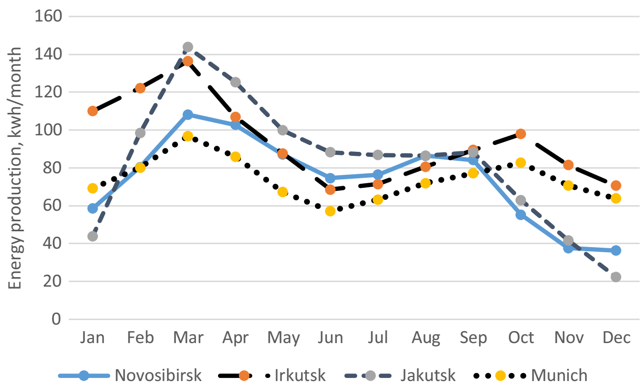



**Table 3**
**Electricity generation of 1 kW of solar panels per year with an optimal tilt angle and in a vertical arrangement**

| Location | Geographical coordinates | Electricity generation, kW · h/year, panel layout: optimal | vertical | Decrease in electricity production when changing the optimal arrangement of panels to vertical, (%) |
|---|---|---|---|---|
| Khabarovsk | 48.512, 135.059 | 1501 | 1192 | 21 |
| Yakutsk | 62.041, 129.74 | 1194 | 975 | 18 |
| Chita | 52.037, 113.497 | 1550 | 1241 | 20 |
| Irkutsk | 52.287, 104.280 | 1413 | 1110 | 21 |
| Krasnoyarsk | 56.013, 92.879 | 1168 | 901 | 23 |
| Novosibirsk | 55.030, 82.922 | 1183 | 891 | 25 |
| Tyumen | 57.154, 65.542 | 1119 | 858 | 23 |
| Munich, (Germany) | 48.136, 11.568 | 1208 | 884 | 27 |

Note: Locations are arranged in decreasing longitude (east to west).

longer day length compared to the winter period. A comparative analysis of the data revealed a downward trend in the differentiation of annual electricity production between the northern and southern regions of Russia.

Comparison of electricity production in different regions indicates higher prospects for the development of solar energy in the northeastern regions of the Russian Federation with a long period of snow cover compared to the southern regions and destroys the established stereotype that solar power plants provide the summer peak in electricity production (Ivanova et al., 2016).

## 5. Discussion of the Results of the Study

The issues of renewable energy development are debatable and widely discussed by the scientific community. What should be the priorities of the state economic policy in terms of promoting the development of renewable energy sources and the role of renewable sources in the context of energy policy transformation? What is the potential for the development of small- and medium-sized businesses and what is their role and participation in the formation of the renewable energy sector, taking into account the specifics of a particular country? What should be the recommendations for the placement of RES in the country? How do the natural and climatic conditions of the country influence the choice of the most promising technologies for the use of renewable energy? The results of the study presented in the article make a certain contribution to the solution of these issues on the example of the experience of the formation of the renewable energy sector in Russia and the development of one of its leading segments – solar energy.

The international situation and economic sanctions determine the expediency of implementing in Russia, at this stage a rather conservative strategy for the development of the renewable energy sector. The possibility of pursuing such an economic policy is determined by the special natural conditions of the country – significant hydrocarbon reserves. As part of a conservative strategy, a rational solution is to rely on small- and medium-sized businesses implementing renewable energy projects for the following reasons.

Firstly, world experience shows that flexibility and adequacy are those important properties of small- and medium-sized businesses that allow them to effectively develop new market niches, which include renewable energy.

Secondly, in the context of the current state priorities of Russia and the existing financial constraints, this way allows attracting private capital of small- and medium-sized businesses to the development of the renewable energy sector.

Thirdly, this is in line with international concepts for the transformation of the energy complex, which implies the decentralization of energy production and an increase in the share of distributed energy.

Fourth, there are real needs for the development of small businesses implementing renewable energy projects in remote and sparsely populated regions of Russia.

The results of the study confirm the presence in Russia of underutilized reserves in this area.

The problem of energy supply is extremely acute for many regions of Russia. According to expert estimates, about 2/3 of the territory of Russia is not covered by a unified energy system. Most of these territories belong to sparsely populated areas of the country (Table 4). In such areas, the average population density often does not exceed 10 people per square kilometer, and when considering territories outside large cities, it can be an order of magnitude lower than this indicator. It is obvious that the creation of large power plants in these regions, as a rule, is not expedient, just like the installation of power lines to them, which require significant costs, the subsequent transmission of energy through which is accompanied by high network losses.

Since electricity supply in these regions, especially in remote locations, is carried out mainly by generation using imported diesel fuel, logistical difficulties inevitably arise. The solution to this problem is the use of solar power plants, which can be considered as sources of additional power supply.

