

# Methodological bases for determining priority territories for the location of renewable energy sources (on the example of Rostov region, Russia)

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**Abstract.** The article presents a theoretical and methodological toolkit for determining priority territories for the placement of renewable energy sources in the Rostov region, based on the principles of synergetic approach. In the conditions of “green transition” and decarbonization of the economy in the Russian Federation to support this process it is necessary to have a tool for optimizing the choice of territory for the placement of alternative energy sources as a variant of hybrid decentralized energy supply. At the same time, for different types of alternative energy sources the territory and its characteristics should be different, respectively, the application of a systematic approach and adaptation of the methodology of complex assessment of the territory for prospective planning of RES implementation in the energy complex of the subject of the Russian Federation are justified. The methodology includes the integration of diverse information into the system of criteria for comprehensive assessment of the territory, GIS-project for the analysis of the RF subject, and the list of territories prioritized for RES deployment in the Rostov region.

## 1 Introduction

Under the conditions of transformation of the energy system of the Russian Federation and the “green” transition, it is necessary to ensure the existence of flexible and sustainable energy, through the use of non-conventional energy sources (hereinafter - RES).

Key characteristics of the “green” energy transition:

- balanced territorial and spatial placement of RES;
- diversification of the energy sector, where centralized energy supply is supplemented by autonomous energy supply [1, 2].

The territorial and spatial infrastructure of the Russian Federation is characterized by the presence of remote hard-to-reach consumers (small towns, villages), which requires the introduction of RES in the energy system of the country.

Compliance with the principles of the Strategy of socio-economic development of the Russian Federation with low greenhouse gas emissions up to 2050 [3] determines the

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development and optimization of decentralized energy supply systems for each subject of the Russian Federation, taking into account the peculiarities of its territory and in the context of the implementation of its sectoral specialization (industrial potential). The most relevant, from the point of view of managing the low-carbon development of a constituent entity of the Russian Federation is to reduce the energy intensity of production, enterprises and their life cycles by involving renewable energy sources (hereinafter - RES) in the energy balance of the constituent entity of the Russian Federation [4, 5].

To achieve carbon neutrality, it is necessary to generalize research in the field of assessment of natural-ecological risks, anthropogenic impact on the territorial system, as well as the development of decentralized energy supply and renewable energy, in particular [6].

The synergetic approach to the territorial-spatial structure of the RF subject provides strategic planning taking into account the development of the fuel and energy complex and the natural-ecological framework [7-10].

After systematization of all presented information and through a series of computer calculations with the help of geoinformation systems, it will be possible to choose the best option for further development of the RF subject. The advantage of using the method of simulation modeling is that it becomes possible to verify the selected option of territory development, application of environmental measures and other processes important for territorial planning without conducting real experiments and surveys. Technically, it becomes possible to demonstrate the results of simulation modeling by applying geographic information systems (such as QGIS, OpenStreetMap and others) to summarize, systematize information and form a database of information about the state of the RF subject in all parameters [11, 12].

## 2 Methods

One of the key approaches to prioritizing the territory for RES deployment is the mapping approach, which includes:

