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Formation of a System of Indicators for Assessing the Implementation of Renewable Energy Sources in the Region

Miroslava Gennadyevna Salko [1], Artyom Romanovich Miloradov [2] and Elena Romanovna Anfinogenova [3]
Tyumen Industrial University, 38 Volodarsky St., Tyumen, Russian Federation
[1]salkomg@tyuiu .ru, [2]artem23364@mail.ru, [3] lena_anfinogenovan@bk.ru

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Abstract: The implementation of renewable energy sources (RES) projects plays an important role in the development of the energy sector worldwide. Potential use various types of renewable energy sources in individual regions is determined by many factors. Justification of the implementation of renewable energy projects in the regions requires the formation of high-quality methodological tools for their assessment. The article presents a scientific study aimed at forming a comprehensive system of indicators for assessing the effectiveness and justifying the feasibility of implementing renewable energy sources in individual regions. The relevance of the study is confirmed by the growing dynamics of investments in environmentally friendly energy worldwide. Generalization of existing methodological approaches to assessing renewable energy projects made it possible to determine priority areas for their development. The authors present a system of evaluation indicators for four parities: regional, innovative, environmental and budgetary. Each parity provides for the technical and economic potential of using various types of renewable energy sources in the region. It is proposed to use an integral criterion to obtain a generalized assessment of the effectiveness of renewable energy sources implementation in the region. The authors provide testing of the proposed methodological approach using the example of the Tyumen region of the Russian Federation. The assessment results allowed us to draw conclusions about the potential for implementing renewable energy sources in this area. The article describes the assumptions and limitations of the recommended system of evaluation indicators. The authors highlight the scientific potential and advantages of using the proposed methodological tools in the practice of planning the development of the energy sector in the region, which determines the significance of this scientific research.

1 INTRODUCTION

Alternative energy based on the use of renewable energy sources (RES) plays a key role in the global energy transformation. In the context of growing energy demand and the need to reduce anthropogenic impact on the environment, the transition to RES is becoming an important strategic direction for many countries. According to the International Renewable Energy Agency (IRENA), the share of RES in global electricity production has reached 26%, with solar and wind energy being the leaders in this sector. In Europe, the USA and China, policy measures and investments in research are actively being implemented, which helps to reduce the cost of energy generated from RES and makes it competitive with traditional sources. Figure 1 shows a graph of annual investments in clean energy worldwide.

[1] http s ://orcid.org/0000-0002-8078-4823
[2] https://orcid.org/0009-0009-2436-8401
[3] https://orcid.org/0009-0008-8390-211X

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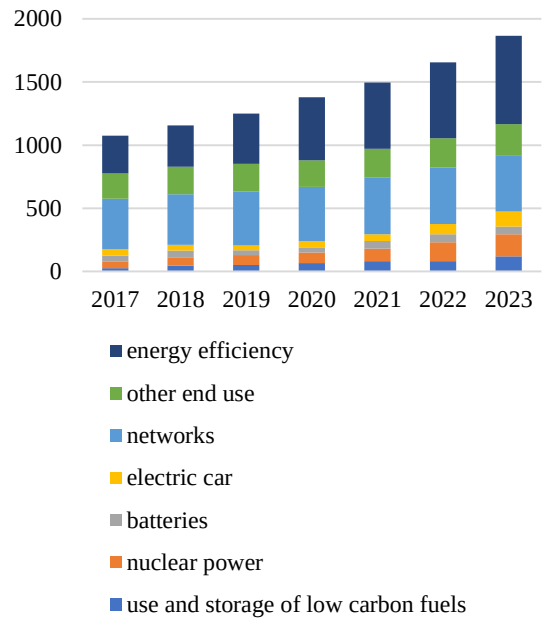

Figure 1: Annual global investment in clean energy, 2017-2023 , US$ billion.

