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The Role of State in Managing the Wind Energy Projects: Risk Assessment and Justification of the Economic Efficiency

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Abstract: Our paper focuses on assessing the role of state funding in supporting wind energy projects with a focus on economic efficiency and risk assessment. In particular, we analyze the new program aimed at supporting Russian renewable energy (RE) projects envisaged for the period from 2024–2035 that involves a reduction in investments in such projects and the introduction of large fines for non-compliance with regulatory requirements for localization and export. These strict rules imposed by the regulatory authorities, as well as the withdrawal by foreign manufacturers of equipment for renewable energy from the domestic energy market, put into doubt the economic feasibility of the participation of sector players in state-supported programs. Our paper assesses the economic justification for the practicality of the Russian energy market to implement renewable energy projects under the influence of negative environmental factors and the reduction of state support programs. We employ a case study of wind energy projects carried out in 2018–2020 as a part of the first sector support program. Our methodology is based on the calculations of the classical indicators of economic efficiency of projects (NPV, IRR, and DPP). Our own approach reveals that these indicators are supplemented by taking into account the cost of specific political, environmental, and economic risks of wind energy projects. Our results reveal that, at the moment, Russian wind energy projects in various scenarios retain a sufficient margin of financial strength and are able to withstand a reduction in the amount of financial support from the state. Our findings allow the formulation of some practical recommendations for reducing the share of governmental support for wind energy projects on the local energy market as a measure of cutting costs and increasing overall economic efficiency.

Keywords: renewable energy; wind energy; state support; energy management; economic efficiency; risk assessment

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1. Introduction

Renewable energy (RE) has become an increasingly important issue in recent years as an increasing number of countries around the world seek to reduce their reliance on fossil fuels and mitigate the effects of climate change. However, the high costs associated with renewable energy projects, particularly in the early stages of their development, often constitute a significant barrier to their implementation. Thus, the state and its stakeholders have an important role in funding renewable energy projects to support their development and help to achieve broader environmental goals.

At present, a considerable number of research studies focus on studying the role and the impact of state policies pursued by various countries in the field of sustainable development on the distribution of energy of the future. Thus, Azam et al. [1] and Fatai Adedoyin et al. [2] emphasize that an increase in state support for alternative energy contributes to the growth of the economic stability of the country. This trend is obvious for those countries which are initially rich in natural energy resources [3–6]. Here, the growth of investment in green energy allows them not only to reduce the negative impact on the environment and slow down climate change, but also to ensure a sustainable structure of production and consumption in the long run. State stimulation of the renewable energy sector is of particular importance in those countries where initially the potential and need for the development of such technologies is accompanied by the lack of appropriate economic opportunities for the population or business [7,8].

In addition, some countries are forced to significantly change the structure of public spending due to the rapid pace of negative climate change [9]. As a result, many authors strongly agree upon the need for a phased reduction in investments in hydrocarbon energy, which causes irreparable harm to the environment, in favor of subsidies for future environmentally friendly energy technologies [10–13].

Nevertheless, such solutions require prompt access to capital-intensive and expensive investments in the development of an appropriate eco-energy infrastructure. This problem cannot be solved only through investment plans adopted even at the highest state level [1]. Therefore, the question remains: which financial resources are the most effective for the implementation of expensive energy projects of the future? Possible options include state budgetary funds [1] provided at various levels, including revenues from newly introduced eco-taxes for business and the population [14,15], private investment [16], etc.

In particular, within the framework of our study, the current feasibility of public and/or private financing of Russian renewable energy projects has been studied. The problem has been considered taking into account the features of existing and prospective programs of state support for the sector, as well as global uncertainty and risks, which are described below in greater detail.

In Russia, which has been selected as a territorial object for this study, the following targets have been set for the energy market to achieve the following volumes of production and consumption of electrical energy using renewable sources: 2010—1.5%; 2015—2.5%; 2024—4.5%; 2035—no less than 6% of the overall volume. These goals are indicated considering the program for the development of the renewable energy sources (RESs) in Russia, finalized in 2022 for the period from 2010 to 2035 [17].

Nevertheless, it needs to be noted that to date, the results achieved on the market differ significantly from the plans that were originally envisaged. Thus, according to the Association for the Development of Renewable Energy [18,19], at the end of 2022, the share of generation by all facilities under the contracts for the provision of capacity based on renewable energy sources (CSA RES) program (more details on that are provided in Section 2) did not exceed even 1% of the volume of electricity consumption in the unified energy system of Russia. As a result, despite the active development of the sector in the wholesale market over the past few years, the current volume of state support is clearly insufficient for achieving the 2024 targets. Meanwhile, the plan is to achieve the 2035 target by obtaining more than 50% through wholesale market support programs as well as using a mechanism to stimulate investment in renewable energy generation in retail markets. In parallel, the Russian domestic energy market is considering the formation of a commercial renewable energy market in this country as well as the activation of the projects implemented by industrial enterprises to meet their own needs for electricity [20].

Additionally, the current situation is aggravated by the ongoing trends and changes that take place in the global market [21–25]. This includes an increase in cost and limited capital [26], as well as geo-economic fragmentation [27]—a violation of the usual economic and logistical ties [27–29] and the need to quickly create new services and ways of interacting with energy suppliers and end consumers [29]. For the Russian RE sector, the consequences of such uncertainty have become very significant and have revealed the following relevant directions for its development as well as for the energy market of which it constitutes an important part [30–37]:

1. Replacement of foreign manufacturers of power equipment that left the Russian market as a result of the geopolitical events of 2022–2023;
2. Forced development of the Russian power engineering market;
3. Development of large-scale research programs to domestically develop technologies for the production of equipment for renewable energy;
4. Accelerated achievement of technological sovereignty, especially in terms of critical energy technologies;
5. Completion of renewable energy projects from previous years, in part the obligations of foreign owners of the Russian energy corporations which were not fulfilled;
6. Improvements to the system for selecting renewable energy projects within the framework of sector support programs;
7. Development of new instruments for investing in domestic renewable projects, including a dedicated green investment market and a commercial renewable energy market.

Therefore, the main purpose of the study is the economic justification for the practical feasibility of state programs to support wind energy projects on the Russian wholesale market (which represents a special case of renewable energy development and management) under the given scenario conditions of the negative impact of environmental factors and the reduction of the volume of concessional project financing.

In accordance with this objective, we propose the following research hypothesis: The impossibility of achieving the target rates of development of the Russian renewable energy market is caused by the inefficiency of existing sector support programs and/or insufficient financing of generating capacities. In addition, in order to study the trends emerging in the market, one should take into account the patterns formed by the projects of the last years of selection from the initial sample.