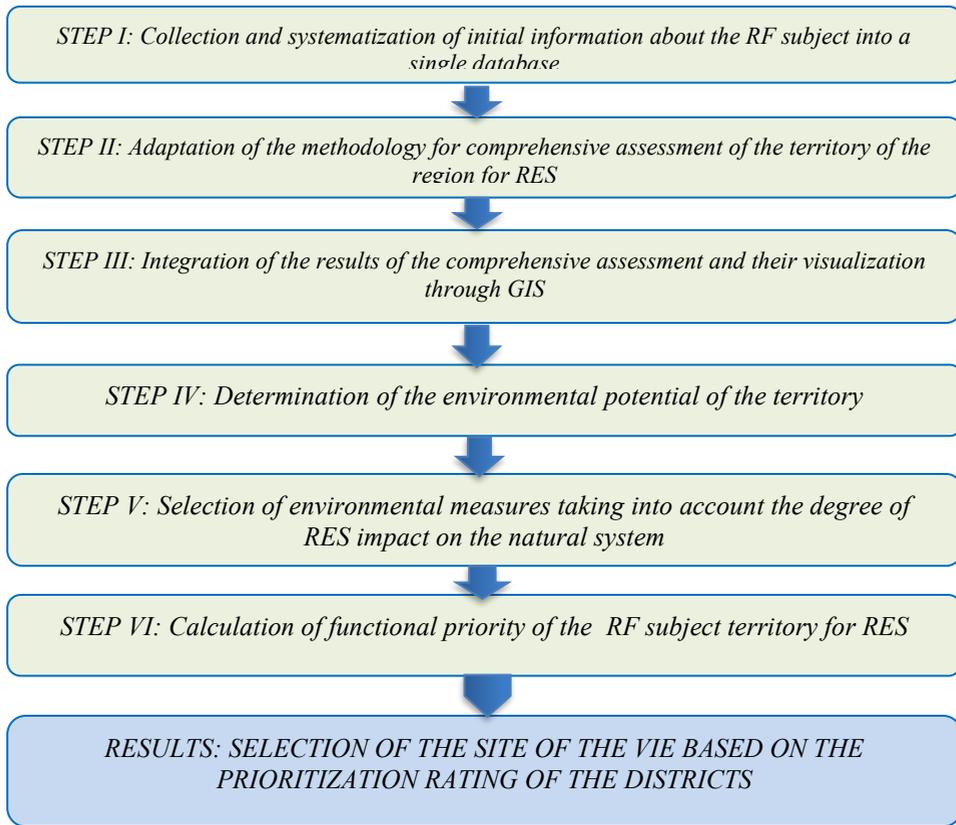
- at the regional level - assessment of RES resources (mapping of the state of natural resources for RES provision) and assessment of RES potential (gross and technical potential);

- at the local level - assessment of the impact of local factors limiting RES deployment (specially protected areas, forest lands, nature reserves, ornithological areas, etc.) [13].

The study uses comparative analysis to determine the provision of the territory with engineering and transport infrastructure facilities, anthropogenic impact and ecological state of the natural landscape; the method of hierarchy analysis and the method of the target function.

An obligatory part of the initial information is statistical information, cartographic material, as well as environmental monitoring data on the state of environmental pollution. Data on prospective capacity development of the energy potential of the region are collected according to the UES SIPR project.

The methodology is presented in the form of the following algorithm (Figure 1):



**Fig. 1.** Algorithm of methodology for determining priority territories for the location of renewable energy sources.

The first step of the methodology algorithm involves collecting raw data from the following sources:

I. Territorial and spatial development of the RF subject (analysis of the existing situation):

1. territorial planning scheme of the RF subject;
2. scheme and program of prospective development of the electric power industry of the UES of Russia and constituent entities of the Russian Federation (hereinafter referred to as the UES SIPR).
3. strategic planning of the constituent entity of the Russian Federation (forecast and plans):

- strategy of socio-economic development of the region;
- strategy for sustainable development of rural areas until 2030.

II. Base of regulatory legal acts in the field of renewable energy sources (hereinafter - RES).

The effective integration of RES into the unified energy system of Russia occurs with the optimal choice of their location in terms of climate-forming factors - sources of energy resource (maximum potential of wind, sun, etc.), and taking into account the need to solve the problems of optimal use and development of grid infrastructure, as well as maintenance of regulation resources in the energy system" [14].

The second step is the allocation of criteria for assessing the sustainability of the territory. The presented research presents the use of a synergetic approach, which includes:

1. adaptation of the methodology of integrated assessment of the territory, which allows to bring together all factors into a single system:

- consideration of natural-climatic factors (solar radiation, average monthly wind speed, altitude differences, etc.);
- consideration of the ecological state of the environment;
- taking into account infrastructural and spatial-economic development of the territory.

2. taking into account local factors limiting RES deployment.

The adapted methodology of complex assessment of the territory allows to integrate cartographic, statistical and tabular materials into a single system in the form of a score ranging from 0 to 1 (Table 1). The territory of a municipality of a constituent entity of the Russian Federation is taken as an assessment area.