Russia, with its significant reserves of traditional energy resources such as oil, gas and coal, is still lagging behind in the development of alternative energy. The share of renewable energy in the country's total electricity production is only 0.2%, which is significantly lower than global figures. (1)

An important aspect of the development of RES in Russia in favor of renewable energy sources is the low efficiency of using traditional energy sources in remote regions of Russia. Many of these territories, such as the Arctic zone, the Far East and Siberia, are characterized by difficult climatic conditions, low population density and lack of developed infrastructure. Centralized energy supply in such areas is often economically inexpedient due to the high costs of construction and maintenance of long power transmission lines, as well as significant energy losses during its transmission over long distances. (2)

The Unified Energy System of Russia (UES of Russia) consists of 71 regional energy systems, which in turn form 7 unified energy systems: the East, Siberia, the Urals, the Middle Volga, the South, the Center and the Northwest. All energy systems are connected by intersystem high-voltage power transmission lines. Unfortunately, not all regions have the opportunity to directly connect to the UES. This includes the territories of the Far East, Karelia, regions of Altai, Komi, Krasnoyarsk Krai, Arkhangelsk, Irkutsk, Murmansk, Tomsk and Tyumen regions (5), Khanty-Mansiysk, Yamalo-Nenets and Nenets Autonomous Okrugs. In the Far East, there is a vast zone of decentralized energy supply with large regions. This zone occupies about 40% of the territory, where 2.5% of the population of the Far East lives. The Far Eastern Federal District unites 11 regions: Amur, Magadan and Sakhalin Oblasts, the Republic of Sakha (Yakutia), the Republic of Buryatia, Zabaikalsky, Khabarovsk, Primorsky and Kamchatka Krais, as well as the Jewish Autonomous Oblast and Chukotka Autonomous Okrug. In addition, there are difficulties in centralized energy supply in the Kaliningrad Oblast and the Crimean Peninsula. In the Kaliningrad Oblast, Kaliningradskaya TPP-2 provides a stable energy supply. The largest electricity producers on the Crimean Peninsula are: Balaklavskaya TPP and Tavricheskaya TPP with a total capacity of 940 MW and Sakskaya TPP with a capacity of 120 MW. In the Far East, the share of decentralized energy supply is large, as well as the use of hydroelectric power plants, such as the Zeiskaya , Bureyskaya and Kolyma HPPs. (3)

In these regions of centralized energy supply, local energy installations based on renewable energy sources can become a good alternative to traditional energy sources.

Despite the obvious advantages of renewable energy sources, such as inexhaustible resources and environmental friendliness, their development in Russia faces a number of problems:

- strong dependence on geographical and climatic conditions. In some regions, the use of a certain type of renewable energy will be ineffective and/or impossible, while in another region the situation may be diametrically opposite. This factor imposes certain difficulties for the use of renewable energy in each region;
- significant capital expenditures on autonomous RES installations. For some RES, appropriate infrastructure is required to start operation, which also increases capital expenditures. In case of incorrect assessment of the efficiency of using alternative sources in a specific region, and subsequent implementation of an alternative energy project, the problem of high capital intensity may become critical;
- environmental and social restrictions. Despite the environmental aspect of renewable energy sources, unlike traditional energy, the use of alternative energy sources can also lead to problems such as landscape changes, harm to flora and fauna,

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and possible pollution during the disposal of alternative energy components.

The selection and implementation of projects for the introduction of renewable energy sources is based on several key principles:

- potential of renewable resources - the natural potential of the region is assessed based on key parameters: solar radiation level (kW h /m² per year), average annual wind speed (m/s), water resources (water flow, fall height) and the availability of biomass for bioenergy;

- reliability and availability of technologies - the efficiency of installations, availability of components, service life and wear of equipment play an important role;

- economic criteria - the cost of electricity production (LCOE), investment costs (CAPEX), operating costs (OPEX) and payback period (Payback Period).

Government support, the ability to connect to the power grid and the availability of the necessary equipment production are also important. Russia has a program to stimulate the development of renewable energy generation in the Unified Energy System by guaranteeing payment for a certain period of time for capacity under a capacity supply agreement (CSA) on the wholesale market "CSA RES", stimulating the construction of solar and wind power plants.

In the context of a significant number of factors and trends in the development of renewable energy sources, the authors highlight the problem of justifying the implementation of a project for the introduction of alternative energy in various regions of the Russian Federation. It should be noted that for different participants in renewable energy projects, different criteria serve as decision-making priorities. For example, for investors, the main criteria will be economic and financial indicators, and for the state - the level of provision of electricity and heat to the main consumers. In addition, the use of a significant number of differently measured indicators to assess the effectiveness of renewable energy projects requires the use of complex methods of approaches.

The hypothesis of the study is that the use of a comprehensive methodology for assessing the efficiency of using alternative energy sources in various regions of the Russian Federation, taking into account the interests of various project participants , will improve the validity of decision-making on the implementation of these projects. In addition, this methodology should assess all renewable energy sources available for use in terms of energy production efficiency , the amount of negative impact on the environment, and also affect the economic implementation and use of alternative sources at the macro-, meso- and micro levels.