It is the northern and northeastern regions of Russia with low population density and with the greatest need for additional power supply that correspond to zones with high albedo values. This makes these territories the most promising for the development of this RES segment. In these areas, the efficiency of solar power

**Table 4**
**Population density in some Russian regions and in Bavaria**

| Region name | Population, thousand people | Area, thousand km$^2$ | Regional capital | Population, thousand people | Population density, person/km$^2$ | Population density excluding the capital of the region, people/km$^2$ |
|---|---|---|---|---|---|---|
| The Republic of Sakha (Yakutia) | 992.1 | 3083.5 | Yakutsk | 330.6 | 0.32 | 0.21 |
| Krasnoyarsk region | 2849.2 | 2366.8 | Krasnoyarsk | 1092.9 | 1.20 | 0.74 |
| Khabarovsk region | 1299.0 | 787.6 | Khabarovsk | 610.3 | 1.65 | 0.87 |
| Transbaikal region | 1043.5 | 431.9 | Chita | 350.9 | 2.42 | 1.60 |
| Tyumen region | 3806.5 | 1464.2 | Tyumen | 816.7 | 2.60 | 2.04 |
| Irkutsk region | 2357.1 | 774.8 | Irkutsk | 617.5 | 3.04 | 2.25 |
| Novosibirsk region | 2780.3 | 177.8 | Novosibirsk | 1620.2 | 15.64 | 6.53 |
| Bavaria, Germany | 13,177.0 | 70.6 | Munich, Germany | 1487.7 | 186.78 | 165.69 |

Note: regions are arranged in the order of increasing population density generation is comparable and often exceeds that of Bavaria, which is a leader in the field of solar energy.

A comparative analysis of various technologies for installing solar panels, carried out by the authors on the basis of data from the Photovoltaic Geographical Information System, allows us to conclude that the vertical method of their location using existing buildings and structures is the most preferable. On the one hand, this is the most budget option available for households and small- and medium-sized businesses; on the other hand, it provides the greatest use of the high scattering of sunlight by the snow cover. This fact is confirmed by many years of experience in the operation of far from single solar power plants in such villages Batagay, Batamay, Dulgalakh, Yuchyugey, etc., located many hundreds of kilometers north of Yakutsk.

It is also important to ensure the availability of renewable energy projects for entrepreneurs. This can be implemented by fully or partially compensating the costs of project implementation in a targeted manner – to households with low average per capita incomes. This measure is especially in demand for depressed regions, where average per capita incomes are usually lower than in successfully developing territories. This could include not only assistance from the state but also from municipal authorities who are interested in creating incentives to increase the level of energy supply and increase business activity in municipalities. The implementation of these measures will contribute to the development of the sector not only of renewable energy but also of small- and medium-sized businesses in general. At the same time, it is necessary to take into account and adapt the experience of similar support in those countries where renewable energy is developing at the fastest pace.

## 6. Conclusions

The processes of transformation of the energy complex taking place all over the world, based on a rational combination of traditional and renewable energy, require the development of a methodological framework for the formation of a state energy policy. The general principles of substantiation of the strategy of transformation of the energy complex from the point of view of the general theory of systems involve the study of the processes of ingressions and disingressions that characterize the appearance and disappearance of links between the systems under consideration.

The article reveals the role of small- and medium-sized businesses in the development of renewable energy, as one of the new subsystems that ensure the sustainability of the development of the energy complex. The general scheme of interaction between small- and medium-sized businesses and renewable energy developed by the authors contains connections that form synergistic effects in the complex under consideration. It is shown that the strengthening of synergy is achieved through state support, including by creating conditions for the participation of small- and medium-sized enterprises in the development of renewable energy. The conclusion is made about the need to coordinate government programs to support small- and medium-sized businesses and renewable energy.

The paper explores the issue of interaction between distributed energy and the sector of small- and medium-sized businesses. The role of renewable energy projects implemented by small- and medium-sized businesses based on small and microgeneration to ensure the decentralization of the energy system is revealed.

Particular attention is paid to the problems of developing the renewable energy sector in Russia and the current priorities of its state policy in this area. The factors hindering the development of renewable energy, including the presence of large reserves of fossil resources, and the prevailing ratio of prices for electricity production in the traditional and renewable sectors of the Russian energy complex, are determined.

Reserves for the development of solar energy in Russia have been identified as a result of the implementation of renewable energy projects by small- and medium-sized enterprises. The need to revise the prevailing views on the growth prospects of this segment of the Russian renewable energy, based on the underestimation of the potential for using solar energy, is shown. Based on the statistical data of the international agency Photovoltaic Geographical Information System, recommendations are formulated for using the vertical method of installing solar panels on the walls of buildings and structures in urban and rural locations. Geographical zones of application of this method (northeastern regions of Russia) have been identified. The results of the study confirm the highest technical and economic characteristics of this method in the regions under consideration. The study of the efficiency of using solar panels, taking into account such parameters as seasonal fluctuations in solar insolation, ambient temperature, and the duration of a higher snow cover albedo, indicates the advantages of the recommended option compared to other technologies, taking into account the natural and geographical conditions of the territories under consideration. The implementation of the formulated recommendations will contribute to the development of remote depressed regions of Russia based on the growth of their power supply and the activation of small- and medium-sized businesses. The obtained theoretical and practical results can be used in other countries with natural conditions similar to Russia (northern regions of China, Mongolia, Canada, and countries of South America).

The main directions of further research may consist of a deeper study of the economic aspects of the problem under consideration. As part of the project analysis methodology, it is expedient to evaluate such economic indicators as net present value and the payback period for the used solar energy technologies in the conditions of the recommended regions. Of particular interest are the issues of accessibility of these projects for small- and medium-sized businesses.

## Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

## Data Availability Statement

Data sharing not applicable – no new data generated.

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