**Table 1.** Comprehensive assessment factors in prioritizing the territory for RES deployment.

Factor group	F	Factor	Evaluation in points
Natural (climate-forming)	F 1	Wind speed	0-1
	F 2	Average monthly number of sunny days	0-1
Infrastructural	F 3	Water supply and wastewater disposal	0-1
	F 4	Gas supply	0-1
	F 5	Transportation	0-1
	F 6	Communication networks	0-1
Spatial-economic	F 7	Investment attractiveness of the region	0-1
	F 8	Distance to major regional centers	0-1
Environmental	F 9	Air pollution	0-1
	F 10	Soil pollution	0-1
	F 11	Anthropogenic load	0-1
	F 12	Water pollution	0-1
	F 13	Ecological potential	0-1

As an example of linear interpolation for the estimation of F2 - Number of sunny days and radiation, an example of the breakdown of the presented factor is demonstrated in Table 2.

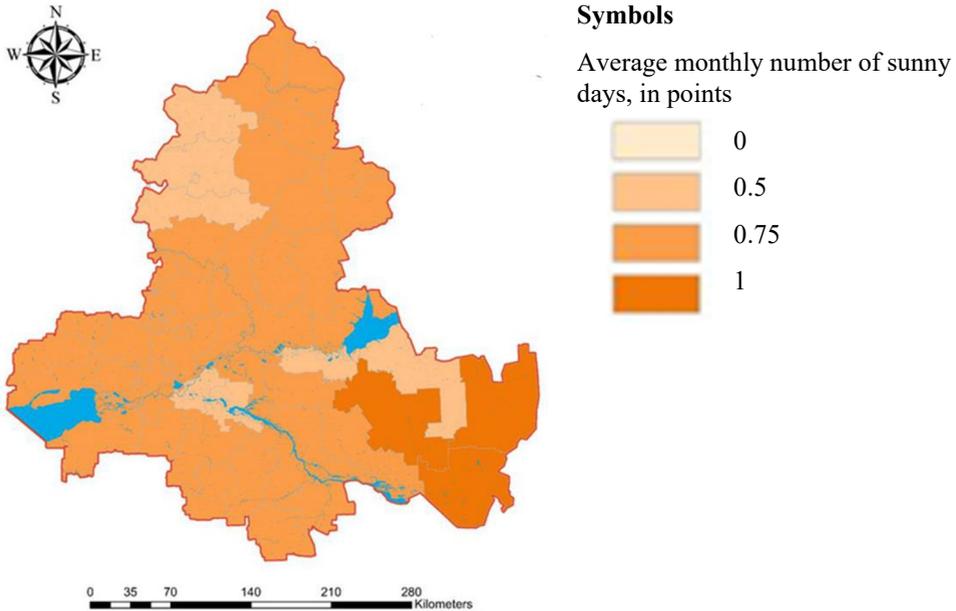
**Table 2.** Territory assessment based on the average monthly number of sunny days for the constituent entity of the Russian Federation.

№	Hours/month	Solar days per month	Score
1	70-105	10-15	0,25
2	112-119	16-17	0,5
3	126-140	17-20	0,75
4	under 140	under 20	1

Each factor is evaluated from 0 to 1 by linear interpolation to allow the evaluation results to be applied in the calculation of the target function.

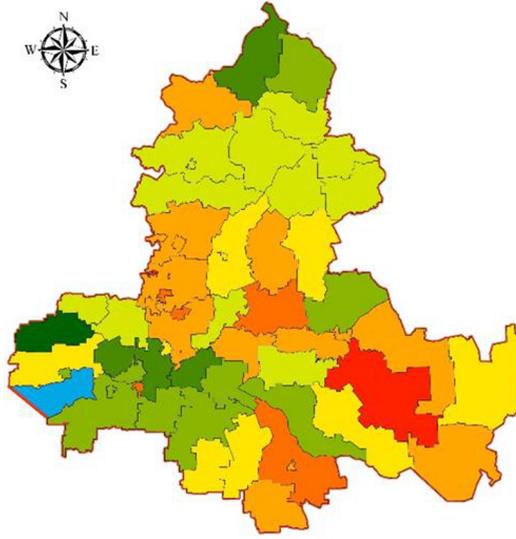
### 3 Results

The results of complex assessment by factors are visualized in the form of maps in the QGIS environment. At the third stage electronic maps with the results of complex assessment of the territory by all three groups of factors are built. As an example, Figure 2 shows the map of complex assessment of the Rostov region territory by the factor F2 - average number of sunny days.