Thence, the main objective of our paper is to study the features of existing and promising tools used for supporting the renewable energy sector on the Russian market and to conduct an empirical assessment of their success. Furthermore, we aim to come up with our own methodology for calculating the cost of the specific risks of wind energy projects based on a comprehensive assessment of their economic efficiency. Moreover, we attempt to develop conditions (four scenarios) for the implementation of wind energy projects, depending on the assigned international credit rating and the amount of financing available under the CSA RES program. In addition, we draw a practical scenario assessment of the economic efficiency of the wind energy projects and the state support program for the RE sector. Finally, we conduct the development of directions for the development of state programs intended for managing wind energy projects.

The main subject of this study are wind power plants (WPPs) which are being built for the needs of the wholesale electricity and capacity market with the support of the state CSA RES program in 2018–2020. This WPPs sampling period is due to the introduction of the new rules for calculating the preferential price per capacity according to CSA RES from 2021 (for more details please see Section 2). In turn, the selection according to these rules was carried out only in 2021 and 2023 (March–April) and cannot be relevantly assessed in this particular study due to the still-small number of selected projects.

An additional subject this paper tackles is the specific risks that accompany renewable energy projects. In particular, we identify three types of these: political, environmental, and economic [38,39]. Their selection is due to the experience accumulated to date in risk management in renewable energy projects. For example, the influence of political risks on the implementation of renewable energy projects is studied in [40–45], environmental risks in [44,46–50], and economic risks in [51–56]. The general methodology of our study is presented in the form of the block diagram depicted in Figure 1, which follows.

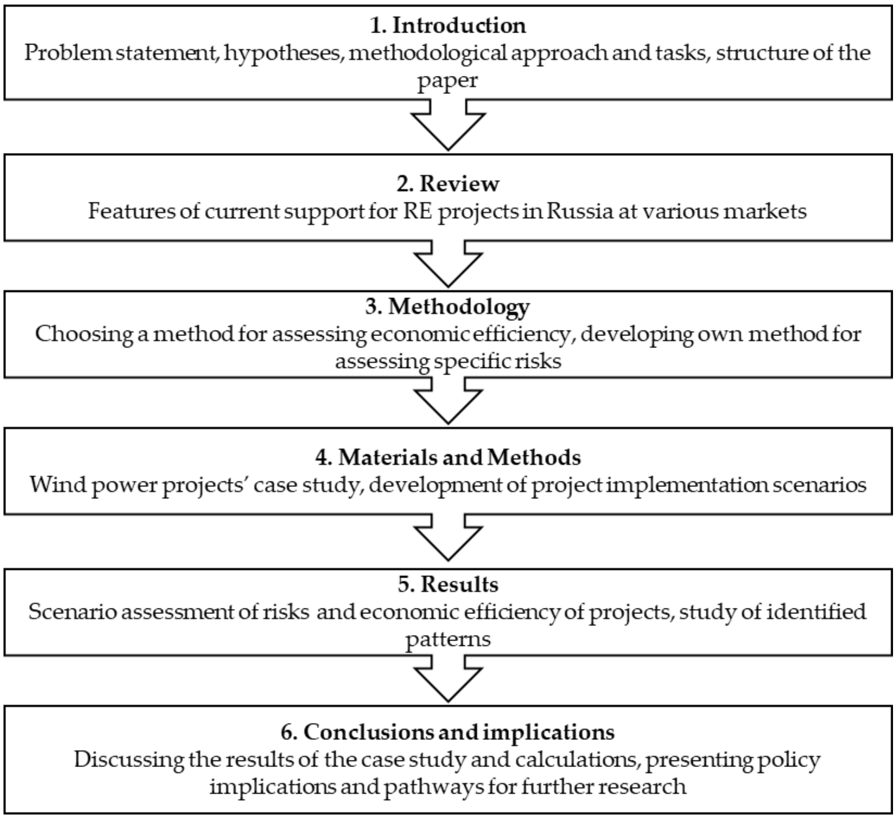

Figure 1. Block diagram for the methodology highlighting various phases of the work. Source: own results.

This paper is structured as follows. Section 2 provides an overview of the existing tools to support renewable energy projects in the wholesale and retail energy markets, as well as the prerequisites for the formation of a commercial renewable energy market. Section 3 describes the methodology of the study, including the assessment of the cost of sector-specific risks. A practical assessment of the cost of such risks and a generalization of scenario conditions for the implementation of wind energy projects under the influence of external negative factors is provided in Section 4. Furthermore, Section 5 is devoted to the results of a scenario assessment of the effectiveness of wind energy projects, considering the impact of specific risks. As a result, Section 6 summarizes the main calculated results of the study based on which practical recommendations are given for improving state programs to support wind energy projects. Appendix A, which complements the paper, presents the calculations reported in the tables for each of the five scenarios for the implementation of the Russian wind energy projects.

2. Review of Tools to Support Renewable Energy Projects in Russia

2.1. Wholesale Electricity and Capacity Market (CSA RES 1.0)

The fundamental mechanism for the formation and development of Russian RESs is the sale of the capacity of qualified generating facilities—that is, the contracts for the provision of capacity based on renewable energy sources collectively known as CSA RES [18,19,57]. Its essence is to conduct a competitive selection of projects for the construction of generating facilities operating based on RESs and approve CSA RES with respect to the selected projects. The contract guarantees payment for installed capacity for 15 years, which ensures a return on invested capital and a rate of return of 12%. This program applies to solar, wind, and small hydro power plants operating on the wholesale energy market.

The first stage of the program implementation (CSA RES 1.0) in Russia was designed for the period from 2013 to 2024. Its main distinguishing feature was the establishment of several mandatory targets for project types [58,59]:

- Limitations on the value of specific capital costs;
- Volume of input of installed electric capacity;
- The degree of localization of production in Russia for the main and auxiliary equipment of generating facilities.

Examples of these indicators for wind power plants are provided in Table 1, which follows [58].

Table 1. CSA RES 1.0 targets for wind energy projects.

Target Value	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Marginal capital cost per 1 kW of installed capacity, thous. RUB	65.8	110	109.9	109.8	109.7	109.6	109.5	109.3	109.2	109.1	85
Installed capacity commissioning volume, MW	-	51	50	200	400	500	500	500	500	500	214.7
Degree of localization, %	-	-	-	-	-	-	65	65	65	65	65

Source: Domestic results based on Ministry of Energy of the Russian Federation data [58].

The main criterion for selecting projects under CSA RES 1.0 was the minimization of capital costs for the implementation of such power facilities by project type. Additionally, all power facilities had to qualify as renewable energy facilities and ensure the achievement of a minimum level of installed electric capacity utilization factor. For example, in 2021, this indicator for wind farms reached 30% [19].

The selection of investment projects under the CSA RES 1.0 program was completed in 2020. The total volume of installed electric capacity of power plants built under CSA RES 1.0 by the end of 2024 will be 5430 MW, including wind farms supplying 3430 MW [18,19,60,61].