The aim of the study is to form a comprehensive system of indicators for assessing the effectiveness of using alternative energy source projects in the regions of the Russian Federation.

Research objectives:

1) Analysis of existing methodological approaches to the formation of evaluation criteria for the effectiveness of renewable energy projects and identification of their shortcomings.

2) Development of methodological recommendations for optimizing the system of indicators for the comprehensive assessment of renewable energy projects in various regions of the Russian Federation.

3) Conducting trial calculations according to the recommended system of indicators using the example of a separate region of Russia.

4) Identification of the advantages and limitations of the application of the recommended methodological approach.

Energy supply systems are ultimately created to fulfill a very specific purpose – to satisfy consumer demand for energy with minimal resource requirements and the least total damage over a certain period of time. The measure the achievement of the set goal is the efficiency of the system, which is characterized by one or more parameters called efficiency criteria. Efficiency criteria allow solving the main task of analyzing energy saving systems - choosing the best option that ensures optimal implementation of the set goal .

To evaluate projects and select the optimal option, various criteria-based evaluation methods are used, among which the following can be distinguished:

- matrix methods are based on the use of tables (matrices), where the objects or alternatives being evaluated are located on one axis, and the evaluation criteria are located on the other. Each cell of the matrix is assigned a value reflecting the degree of compliance of the object with a certain criterion. The results are then analyzed to make informed decisions;

- qualitative assessment is aimed at identifying and analyzing the essential characteristics of an object without using numerical indicators. It focuses on descriptive aspects such as properties, qualities, and features of the object. Qualitative methods do not involve the use of strict mathematical models and are often used at the initial stages of research to form hypotheses and understand the problem;

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- quantitative measures involve the use of numerical indicators and metrics to evaluate objects or phenomena. They ensure objectivity and allow statistical analysis of data, and may include scoring systems for more accurate evaluation;

- the economic-analytical method is an approach to assessing the effectiveness of projects based on a comprehensive analysis of economic indicators and factors influencing the implementation of the project. This method is widely used in the energy sector to justify investment decisions and assess the feasibility of introducing new technologies or modernizing existing capacities.(18)

To form a system of indicators for assessing the effectiveness of the implementation of renewable energy sources, the authors reviewed the works of Shutkin O. I. on the implementation of a parity system as a method for multi-criteria assessment of the energy efficiency of renewable energy projects, works on the matrix method of criterial assessment authored by Zbarsky A. M., Volov V. T. and Garanin M. A., as well as the work of Artemyev A. Yu., Shakirova V. A. and Yakovlina N. N. on the multi-criteria selection of areas for the placement of wind power plants. (4, 10, 11)

as a basic methodological approach to the formation of a recommended set of indicators for assessing the effectiveness of renewable energy implementation in the regions.

Comparative characteristics of the main methods of multi-criteria assessment are presented in Table 1. (15,16).

Table 1: Basic methods of multi-criteria project evaluation.

Group of methods	Methods	Characteristics
Factor analysis	Index (Irving Fisher)	Creating indicators to measure dynamics and changes in economic indicators (eg price index)
	Elimination (Charles Spearman , Lewis Thurstone)	Excluding irrelevant factors from the analysis to simplify the mode
	Balance Sheet (Vasily Leontiev)	Using balance equations to analyze relationships between economic variables (income and expenses)
Classic method	Analytical tables (William Petty, Karl Marx)	Used to systematize data in a convenient format for analysis, which may include various indicators and their dynamics
	Absolute Differences (William Petty, Karl Marx)	Determine the difference between values, allowing you to estimate a change or deviation (for example, the difference in income over a period)
	Relative quantities (Irving Fisher)	Express the relationship of one quantity to another, often as a percentage (eg profitability)
	Comparison (Adolphe Quetelet)	Analyzes two or more indicators to identify differences and patterns (eg comparing financial results across periods or institutions)
	Grouping of indicators (Adolphe Quetelet)	Organizes data into groups based on specific criteria (eg by activity or region)
Economic - analytical method	Correlation and Regression Analysis (Francis Galton, Karl Pearson, Ronald Fisher)	Studies the relationship between variables; correlation shows the strength of the relationship, regression analysis allows you to predict the value of one variable based on another
	Cluster Analysis (Robert Tryon)	Grouping objects by similar features to identify natural clusters
	Econometrics (Ragnar Frisch, Jan Tinbergen, Lawrence Klein)	Used to build models that describe economic processes and make forecasts.
	Mathematical programming (Leonid Kantorovich, George Dantzig , Tjalling Koopmans)	Optimization of decisions based on mathematical models with constraints (eg profit maximization or cost minimization)
	Wilson Model (Ford Wilson)	A model that describes the interaction of economic agents under conditions of uncertainty and risk, often used in game theory