**Fig. 2.** Average monthly number of sunny days on the territory of Rostov region.

The fourth stage involves integration of the block with environmental factors (air pollution, soil pollution, water pollution, and environmental potential of the territory) into the system of complex assessment of the territory. Environmental protection is an integral part of the concept of improving the comfort of living, so the analysis of the environmental situation and the development of a set of measures is one of the key stages in the formation of a simulation model of sustainable development of the territory of the subject of the Russian Federation in the introduction of RES. The considered measures are evaluated from the point of view of their efficiency and are also implemented in the process of complex assessment of the territory in the QGIS environment. Maps on the following parameters are developed for the whole constituent entity of the Russian Federation with a breakdown by municipalities. Figure 3 shows an example - a map of the environmental potential of the Rostov region, calculated from a set of factors F9-F12. The lower the resulting score after the integral assessment of factors, the worse the state of the territory's ecological potential. The result is presented in Figure 3. The most polluted areas are highlighted in green, the areas with the best conditions are highlighted in red and orange.



**Fig. 3.** Environmental potential.

Taking into account the obtained results of the assessment of the ecological landscape of the RF subject territory, measures to reduce anthropogenic, agricultural and industrial load are developed and proposed. An example is presented in Table 3. This process is a modeling of improving the comfort of living in the territory of the RF subject within the natural and technogenic environment, and the measures are presented according to the environmental factors stated above with an assessment of their effectiveness [15-20].

**Table 3.** Measures to reduce anthropogenic impact and increase the ecological potential of the RF subject.

Type of RES	Direct environmental impact of RES	Indirect environmental impact of RES	Measures and their effectiveness	Environmental capacity component
Solar energy	Air emissions (CO <sub>2</sub> , SO <sub>2</sub> , NO <sub>x</sub> )	No effect	Special zones based on the class of harmfulness, cleaning of emissions from impurities	Atmospheric air pollution
	Pollution from disposal of collectors and panels	No effect	Developing a recycling plan for collectors and panels	Soil contamination
Wind power	Air emissions (CO <sub>2</sub> , SO <sub>2</sub> , NO <sub>x</sub> )	Noise, a threat to birds	Special zones based on the class of harmfulness, cleaning of emissions from impurities, increasing the distance to settlements	Atmospheric air pollution
	Pollution from metal recycling	High metal production intensity and vibration	Development of a plan for environmentally friendly utilization and recycling of materials. Introduction of environmentally friendly materials in the production of wind turbine components (wood, fiberglass, etc.).	Soil contamination
Biofuels	Air emissions (CO <sub>2</sub> , SO <sub>2</sub> , NO <sub>x</sub> ) minimal level	No effect	Waste treatment technologies for livestock and crop production are in themselves a measure to reduce air, water and soil pollution	Atmospheric air pollution
	No effect	No effect	Development of a system for recycling waste into secondary raw materials	Soil contamination

At the fifth stage, in accordance with the methodology of functional prioritization assessment [21], the calculation of the target function of the Rostov region territory for the use of RES in residential construction was made for three types of RES: solar energy, wind energy and biofuel energy.

To determine the significance of each factor, experts filled out expert survey questionnaires “Factor significance coefficients of complex assessment factors for RES development”. The results of questionnaire processing are presented in the form of a prioritization matrix in Table 4.

As a result of multiplication of the prioritization matrix by the results of the comprehensive assessment of the territory, the rating is obtained. Thus, the formula for calculating the target function has the form (formula 1):

$$P^j = \sum Q_i \cdot R_i^j, \quad (1)$$

where Q is the value of the factor of relative value of the territory (F1-F10);

R - significance coefficient of the i-th factor for the j-th type of RES;

P - indicator of the territory rating for the j-th type of RES.

**Table 4.** Prioritization matrix with the results of processing the questionnaires of the expert survey “Significance coefficients of comprehensive assessment factors for RES development”.