2.2. Wholesale Electricity and Capacity Market (CSA RES 2.0)

The decision to launch the second phase of the program, aimed at supporting renewable energy in the wholesale market (CSA RES 2.0) in Russia, was made in 2021 in order to strengthen the established scientific and technical potential of the RE sector. The program was envisaged for the period from 2024 to 2035 and was aimed, in particular, at [19,61]:

1. Increasing the competitiveness of the Russian industrial cluster;
2. Increasing exports of high-tech equipment based on renewable energy;
3. Achievement (by 2036) of parity between the per-unit price of electricity and RES capacity and the weighted average unregulated price of electricity and capacity on the wholesale market.

The principal differences in the new wholesale market support program are as follows:

- New competitive selection criterion—the declared efficiency indicator of the generating facility (per-unit price value);
- Transition from volume restrictions to cost restrictions: instead of restrictions on annual volumes of capacity commissioning, annual volumes of support in rubles were established (total under the program—360 billion rubles);
- Transition to a scoring (instead of percentage) methodology and new target indicators for the localization of the main and auxiliary equipment of renewable energy generating facilities and tougher penalties for non-compliance with target indicators;
- The introduction of export requirements, the possibility of changing installed capacity, additional criteria for changing locations, and increasing the requirements for the readiness of generating facilities.

Examples of some indicators for wind farms are provided in Table 2, which follows below [18].

The first competitive selection for CSA RES 2.0 was held in September 2021. Within the framework of this selection, the reduction in the cost of applied electrical energy by more than 50–70% of the limit values made it possible to almost double the total amount of selected capacity, which all was possible due to innovations in this field [18,19]. The 2022 competition was completed from March-April 2023 due to geopolitical reasons [62].

Table 2. CSA RES 2.0 targets for wind energy projects.

Target Value	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Amount of support, billion rubles	3.87	3.63	3.41	3.19	2.99	2.80	2.63	2.45	2.30	2.14	2.00
Degree of localization, points	87	87	87	87	87	87	102	102	102	102	102 *
Export, %	20	20	20	20	20	40	40	40	60	60	60

Note: * corresponds to 80–90% depending on the applied technologies. Source: own results based on Renewable Energy Development Association data [18].

With regard to the above, some experts predict that with regard to the reduction in electricity prices, by 2035 the total amount of capacity built under the CSA RES 2.0 program could be up to 10 GW [18,19].

2.3. Retail Electricity Market

On the Russian retail power and energy market, state stakeholders and organizations support not just solar, wind, and hydropower technologies, but also power plants using biogas, biomass, and landfill gas. This support mechanism is based on the competitive selection of the projects at the level of individual regions and their inclusion in the relevant program for the development of the electric power industry. The selection criterion is the minimum price of electricity. As a result, the establishment of the long-term tariff is determined by indexing the required gross revenue for a 15-year period with a discount rate of either 14% or 12% [63]. The subsequent fulfilment of contracts for the sale of generated electrical energy to territorial grid organizations (TSOs) allows compensation for losses in the amount of less than 5% of total losses at a regulated tariff and guarantees investors a return on the invested funds in the construction and operation of the facility, as well as collecting revenue from the invested capital [63]. In addition, it is intended that the cost of the power facility will be partially compensated for its technological connection to the grid in the amount of below 50% of the cost of technological connection, at the expense of the federal budget. This mechanism is based on the following principles:

- Minimization of the increase of prices (tariffs) for electricity for end consumers in the retail market;
- Opposition to the volume of electricity production by qualified RES generating facilities exceeding 5% of the predicted losses of TSOs in the region;
- Minimization of possible environmental damage;
- Solutions to social problems in the region of project implementation.

For the period from 2021–2022, more than 255 MW of predominantly solar and biogas generation were selected based on the results of the competition. According to the experts, the potential of the Russian retail renewable energy market is in the range of 3–4 GW [18,19]. At the moment, the operation of this mechanism has been extended from 2024 to 2035.

2.4. Development of the Commercial Renewable Energy Market in Russia

One of the main trends in the Russian energy sector is the formation of a commercial market for renewable energy, which would operate independently and without state support [64,65]. This envisages the development of free bilateral agreements for the purchase and sale of electricity and capacity as an alternative to the CSA program for RESs.

Currently, there are so-called "green" DDSs in electricity trading. They supply electricity as well as generation attributes from a qualified generating facility at a pre-negotiated volume and at an agreed price. However, in the case of capacity trading, there is no special mechanism for targeted return on investment in the construction of generation-independent producers of electricity obtained from RESs.

As a result, there is a need in the energy market for a new investment mechanism that would stimulate voluntary demand for renewable energy generation. On the side of generators, such a need is due to the need to attract capital-intensive investments in the construction of the new facilities, as well as the possibility of choosing contractors. On the side of consumers, this is predetermined by the possibility of choosing the terms of a long-term contract with a renewable energy generator, fixing the price of electricity for a long time and reducing its final cost.

Currently, the Market Council Association [66] is discussing a draft investment agreement with professional market participants. It represents a variety of DDSs for the purchase and sale of electricity (capacity) with a special procedure for paying for capacity on the wholesale market, which can be concluded with regard to a new (future) generation facility for a certain period of time. The essence of the proposed mechanism is shown in Figure 2.

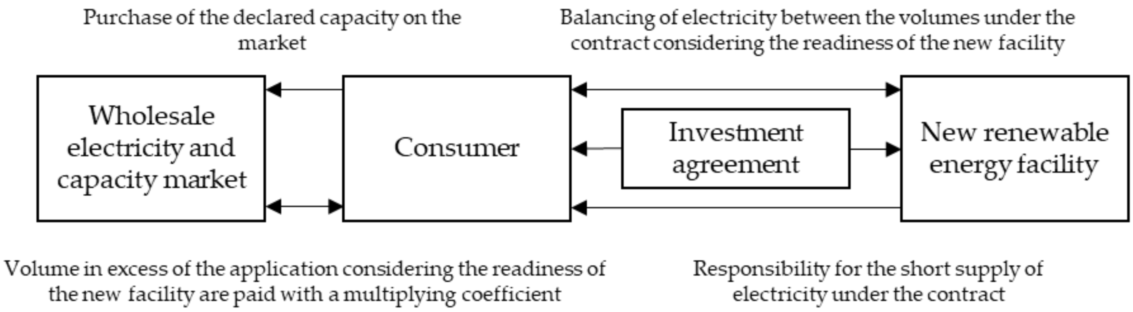

Figure 2. Draft concept of the DDS mechanism in the Russian renewable energy market. Source: own results.

3. Research Methodology

Assessment of the economic efficiency of wind energy projects is carried out using the widely used classic investment analysis tools net present value (NPV) and internal rate of return (IRR) [67] and is also supplemented by a qualitative assessment of the achieved payback stage of projects (DPP). Further, this toolkit is refined by taking into account the industry specifics of the Russian energy market (see Section 2.1) and our own approach to assessing the specific risks of renewable energy projects (see Sections 2.2–2.4).