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The generally accepted classical methods of multi-criteria assessment are similar in many ways in their assessment principle, but each of them reflects a certain aspect. The authors recommend using the economic and analytical method of multi-criteria assessment of energy efficiency of renewable energy sources. An interesting approach within the framework of this method to the formation of a system of indicators for assessing the effectiveness of the introduction of renewable energy sources in the region is observed in the scientific research of Shutkin O. I. (4) It is based on a system of four parities: market parity; generation parity, fuel parity and social parity.

The authors propose to supplement the existing economic-analytical methodology based on the parity system with additional indicators that take into account the environmental conditions of project implementation, the level of innovative development, budgetary and regional efficiency (Fig. 2).

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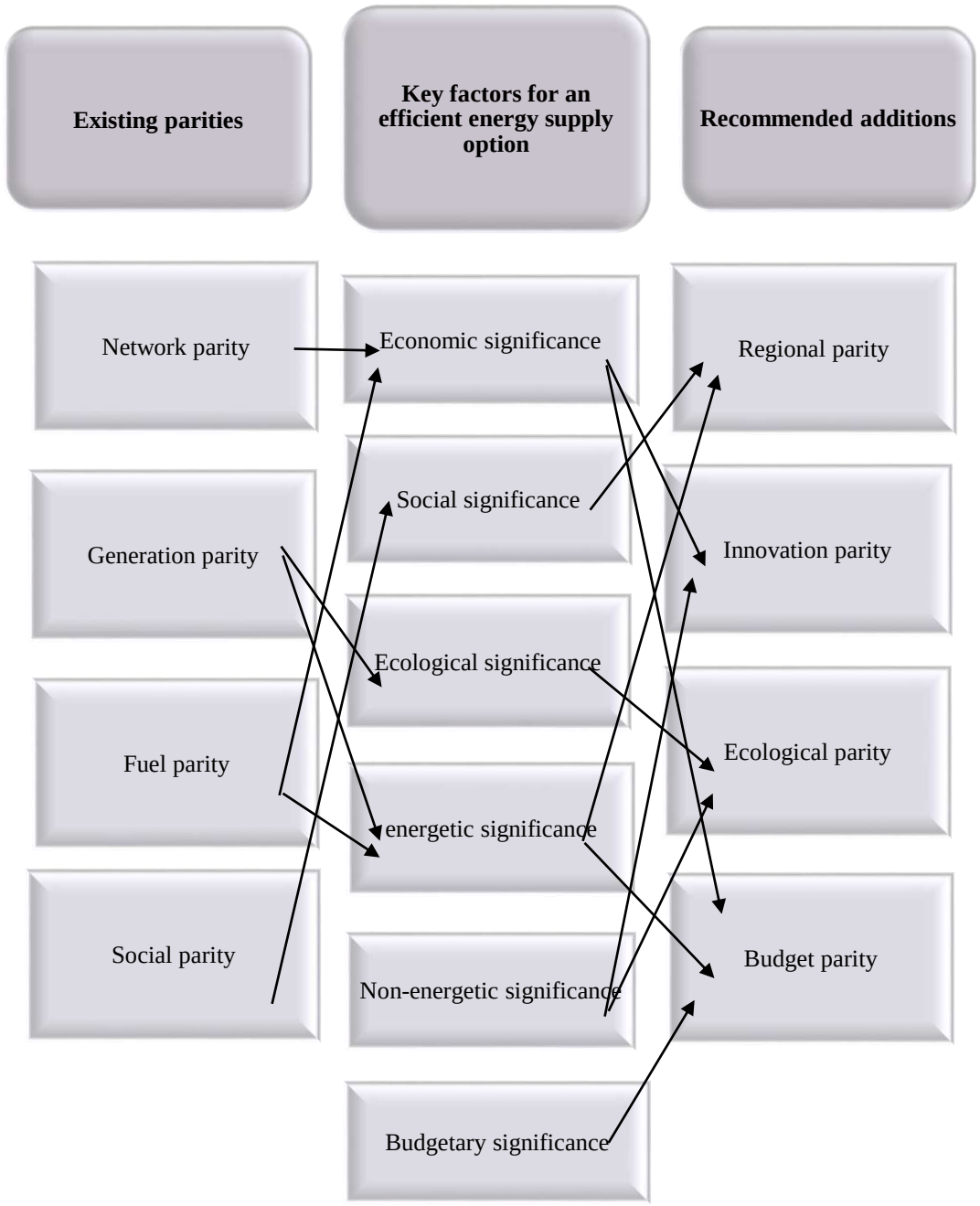

" ⟶" in the indicator the factor for a specific energy supply option is taken into account

Figure 2: Factor relationship of evaluation indicators of renewable energy projects.