Type of RES (P)	Factor (Q)	Number of sunny days and radiation	Wind speed	Water supply and wastewater disposal	Gas supply	Radius of processing plants	Transport	Communication networks	Investment attractiveness привлекательность	Distance to major regional centers
Solar energy	1	0.5	0.5	0	0	0.5	0.5	1	0.5	
Wind power	0	1	0.5	0	0.5	0.5	1	1	1	
Biofuels	0	0	0	1	0.5	1	1	1	1	

The higher the P indicator, the higher the priority of the RF constituent entity's area for RES deployment. List of priority territories for RES development for all three types of RES:

Urban districts and cities:

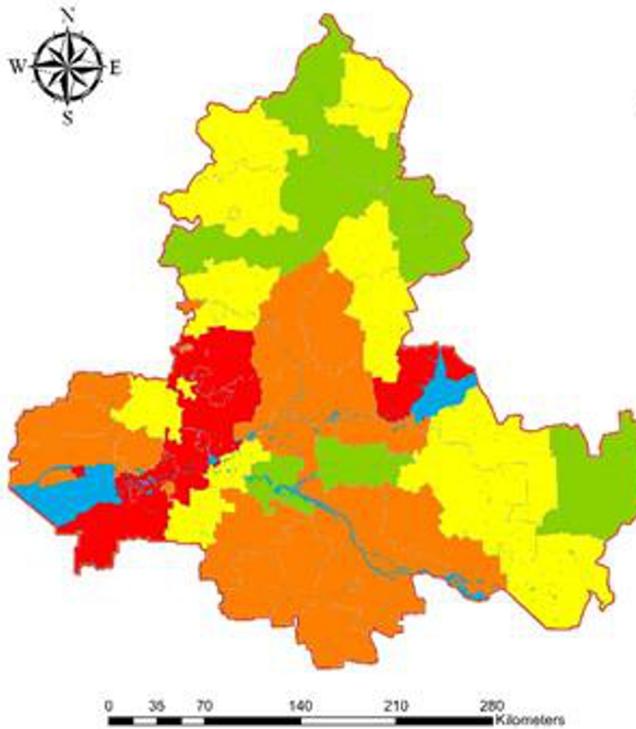
- Rostov-on-Don,
- Azov,
- Zverevo,
- Novocherkassk,
- Taganrog,
- Shakhty,

Municipal districts:

- Azovsky district,

- Aksai district,
- Krasnosulinsky district,
- Oktyabrsky district.

Visualization of the functional priority of the territory of the RF subject for the development of solar energy is presented in Figure 4 in the form of an electronic map, which is built as a result of the calculation of the target function. Territories with high potential and priority for solar energy development are highlighted in red, territories with the lowest potential are highlighted in green.



**Fig. 4.** Distribution of functional priority rating for RES deployment on the territory of Rostov region - solar energy.

Areas with insufficient potential for RES development:

- Zavetinsky district,
- Remontnensky district,
- Sholokhovsky district,
- Chertkovsky district,
- Bokovsky district, etc.

The choice of the RES location is possible in the listed districts taking into account measures to reduce the load on the natural and technogenic environment.

## 4 Discussion and conclusion

The developed simulation model makes it possible to ensure sustainable development of the subject of the Russian Federation due to:

- integrating various characteristics of the territory into a single system;

- formation of information on possible risks, threats and environmental damage in case of RES deployment;
- formation of a preliminary list of preventive measures as mandatory for RES deployment;
- possibility to perform multiple assessment of the territory when making changes to the developed model;
- possibility to select priority areas for RES deployment, etc.

Geoinformation systems allow to demonstrate possible changes in the regional system on such parameter as comfort and ecological landscape of the territory by reducing the anthropogenic load, implementation of environmental measures.

The presented adapted methodology of complex assessment of the territory and simulation model is a universal toolkit that can be used in any other subject of the Russian Federation at the regional level [21-23]. The theoretical significance of the study lies in taking into account the socio-economic, environmental and infrastructural characteristics of the territory when planning and developing the RES network. The practical part of the developed toolkit consists in the possibility of optimizing management decisions when forming a regional climate change adaptation plan, including mitigation measures, as well as for providing hard-to-reach remote areas with alternative sources of electricity.

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