The choice of such a classical method for evaluating WPP investment projects is based on a review of existing specific criteria, indicators, and methods for calculating the efficiency of renewable energy projects in general, carried out by Chebotareva and Dvinayninov [24]. As a result, given the publicly available data on WPPs projects, the most relevant is the use of NPV, IRR, and DPP tools.

The effectiveness of wind energy projects according to these indicators is assessed at two stages of implementation: (1) after the expiration of the 15-year period of support through CSA RES and (2) after the end of the planned 25-year life of these power facilities. The main task of such a clarifying assessment is to study the boundaries of the possibilities of wind energy projects to achieve a positive economic result within the period of the CSA RES under various conditions. The graphical interpretation of the research methodology is shown in Figure 3, which follows.

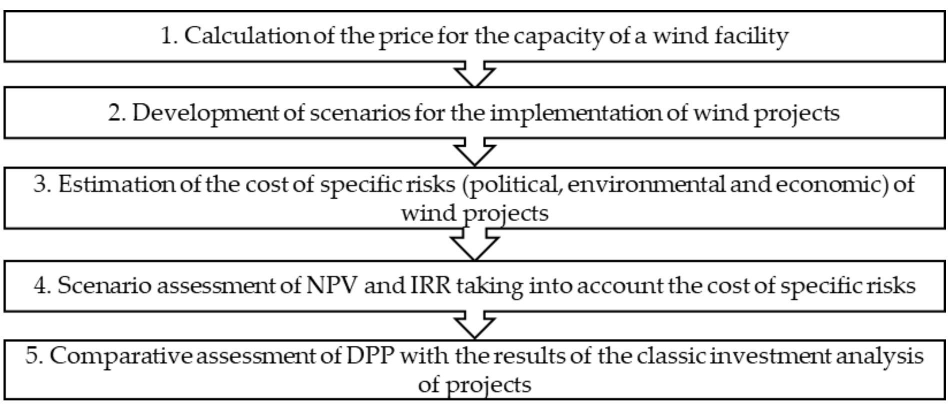

Figure 3. Methodology for assessing the effectiveness and risks of wind energy projects. Source: own results.

3.1. Methodology for Calculating the Final Price for the Capacity of a Wind Facility

To estimate cash flow for the projects implemented under the CSA RES program, an additional calculation of the final price of capacity over the 15-year project support period is required. Such an assessment is based on the following methodological guidelines, which are the rules for determining the price of capacity for renewable energy facilities which are presented in Decree of the Government of the Russian Federation No. 449 [68]. The Decree presents these calculations according to the methodology adopted for the projects selected before 1 January 2021.

Thus, the capacity price of a wind generation facility is determined as the product of the share of costs offset by the capacity fee and the total costs, including capital costs, operating costs, and property tax costs.

The planned amount of capital costs subject to compensation is declared in the documentation for the competitive selection of projects approved by the competitive commission and subsequently adjusted in accordance with the stipulated coefficients. In particular, the target indicator of the degree of localization is used:

- 1 if the actual degree of localization is greater than or equal to the value of the target indicator;
- 0.45 if the degree of localization of the wind generation facility is below the target.

The second adjustment is made on the basis of the profit accounting coefficient of the wholesale electricity and capacity market (after the payback period and before the end of the life of the generating facility). In the case of wind generation facilities, this comes out to 0.9.

The value of specific operating costs is set, as of 1 January 2012, by types of generating facilities and is indexed for each subsequent period in accordance with the official consumer price index. In the case of wind generation, this makes 118 thous. RUB/MW per month.

As a result, the component of the price for the capacity of objects which ensures the return on capital and operating costs is determined by the following Equation (1):

$$KE_i = ((R_i \times NP_{i-1})/(1 - NP) + r_i)/12 + ER_i, \quad (1)$$

where KE_i is the price of capacity which ensures a return on capital and operating costs in the i-th year; R_i is the amount of invested capital at the beginning of the i-th year; NP is income tax rate; r_i is the return on invested capital in the i-th year; and ER_i is the product of the value of the operating costs of the i-th year and the share of costs compensated by the payment for the capacity of the wind facility

The property tax expenses are calculated according to the value of the property and the current tax rate. This value is adjusted for the preliminary share of costs compensated by payment for the capacity of generating wind facilities [68].

Then the final indicator of the price for capacity is adjusted based on the fulfillment of the load factors of the wind facility, the use of installed capacity, and the consumption of capacity for own/economic needs [68].

3.2. Methodology for Assessing Political Risk

When assessing political risks, the hypothesis can be formulated as follows: "the more stable the position of the state in the domestic and international arena, the lower the political risk", that is:

1. It is less likely that the state would face financial and other difficulties (for example, the probability of default);
2. There are more stable processes of implementation of various government programs, including the support for the RE projects.

In order to assess the declared degree of stability of the state's position, it might make good sense to use a rating approach, i.e., the average value of credit ratings assigned to the state (as well as forecasts of them) by both domestic and foreign rating agencies.

The averaging of the values of the assigned ratings is used to ensure a certain degree of objectivity in such a qualitative assessment method.

Then the probability of political risk realization, i.e., the probability of state default and the impossibility of providing state support to projects in the sector, corresponds to the probability of default according to the obtained rating calibrated by the number of years from the date the rating was initially received.

The monetary equivalent of the political risk in each period i is calculated by the equation expressed by Equation (2):

$$PR_i = PD_i \times RC_i, \quad (2)$$

where PR_i is the monetary equivalent of political risk; PD_i is the probability of project default according to the data of rating agencies; and RC_i is the amount of state support for the project, equal to the revenue received by the facility under CSA RES.

It needs to be noted that the accounting for political risks occurs only during the first 15 years of implementation of wind energy projects (the period of state support). When ratings are periodically reviewed, the political risk assessment also needs to be updated.

3.3. Environmental Risk Assessment Methodology

This toolkit involves assessing the damage caused to the environment by the implementation of the project (the amount of greenhouse gas emissions in CO_2 equivalent (including at the stages of production of individual components of the required equipment, as well as their disposal, the so-called "hidden carbon footprint")).

Within the framework of our own methodology, we propose calibrating the damage caused by the volume of annual greenhouse gas emissions that can be avoided through the use of RE technologies compared to traditional ones. Such an "adjustment" is a kind of incentive measure of wind energy projects, as it increases the values of the final indicators of efficiency.

The assessment of greenhouse gas emissions at individual stages of projects is carried out by experts. Thus, information on the size of the "carbon footprint" (Em_{CO2i}) was estimated in a paper by Pehl et al. [69] and Deemer et al. [70], while the information on the price of emissions (Pr_{CO2}) was calculated according to official reviews and recommendations [71,72].