The methodology for calculating the recommended system of indicators is as follows:

1. Regional parity: reflects the specific potential for the use of renewable energy sources in the region, taking into account the available energy resources. The ratio of the amount of resource productivity in the region to the costs of producing 1 kW of electricity is expressed by the formula:

$$RP = \frac{\sum \frac{REL(n)}{EPC(n)}}{EPC(global)} \quad (1)$$

where RP is the regional parity, conventional units.

REL (n) – resource efficiency level of a renewable energy source, conventional units.

EPC (n) – costs of producing 1 kW of electricity using renewable energy sources, RUB.

n – types of renewable energy sources ZPE

EPC (global) – total costs of producing 1 kW of electricity, RUB.

2. The innovation parity will reflect the scientific contribution from the use and/or development of a renewable energy project for the region, as well as the competitiveness of the renewable energy project in terms of advanced technologies and the ability to ensure sustainable energy development. The ratio of the increase in electricity generation due to the introduction of new technologies to the costs of improving technologies is presented by formula 2.

$$IP = \frac{\Delta I}{CIT}, \quad (2)$$

where IP is the innovation parity, conventional units.

ΔI – increase in electricity generation due to the introduction of new technologies, kW*h

CIT – costs of technology improvement, RUB.

3. Ecological parity will reflect the level of positive impact on the environment from the use of renewable energy sources. Calculation formula 3 is the ratio of the reduction in emissions into the atmosphere to the cost of producing 1 kW of electricity.

$$EP = \frac{\Delta EV}{EPC}, \quad (3)$$

where EP is the ecological parity, conventional units.

Δ EV – reduction in emissions into the atmosphere, kg.

EPC – costs of producing 1 kW of electricity, RUB.

4. Budget parity will reflect the positive impact on the region's economic indicators due to the implementation of the renewable energy project. The ratio of the increase in tax revenues to the cost of producing 1 kW of electricity is presented by formula 4:

$$BP = \frac{\Delta TR}{EPC(global)} * 10^{-7}, \quad (4)$$

where BP is the budget parity, conventional units.

ΔTR – increase in tax revenues, RUB.

EPC (global) – costs of producing 1 kW of electricity, RUB.

5. The level of resource efficiency » in renewable energy projects (RES) will be interpreted as the efficiency of using natural resources to generate electricity. It is measured in conventional units reflecting the amount of electricity produced per unit of resource used (formulas 5-9).(4)

6. $$REL(sun) = \frac{EP}{Spanel*Hsun} \quad (5)$$

where REL (sun) is the level of resource efficiency of solar energy, conventional units.

EP – generated electricity, kW*h

S panel – total area of solar panels, m²

H sun – level of solar radiation (insolation) on the panel surface, kW*h/m²

$$REL(wind) = \frac{EP}{Swind*Fwind}, \quad (6)$$

where REL (wind) is the resource efficiency level of wind energy, conventional units.

EP – generated electricity, kW*h

Swind – area over which wind flow is measured, m²

F wind – wind energy level (wind force), m/ s

$$REL(bio) = \frac{EP}{Mbio*Hbio} \quad (7)$$

where REL (bio) is the level of resource efficiency of bioenergy, conventional units.

EP – generated electricity, kW*h

Mbio – mass of biofuel , kg

H bio – specific calorific value of biofuel , kW*h/kg

$$REL(geothermal) \frac{EP}{Stonnel*Htonnel} \quad (8)$$

where REL (geothermal) is the level of resource efficiency of geothermal energy, conventional units.

EP – generated electricity, kW*h

Stonnel – thermal capture area of the well, m²

H tonnel – specific geothermal power, kW*h/m²

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$$\text{REL(hydro)} = \frac{\text{EP}}{Qwater*Hwater}, \quad (9)$$

where REL (hydro) is the level of resource efficiency of hydropower, conventional units.

EP – generated electricity, kW*h

Qwater – volume of passing water, m³

H water – specific hydroelectric power, kW*h/m³

7. To calculate the cost of producing 1 kW of energy, formula 10 will be used:

$$\text{EPC} = \frac{\left(\frac{Cstart}{Y}\right)}{Vyear.} + R(exploitation) \quad (10)$$

where EPC is the cost of producing 1 kW of electricity, RUB.

Cstart – initial installation cost, RUB.

Y – service life of the installation, years

Vyear . – annual electricity generation, kW*h

R (exploitation) – operating costs per 1 kW of electricity, rub.

8. The overall integrated indicator of the efficiency of renewable energy sources in the region, which represents the total sum of the values of all parities:

$$\text{OPI(region)}=\sum RP, IP, EP, BP \quad (11)$$

The integrated indicator for assessing the efficiency of using various types of renewable energy sources is a combination of indicators of regional, innovative, ecological and budget parity. This indicator is calculated as the sum of the values of the four components, where each of them analyzes the impact of renewable energy sources taking into account the specifics of the region, the degree of innovative development, ecological advantages and budget parameters. This allows for the formation of a comprehensive assessment of the efficiency of implementing renewable energy sources in a particular region.

The Tyumen Region of the Russian Federation was selected as the object of the study to assess the effectiveness of the implementation of renewable energy projects. The Tyumen Region is one of the largest regions of Russia. Its area is about 1.4 million square kilometers. The region has a diverse climate - from continental to arctic, which creates unique conditions for various types of renewable energy. The region has a fairly high solar activity, especially in the summer months. The Tyumen Region, due to its open terrain, has the potential to use wind turbines, especially in the northern part of the region, where wind speeds can be high. Agriculture and forestry in the region provide an opportunity to produce biomass and biogas, which can also be a source of energy. The Tyumen Region, known for its extensive water resources, has significant potential for the implementation of small hydropower technologies, due to the installation of vortex hydroelectric power plants (VHPP). The hydrological conditions of the region, including high runoff and constancy of flows in the warm months, create a favorable environment for the use of VHPP. Tyumen Oblast is located in a zone with developed geology, which includes powerful layers of sedimentary rocks and underground heat sources. According to available data, the temperature at depths of 2-3 kilometers can reach 70-100 °C, which makes it possible to use geothermal energy for heating and generating electricity.

In order to substantiate the implementation of priority projects for the use of renewable energy sources in the Tyumen region, the efficiency of their use was assessed using the proposed system of indicators. Average technical and economic characteristics are used to calculate regional parity. by types of renewable energy sources (table 2)

Table 2: Technical and economic characteristics of renewable energy installations.

Type of renewable energy sources	Start-up costs , rubles	Installation life , years	Operating costs , rubles/kW	Annual electricity production, kW*h
Solar energy	50000	20	3	1200
Wind energy	60000	25	3	2000
Bioenergy	60000	20	4	4000
Geothermal energy	80000	30	5	6000
Hydropower	150000	50	2	8000

the level was calculated. resource efficiency according to formulas 2-9 and the costs of producing 1 kW of electricity for each type of renewable energy source according to formula 11. The calculation results are presented in Table 3.

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Table 3: Comparative analysis of costs per 1 kW of electricity by type of renewable energy sources.

Type of renewable energy sources	Resource efficiency level, conventional units	Costs of producing 1 kW of electricity, rubles/kW
Solar energy	0.215	5.0 8
Wind energy	0,013	4.2
Bioenergy	0.301	4.75
Geothermal energy	0.25	5.4
Hydropower	0.714	2,375

To calculate the total costs of producing 1 kW of electricity, we will use the formula for finding the arithmetic mean value, as a result, the total costs of producing 1 kW of electricity for various types of renewable energy sources ZPE (total) will be 4.36 rubles.

The above calculations allow us to calculate the value of regional parity:

$$RP = \frac{\sum \frac{Rl(n)}{EPC(n)}}{EPC(global)} = \frac{\frac{0,215}{5,08} + \frac{0,013}{4,2} + \frac{0,301}{4,75} + \frac{0,25}{5,4} + \frac{0,714}{2,375}}{4,36} = 0,104 \text{ усл. ед.}$$

The regional parity value of 0.104 conventional units indicates a low level of integration of renewable energy sources into the regional energy structure, which may indicate insufficient use of renewable energy sources in the Tyumen region compared to more developed regions. This may also reflect the weak development of relevant infrastructure projects and government support to stimulate the growth of the renewable energy sector.