The final assessment of the monetary equivalent of environmental risk (EC_i) is presented in Equation (3) for all periods of the full lifecycle of wind projects (see Equation (3) below):

$$EC_i = Em_{CO2i} \times Pr_{CO2} \quad (3)$$

3.4. Methodology for Assessing Economic Risk

The economic risks of a wind energy project need to be measured by taking into account such macroeconomic indicators as changes in exchange rates, the refinancing rate, lending rates, the cost of electricity [73,74], etc. Therefore, in our methodology, we propose adapting the principles of the theory of economic capital [75], which reflects the above indicators in the field of renewable energy. The economic risk (CaR_i) of sector projects is estimated by the following Equation (4):

$$CaR_i = EAD \times LGD \times (N((N^{-1}(PD_i) + R^{1/2} \times N^{-1}(\alpha_i))/(1 - R)^{1/2}) - PD_i) \times M_i, \quad (4)$$

where EAD is the total cost of the project; LGD is the industry average indicator of the expected relative size of losses in the event of a project default; PD_i characterizes the probability of project default and corresponds to the level of the rating assigned to the state; R is the correlation coefficient of the state of the project within the general state of the industry; α_i is the level of reliability, determined by the correspondence table between the target probability of default and the rating of the state; and M is the effective investment period.

4. Materials and Methods

4.1. Characteristics of Wind Energy Projects

In our study, we focused on 34 wind energy projects implemented on the Russian wholesale market based on the results of the selection of the CSA RES program in 2018–2020 [76]. A brief description of these is presented in Table 3 below.

All of the presented projects belong in the first price zone [57,68] and have been implemented mainly with the participation of the initiating companies—VetroOGK-2 JSC (a subsidiary of the Rosatom Corporation) and LLC Wind Farms FRV (a subsidiary of PJSC Fortum, both located in Moscow). The standard operating life of these wind power facilities is established by law [68] and is set at 25 years.

Table 3. Technical and economic indicators of wind energy projects.

Name	Selection Year	Launching Year	Capacity [1]	CAPEX [2]
Experimental WPP-121	2020	2024	20	65
Experimental WPP-127	2020	2024	15	65,05
Experimental WPP-130	2020	2024	40	65
Experimental WPP-128	2020	2024	22,5	65
Experimental WPP-125	2020	2024	20	65
Experimental WPP-129	2020	2024	40	65
Experimental WPP-131	2020	2023	35	65
Stavropol WPP-24	2019	2024	71,25	64,867
WPP WindFarm-35	2018	2019	19	80,305
WPP WindFarm-34	2018	2019	22,8	81,104
WPP WindFarm-36	2018	2019	19	81,205
WPP WindFarm-31	2018	2019	19	80,609
WPP WindFarm-32	2018	2019	19	81,201
Experimental WPP-67	2018	2021	10	130,926
WPP WindFarm-41	2018	2021	37,8	59,339
WPP WindFarm-42	2018	2021	37,8	59,339
WPP WindFarm-37	2018	2021	37,8	59,339
WPP WindFarm-38	2018	2021	37,8	59,339
WPP WindFarm-48	2018	2021	37,8	59,339
WPP WindFarm-49	2018	2021	37,8	59,339
Experimental WPP-52	2018	2021	20	93,028
WPP WindFarm-61	2018	2023	38,7	63,004
WPP WindFarm-59	2018	2023	37,8	68,555
WPP WindFarm-60	2018	2023	37,8	68,555
WPP WindFarm-57	2018	2023	37,8	68,555
WPP WindFarm-58	2018	2023	37,8	68,555
WPP WindFarm-52	2018	2023	37,8	62,209
WPP WindFarm-51	2018	2023	37,8	62,911
WPP WindFarm-71	2018	2023	38,7	62,406
WPP WindFarm-74	2018	2023	38,7	62,41
WPP WindFarm-75	2018	2023	38,7	68,555
WPP WindFarm-78	2018	2023	38,7	68,555
WPP WindFarm-82	2018	2023	38,7	68,555
WPP WindFarm-83	2018	2023	38,7	70,801

Note: [1] Installed capacity unit—MW; [2] the unit of measurement of specific capital investments is thous. RUB/kW. Source: own results.

4.2. Input Data for Risk Assessment of Wind Energy Projects

4.2.1. Political Risks

The political risk assessment is carried out during the 15-year period of support for wind energy projects under the CSA RES program. The amount of state support for each wind energy project is determined annually in accordance with the estimated technical and economic indicators of the projects selected through the competition (shown in Table 1 above).

Project default probability assessment (PDi) is based on the data forecast of the state's national credit rating provided by rating agencies. In this study, such rating agencies include representatives of the "big three"—the most famous and reputable agencies that cover 95% of the global market: Standard & Poor's (S&P), Fitch Group, and Moody's. Among the four Russian credit rating agencies accredited by the Bank of Russia, the final list includes only ACRA, the only agency that sets the national credit rating of Russia.

To calculate the average of the issued credit ratings of the state, the interpretations of the international scales of all agencies were compared [77–80], and the final ratio was compiled and is presented in Table 4.

Table 4. Ratio of international scales of four rating agencies.

ACRA	S&P	Fitch	Moody's
AAA	AAA	AAA	Aaa
AA	AA	AA	Aa
A	A	A	A
BBB	BBB	BBB	Baa
BB	BBB−	BB	
B	BB+	B	Ba
CCC	BB		B
CC	B, CCC	CCC	Caa
C	CC	CC, C	Ca
RD	-	-	
SD	C	RD	-
D	D	D	C

Source: own results.

Subsequently, the average rating would determine the probability of project default in given scenarios, depending on the year of the wind energy project implementation (for more details, see the information presented in Section 3.3 above).

4.2.2. Ecological Risks

According to the results of a preliminary expert assessment in [69,70], the information on the level of "carbon footprint" (in CO_2 equivalent) in wind energy projects is as denoted in Table 5, which follows. It needs to be noted that according to the experts' opinions, the equipment used at the wind power facilities is either completely subject to disposal/recycling (in this case, the "carbon footprint" is taken into account in the newly created facilities), or after the end of the planned period and the necessary repairs, the operation of such facilities would resume. Therefore, at the current stage, this indicator is set to be equal to zero. Please see Table 5 for more details below.

Table 5. The size of the "carbon footprint" by the stage of implementation of the wind project, grams—kWh.

Project Stage	Equipment Manufacturing	Energy Generation	Equipment Utilization
Footprint value—CO_2 equivalent	11	4	0 *

*: According to the experts' opinions, the equipment used at wind power facilities is either completely subject to disposal/recycling (in this case, the "carbon footprint" is considered in newly created facilities), or after the end of the planned period and the necessary repairs, the operation of such facilities continues. Therefore, at the current stage, this indicator is set at zero. Source: own results.

In order to assess the amount of annual greenhouse gas emissions that can be avoided through the use of renewable energy technologies in comparison with traditional technologies, a value of 93 g/kWh (average emissions from the coal and gas energy generation) was taken as a comparable indicator [69,70]. The price of emissions is fixed at the level of −6 USD/ton of CO_2 (the minimum cost of a quota on the market, set in China), or 438 RUB/ton of CO_2 (at the rate of 73 RUB/USD) [71,72].