Type of renewable energy sources	Reducing emissions into the atmosphere, ΔEV, kg	Production costs, EPC rubles/kW	Value of ecological parity, conventional units
Solar energy	1000 grams – 40 grams = 0, 96	5.08	0 ,190
Wind energy	1000 grams – 15 grams = 0 , 985	4.2	0.234
Bioenergy	1000 grams – 0 grams = 1	4.75	0,210
Geothermal energy	1000 grams – 50 grams = 0, 95	5.4	0.176
Hydropower	1000 grams – 7 grams = 0, 993	2,375	0.418

Calculating innovation parity will allow us to assess the scientific and technical contribution of renewable energy projects, as well as the competitiveness of these projects in terms of advanced technologies. Innovation parity takes into account the degree of implementation of innovations and technologies that affect the sustainable development of the region's energy sector. In the case of the Tyumen region, a significant increase in innovation activity is confirmed by its increase from 25th to 10th place in the ranking of innovative development of regions in 2021. (19)

Innovation parity is calculated using formula 2 and is:

$$IP = \frac{38124000}{101337000} = 0,38 \text{ усл. ед.}$$

The increase in electricity generation due to the introduction of new technologies (ΔВЭ) in the Tyumen region amounted to 38,124 thousand rubles. (6) The costs of improving the FTA technologies amounted to 101,337 thousand rubles. (7)

The score of 0.38 conventional units indicates an average level of integration of innovative technologies in the field of renewable energy in the Tyumen region. This may indicate the presence of significant opportunities for improving indicators through increased investment in the development of renewable energy sources, as well as improving infrastructure and state support.

The next indicator for assessing the efficiency of renewable energy use in the region is ecological parity (formula 3). This indicator allows us to assess how effectively the use of renewable energy sources affects the ecological situation in the region, reducing carbon emissions and improving overall ecological sustainability (8,9,12,13,14,17). The calculation results are presented in Table 4.

Table 4 : Calculation of ecological parity for each type of renewable energy source.

The calculation results show that the lower the value of the cost of producing 1 kWh of electricity and the greater the difference in the reduction of emissions into the atmosphere, the greater the value of each individual parity, which shows the effectiveness of its positive impact on the environment. The value of the general ecological parity by the arithmetic mean EP(total) will be 0.246 conventional units.

The next indicator for assessing the effectiveness of the implementation of renewable energy sources in the region is budget parity (formula 4). It shows the

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positive impact on the economic indicators of the region from the use of renewable energy sources (Table 5). (17)

Table 5 : Calculation of budget parity.

Year	Tax revenues , billions rubles	Increase in tax revenues due to the introduction of renewable energy sources, million rubles. (ΔTR)	Value of budget parity, conventional units.
2023	177.46 .	5,874	0.135
2024	178,04		

The calculated values of all parities allow us to calculate the integrated indicator of the efficiency of using renewable sources (IER (region)) in the Tyumen region:

OPI(Tyumen region) = 0.104 + 0.38 + 0.2456 + 0.135 = 0.8646 arb . units

The value of the indicator 0.86 conventional units is quite high, which reflects the high level of efficiency of the implementation of renewable energy sources in the Tyumen region. Also, having analyzed each of the parities, the strengths and weaknesses of the region in the use of renewable energy sources become noticeable (Table 6).

Table 6: Characteristics of the integrated efficiency indicator for types of renewable energy sources.

Estimation range , conventional units	With characteristics	Indicator value
1.01 and above	Typical for bio-power plants (low emissions, high resource efficiency)	Maximum level of efficiency of renewable energy use
0.81 – 1	Typical for solar power plants (low emissions, high resource efficiency, average efficiency)	High level of efficiency in using renewable energy sources
0.61 – 0.8	Typical for hydroelectric power plants (low emissions, high capital intensity, high resource productivity)	Increased efficiency of renewable energy use
0.41 – 0.6	Typical for wind power plants (low resource efficiency, low emissions, high efficiency)	Average level of efficiency of renewable energy use
0.21 – 0.4	Typical for geothermal power plants (low efficiency, high emissions, high capital intensity)	Low level of efficiency of renewable energy sources
0 – 0.2	Typical of coal-fired thermal power plants (low efficiency, high emissions, use of exhaustible resources)	Extremely low level of efficiency in using renewable energy sources

The gradation of the ranges of the general indicator of the efficiency of the use of renewable energy sources consists of six divisions from 0 to 1.01 and higher. Each division corresponds to an example of the characteristics of the type of power plants, which allows for a more detailed presentation of the region's potential in the use of renewable energy projects. The Tyumen Region is characterized by a high level of efficiency in the use of renewable energy sources, which is typical for solar power plants with a low level of emissions of harmful substances and a high level of resource efficiency . At the same time, to improve the efficiency of the use of renewable energy sources in the region, it is recommended to increase the capacity of bio -power plants to increase efficiency.