4.2.3. Economic Risks

In order to assess the economic risks related to the project in question, the following assumptions have been made by the authors of this paper:

1. LGD is assumed to be 0.1% for all wind facilities. This is equivalent to the average minimum risk level accepted in the Russian financial market. In Russian practice, all renewable energy projects implemented with state support have a positive history;
2. The probability of default PD is a variable and depends on the scenario conditions for the implementation of projects (see Section 4.3);
3. The correlation coefficient R is set as equal to 0.5 for all objects, since the project is being implemented in the current economic conditions and with state support for the sector.

4.3. Scenario Conditions for Evaluating the Effectiveness of Wind Energy Projects

As part of the cost–benefit analysis of projects, we have developed five scenarios (Table 6). All scenarios are based on the principles of stress testing in order to identify negative conditions under which wind energy projects would retain the ability to achieve a positive economic outcome.

Table 6. Conditions for scenario evaluation of the efficiency of wind energy projects.

Criteria	Basic (0o) Scenario	1st Scenario	2nd Scenario	3rd Scenario	4th Scenario
Average credit rating	"BBB" [1]	"CC" [2]	"BB" [3]	"BBB" [1]	"BBB" [1]
Provision of support under CSA RES	100%	100%	100%	95% [4]	90% [4]

Note: [1] The average value of the credit rating of the four rating agencies from December 2021—January 2022. [2] The average value of the credit rating exclusively of the "big three" agencies as of March 2022. [3] Average value of the credit rating of four rating agencies as of March 2022. [4] Author's hypotheses.

In accordance with the developed scenarios, Tables 7–9 present the distribution of default probabilities of wind energy projects depending on their assigned rating and the year of project implementation [77].

Table 7. Probability of project default with "BBB" rating, %.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
0.21	0.6	1.02	1.53	2.06	2.56	3.01	3.45	3.89	4.33	4.96	5.52	6.09
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
6.69	7.3	7.9	8.5	9.2	9.9	10.6	11.3	12	12.8	13.5	14.3	

Table 8. Probability of project default with "CC" rating, %.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
26.87	36.05	41.23	44.27	46.75	47.77	48.85	49.67	50.64	51.35	51.86	52.38	52.90
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
53.43	53.96	54.50	55.05	55.60	56.16	56.72	57.28	57.86	58.44	59.02	59.61	

Table 9. Probability of default by the project with a rating of "BB", %.

1	2	3	4	5	6	7	8	9	10	11	12	13
0.8	2.46	4.41	6.29	8.01	9.64	11.03	12.26	13.4	14.39	15.16	15.67	15.89
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
15.79	15.38	14.67	13.70	12.52	11.19	9.78	8.35	6.96	5.67	4.50	3.48	

5. Results

The initial assessment of the economic efficiency of these wind energy projects in terms of NPV and IRR, without taking into account the cost of specific risks, was carried out earlier by Chebotareva [59]. The object "Experimental WPP-67" was excluded from the initial sample of 34 projects which, even with the classical assessment of NPV and IRR, is stranded. Below are the results of the evaluation of the economic efficiency of these projects that reflect the cost of risks within the five proposed scenarios.

5.1. Scenario 0: Basic

The results of the assessment of the economic efficiency of wind energy projects in the basic (zero) scenario are presented in Table A1. Compared to the classic efficiency assessment, the following changes can be noted:

- Seven projects have ceased to achieve positive economic impact. These projects were selected according to the 2018 competition and are characterized by high specific capital costs (from 68.5 to 93 thous. RUB/kW);
- Four projects have achieved results only within the planned 25-year operating life of wind facilities (previously within the measures of CSA RES program). All of them were selected at the 2018 competition and the specific capital investment averages 59 thous. RUB/kW;
- The group of 22 projects that have retained the achievement of economic effectiveness at the previous time stage includes: all projects in 2020 (within the measures of the CSA RES program), projects in 2019 and 2018 (within the planned operating life). Moreover, the average value of specific capital costs in 2019 and 2020 was up to 65 thous. RUB/kW and up to 81.2 thous. RUB/kW in 2018.

As a result, it is the 2019–2020 projects that would be put into operation in 2023–2024 that appear to be characterized by the most optimal level of capital costs. Under the market conditions of the basic scenario, these projects have sufficient financial strength to cover the costs of specific risks and maintain the achievement of economic results at the same level. In turn, for the projects selected in the 2018 competition, such a pattern did not emerge.

5.2. Scenarios 1 and 2: Credit Rating Weakening

The results of the evaluation of the wind projects in the first scenario are presented in Table A2. The sharp decline in credit ratings to "CC" and the increased likelihood of project default demonstrates that under these conditions:

- Seven projects in 2020 would maintain a positive economic result, but it would be possible to achieve this only within the 25-year life cycle of wind facilities;
- Three projects would retain the possibility of achieving a positive result within the planned period of operation. These included a single project in 2019, as well as two projects in 2018, with a minimum value of specific capital costs (59.3 thous. RUB/kW);
- 18 projects from the 2018 selection, which previously showed a positive result, moved to the default zone.

The conclusions obtained in the first scenario confirm the regularities of the basic conditions. The 2019 and 2020 selection projects have a sufficient margin of financial strength over the entire life of the wind facilities. This allows them to maintain economic efficiency even in the event of a sharp weakening of the credit rating.

The cost-effectiveness assessment results for the second scenario are presented in Table A3 in Appendix A. Downgrading their credit rating by only one point naturally did not significantly affect the ability of wind energy projects to achieve the "base" economic result.

- In general, the stages of achieving a positive effect on projects would remain unaltered;
- Only four 2018 selection projects would have ceased to achieve a positive result which was previously possible within a 25-year time frame.

Similar calculations also confirm the conclusions about the high level of financial stability of projects in the last years of selection.

5.3. Scenarios 3 and 4: Reducing Financial Support

The results of project evaluation under the third scenario are presented in Table A4, which can be found in Appendix A. It should be noted that performance indicators generally reacted rather weakly to the 5% decline in revenue under the support program. For the majority of these projects, the payback period was kept within the limits of CSA RES. By the end of the planned life of wind facilities, the average NPV value decreased by 20%. This happened primarily due to the 2018 selection projects, the payback period of which became longer. Projects in 2020 reacted best to a 5% reduction in revenue and an NPV reduction of 8%; for projects in 2019, the figure was 13%. The payback stages of these projects have not fundamentally changed.

The results of the project performance evaluation in the fourth scenario are summarized in Table A5, denoted in Appendix A. It becomes apparent that after a 10% decrease in revenue, the economic efficiency of projects begins to decline sharply, and the margin of safety is minimized. In 2020, negative changes also affected projects which were previously characterized by a significant level of financial strength. Only one project retained the ability to achieve an effect within the CSA RES period; the rest, within a 25-year period, were similar to the 2019 project. It is natural that among the projects of 2018, 14 projects have ceased to be recoupable, and 11 have retained this possibility only within their planned operating life.

Thus, the scenario, which postulates a 10% reduction in revenue under the CSA RES program, made it possible to identify the threshold value—the existing opportunity to regulate the provision of financial support for wind energy projects on the Russian market for RES.

6. Conclusions and Implications

All in all, it becomes clear that achieving the goals set for RE development continues to be one of the priority tasks for the further development and diversification of the Russian energy market. However, the low rates of commissioning new generating capacities based on RESs are accompanied not only by the emergence of specific industry risks but also by the breakdown of the global energy market model that was in operation for many years. At present, the Russian economy is required to achieve technological sovereignty through the rapid replacement of foreign energy technologies and the development of domestic engineering with a focus on the needs of renewable energy. Meanwhile, state support at various levels is targeted at fostering the construction of generating capacities and developing appropriate programs, in both the wholesale (in the form of CSA RES 2.0) and the retail markets. At the same time, the prerequisites are currently being created for the formation of a completely new separate commercial sector of renewable energy.

In order to achieve the set goal—to study the validity of state support for wind energy projects in the wholesale market—we have developed five scenarios in this paper: one basic and four that take into account the negative impact of the external environment as well as a gradually decreasing amount of state support. In addition, we have proposed a hypothesis for testing that such support programs might be either inefficient in nature or insufficient in terms of project funding. It was clarified that when studying this issue, one should take into account not only the general dynamics of all projects, but, first of all, the emerging patterns of "behavior" of projects in the most recent years of selection. In this study, wind power projects in 2019 and 2020 became the subjects of our analysis. Analyzing them allowed us to clearly see the current trends in the formation of specific capital costs, depending on the development and implementation of new production technologies, changes in the financial safety margin of such projects, etc.

The empirical part of our paper revealed that the support of wind energy projects through the state CSA RES program can be economically justified even in the case of the negative scenario conditions. Consequently, in the course of our work, only the second part of the hypothesis put forward by the authors has been confirmed, indicating the threats from the lack of funding to renewable energy projects.

Our empirical analysis of Russian wind energy renewable energy projects showed that the projects selected specifically from 2019 and 2020 were characterized by a gradually decreasing level of capital costs and also had a sufficient margin of financial strength. Under the given market conditions (scenarios), this is sufficient not only to cover the cost of specific risks, but also to maintain the level of economic results achieved at the same time.

Our study of the scenarios of the impact of international ratings on the effectiveness of projects has also shown that in the event of a slight fluctuation in the rating relative to the basic conditions, the studied performance indicators do not change significantly. Thus, in the case where the rating was downgraded to "BB", the economic efficiency indicators changed in general logic mainly among the 2018 projects. In the event of a sharp downgrade of the rating to the almost pre-default state of "CC", only 2018 projects moved to the default zone. The projects in 2019 and 2020 continued to yield a positive economic result and confirmed their overall resilience to adverse external changes.

Moreover, at present, the Russian energy market has created such conditions for the implementation of wind energy projects that provide them with the opportunity to achieve a positive economic result faster than the time frame provided by the 15-year CSA RES program, even taking into account the cost of specific risks. Additional calculations provided the following outcomes:

- The classical DPP calculation method estimates the average payback period of projects: 2020—12.2 years, 2019–2020—12.5 years;
- Methodology for calculating DPP taking into account the cost of risks: 2020—13.1 years, 2019–2020—13.5 years.

Our results allow us to clarify the possible directions for the development of state programs to support the wind energy projects which are becoming extremely relevant given the emerging uncertainty of the external environment:

1. Gradual reduction of the terms of providing support for wind projects through CSA RES to 13 years;
2. Gradual reduction in the volume of financial support provided during the 15-year period of the CSA RES program within 10%.

According to our findings, these measures would reduce the economic burden on the main payers of such programs, namely electricity consumers and industrial enterprises as well as public utilities (the general population).

Overall, it becomes clear that one of the key factors that any state authorities and stakeholders need to consider when funding renewable energy projects, either in Russia or in any other country, is the level of risk involved. As with any new technology or industry, there are inherent risks associated with renewable energy projects, including technological, financial, and regulatory risks. Therefore, a comprehensive risk assessment needs to be properly conducted for identifying and quantifying these risks and developing appropriate risk management strategies.

In addition to the risk assessment, the authorities need to justify the economic efficiency of funding renewable energy projects. While renewable energy projects in Russia can be expensive to implement, they also have significant long-term economic benefits. For example, they can reduce dependence on expensive fossil fuels and help to create new jobs in the renewable energy industry. Moreover, as technology becomes more widespread, economies of scale can be achieved, leading to further cost reductions.

Moreover, in order to achieve the economic efficiency of funding renewable energy projects, the stakeholders, both in Russia and worldwide, can use a variety of funding mechanisms. These include direct subsidies, tax incentives, and loan guarantees. Direct subsidies can help reduce the cost of renewable energy projects in the early stages of development, while tax incentives can encourage private investment in the industry. Loan guarantees can provide a lower cost of financing and reduce the risk for investors.

However, the general trend towards a reduction in state support for RES projects, observed in the Russian energy market, makes the use of the project financing tools for the RES sector most attractive, as well as the development of various forms of specific "green" investments (for example, bonds, certificates, etc.). Thus, the construction of solar power plants in the Astrakhan region (southern Russia) is already financed by refinancing loans issued during CSA RES 1.0 through the issue of "green" bonds of project financing and securitization, as recently shown in Chebotareva [81]. At present, similar trends are being observed in the construction of wind farms, in particular those based on EPC contracts. According to quite a number of experts, such specific instruments can not only increase the financial and economic feasibility of renewable energy projects, but also make this sector more attractive to private institutional investors. However, up until now, only a few (predominantly foreign) companies have shown interest in their private investment initiatives within Russian RES projects.

All in all, it can be concluded that the state has an important role to play in funding renewable energy projects, as they are critical for achieving broader environmental goals. A comprehensive risk assessment and justification of the economic efficiency of RE projects are essential for ensuring that public funds are allocated effectively. Furthermore, the use of appropriate funding mechanisms can help to reduce the financial risk associated with RE projects and to promote their widespread adoption.

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Appendix A

Table A1. Economic efficiency of wind energy projects in the basic (zero) scenario.