The methodology for assessing the efficiency of using renewable energy sources using the proposed parity system can be very relevant for various regions of Russia. The proposed system of indicators is applicable to the analysis of various types of renewable energy sources and allows for a comparative analysis between different energy sources, including both traditional (coal, gas, nuclear) and alternative ones. As a result of the trial calculations, certain assumptions were made due to the lack of data. For example, to assess the environmental parity, a comparison of emissions from TPP-2 in the Tyumen Region and renewable energy installations, such as hydro- , bio- and geothermal stations, was used with the transition to a unit of measurement of 1 kW h . This made it possible to assess the significance of reducing emissions into the atmosphere due to the introduction of renewable

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energy sources. Also, the use of the coefficient 10^{-7} in the calculations of environmental parity is due to the need to convert the values of emissions and capacities into a more convenient format for analyzing and accounting for data in units and kilowatt-hours.

Structuring the integral indicator of the efficiency of using renewable energy sources is an important aspect of the methodology, as it allows us to identify the most effective projects taking into account all significant factors. For this indicator indicator, it is possible to use more specific assessment ranges, taking into account the significance of each of the criteria: environmental, innovative, regional and budgetary. This approach will allow for a more in-depth analysis of the impact of various types of renewable energy sources on the technological development of the region, its environmental situation and financial sustainability.

In addition, the study used average technical and economic indicators of the most popular RES installations. If it is necessary to evaluate specific models of power plants operating on RES, it is possible to increase the accuracy of the calculations and obtain a more reliable idea of the potential and possibility of using renewable energy for certain projects in the region. At the same time, the proposed set of evaluation indicators does not require adjustment to assess the effectiveness of implementing RES projects with certain technological installations, which confirms the universality and viability of the author's recommendations.

The authors proposed a set of indicators for assessing the effectiveness of projects for the introduction of alternative energy sources in the region. The study analyzed existing methodological approaches and proposed recommendations for expanding the evaluation criteria. In particular, special attention was paid to the development of parities, such as regional, innovative, environmental and budgetary, which make it possible to increase the validity of assessing the effectiveness of the introduction of renewable energy sources, taking into account the natural and climatic characteristics of the region, the level of innovation development, environmental impact and economic efficiency. The developed system of indicators is based on the principles of system analysis and includes both quantitative and qualitative parameters adapted to the conditions of a particular region.

The advantage of this scientific study is the recommended comprehensive approach to assessing the potential for the use of renewable energy sources in the region, taking into account the most significant factors and conditions for the development of energy. The proposed parity system as a comprehensive system of indicators allows expanding the feasibility study of projects for the implementation of renewable energy sources in the regions. Of particular interest in the scientific study is the methodology for calculating parities, taking into account the technical potential of the alternative energy sources used and the financial and economic indicators of their use. The choice of the parity system by the authors is based on factors that determine the optimal option for energy supply to the region. This approach allowed the authors to propose an integrated indicator for assessing the effectiveness of renewable energy implementation in the region in order to simplify the interpretation of the final assessment results.

In general, the proposed system of indicators for assessing the implementation of renewable energy sources in the region will allow:

- expand the range of methodological tools for assessing the effectiveness of the implementation of alternative energy projects in the country;
- to increase the validity of the choice of individual types of alternative energy sources for different regions of the country;
- to substantiate the potential for the use of renewable energy sources in individual regions of the country, taking into account their potential for use;
- to increase the evidence base for the formation of innovative development programs in the country’s energy sector.

The practical significance of this scientific study is to improve the validity of investment decisions and the development of state support programs for renewable energy projects. The proposed methodological approach will optimize the use of budget funds aimed at developing renewable energy sources in the regions, ensuring their higher efficiency. The recommended system of indicators is aimed at improving the validity of management decisions on the efficient use of energy resources. The conducted studies are adapted for strategic and territorial planning of the energy sector development, and can also be used for monitoring and comparative analysis of sustainable energy development in regions.

Thus, the conducted scientific research has scientific and practical significance in assessing the effectiveness of the implementation of renewable energy sources in the regions.

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