Project Name	Performance Indicators	DPM RES [1]	Operating Lifetime [2]	Commentary (Comparative DPP) [3]
Experimental WPP-121	NPV, thous. RUB IRR, %	65,136.85 0.80	445,022.18 3.68	Within the measures of CSA RES program
Experimental WPP-127	NPV, thous. RUB IRR, %	49,381.12 0.81	334,913.36 3.69	Within the measures of CSA RES program

Table A1. *Cont.*

Project Name	Performance Indicators	DPM RES [1]	Operating Lifetime [2]	Commentary (Comparative DPP) [3]
Experimental WPP-130	NPV, thous. RUB IRR, %	130,273.71 0.80	890,044.37 3.68	Within the measures of CSA RES program
Experimental WPP-128	NPV, thous. RUB IRR, %	73,453.58 0.80	500,928.13 3.68	Within the measures of CSA RES program
Experimental WPP-125	NPV, thous. RUB IRR, %	65,136.85 0.80	445,022.18 3.68	Within the measures of CSA RES program
Experimental WPP-129	NPV, thous. RUB IRR, %	130,273.71 0.80	890,044.37 3.68	Within the measures of CSA RES program
Experimental WPP-131	NPV, thous. RUB IRR, %	212,631.16 1.41	877,471.91 3.99%	Within the measures of CSA RES program
Stavropol WPP-24	NPV, thous. RUB IRR, %	−362,452.87 −1.48	874,871.84 2.29	Within the planned operating lifetime
WPP WindFarm-35	NPV, thous. RUB IRR, %	−214,645.11 −2.40	75,396.17 0.59	Within the planned operating lifetime
WPP WindFarm-34	NPV, thous. RUB IRR, %	−270,965.87 −2.50	76,969.49 0.50	Within the planned operating lifetime
WPP WindFarm-36	NPV, thous. RUB IRR, %	−227,140.95 −2.52	62,830.83 0.49	Within the planned operating lifetime
WPP WindFarm-31	NPV, thous. RUB IRR, %	−273,814.61 −3.10	−11,770.39 −0.09	Within the planned operating lifetime
WPP WindFarm-32	NPV, thous. RUB IRR, %	−282,034.10 −3.17	−20,035.59 −0.16	No longer profitable
Experimental WPP-67	NPV, thous. RUB IRR, %	−452,384.75 −6.47	−286,261.38 −2.87	No longer profitable at the current conditions
WPP WindFarm-41	NPV, thous. RUB IRR, %	−15,805.35 −0.13	564,411.65 3.00	Slowed down before the planned operating lifetime
WPP WindFarm-42	NPV, thous. RUB IRR, %	−15,805.35 −0.13	564,411.65 3.00	Slowed down before the planned operating lifetime
WPP WindFarm-37	NPV, thous. RUB IRR, %	−105,016.22 −0.85	419,551.26 2,30	Slowed down before the planned operating lifetime
WPP WindFarm-38	NPV, thous. RUB IRR, %	−105,016.22 −0.85	419,551.26 2,30	Slowed down before the planned operating lifetime
WPP WindFarm-48	NPV, thous. RUB IRR, %	−134,337.27 −1.10	371,939.80 2.06	Within the planned operating lifetime
WPP WindFarm-49	NPV, thous. RUB IRR, %	−134,337,27 −1,10	371,939.80 2,06	Within the planned operating lifetime
Experimental WPP-52	NPV, thous. RUB IRR, %	−401,137.64 −4.28	−65,810.70 −0.47	No longer profitable
WPP WindFarm-61	NPV, thous. RUB IRR, %	−428,890.50 −3.85	44,598.82 0.26	Within the planned operating lifetime
WPP WindFarm-59	NPV, thous. RUB IRR, %	−543,854.38 −4.72	−82,189.46 −0.47	No longer profitable
WPP WindFarm-60	NPV, thous. RUB IRR, %	−543,854.38 −4.72	−82,189.46 −0.47	No longer profitable
WPP WindFarm-57	NPV, thous. RUB IRR, %	−543,854.38 −4.72	−82,189.46 −0.47	No longer profitable
WPP WindFarm-58	NPV, thous. RUB IRR, %	−543,854.38 −4.72	−82,189.46 −0.47	No longer profitable
WPP WindFarm-52	NPV, thous. RUB IRR, %	−327,544.80 −2.97	193,079.39 1.13	Within the planned operating lifetime
WPP WindFarm-51	NPV, thous. RUB IRR, %	−343,351.33 −3.09	177,165.03 1.03	Within the planned operating lifetime
WPP WindFarm-71	NPV, thous. RUB IRR, %	−263,267.84 −2.28	330,230.53 1.81	Within the planned operating lifetime

Table A1. *Cont.*

Project Name	Performance Indicators	DPM RES [1]	Operating Lifetime [2]	Commentary (Comparative DPP) [3]
WPP WindFarm-74	NPV, thous. RUB IRR, %	−324,902.06 −2.86	219,992.26 1.24	Within the planned operating lifetime
WPP WindFarm-75	NPV, thous. RUB IRR, %	−466,559.84 −3.85	77,368.06 0.41	Within the planned operating lifetime
WPP WindFarm-78	NPV, thous. RUB IRR, %	−337,926.96 −2.69	307,590.06 1.55	Within the planned operating lifetime
WPP WindFarm-82	NPV, thous. RUB IRR, %	−500,861.94 −2,89	15,975.53 0.97	Within the planned operating lifetime
WPP WindFarm-83	NPV, thous. RUB IRR, %	−552,637.92 −4.50	−36,153.67 −0.19	No longer profitable

[1] Efficiency by the end of the CSA RES support program. [2] Efficiency by the end of the planned life of the WPP. [3] Assessment of the possibility of achieving a positive effect within the established time frame in comparison with the results of the initial assessment in [59].

Table A2. Economic efficiency of wind energy projects in the first scenario.

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
Experimental WPP-121	NPV, thous. RUB IRR, %	−200,098.52 −2.60	185,893.88 1.50	Slowed down before the planned operating lifetime
Experimental WPP-127	NPV, thous. RUB IRR, %	−149,606.96 −2.59	140,509.11 1.51	Slowed down before the planned operating lifetime
Experimental WPP-130	NPV, thous. RUB IRR, %	−400,197.04 −2.60	371,787.76 1.50	Slowed down before the planned operating lifetime
Experimental WPP-128	NPV, thous. RUB IRR, %	−224,936.21 −2.60	209,408.79 1.50	Slowed down before the planned operating lifetime
Experimental WPP-125	NPV, thous. RUB IRR, %	−200,098.52 −2.60	185,893.88 1.50	Slowed down before the planned operating lifetime
Experimental WPP-129	NPV, thous. RUB IRR, %	−400,197.04 −2.60	371,787.76 1.50	Slowed down before the planned operating lifetime
Experimental WPP-131	NPV, thous. RUB IRR, %	−274,752.35 −1.93	400,775.77 1.78	Slowed down before the planned operating lifetime
Stavropol WPP-24	NPV, thous. RUB IRR, %	−1,178,431.31 −5.05	80,605.35 0.20	Sustained within the planned operating lifetime
WPP WindFarm-35	NPV, thous. RUB IRR, %	−491,009.04 −5.81	−193,799.95 −1.47	No longer profitable
WPP WindFarm-34	NPV, thous. RUB IRR, %	−604,061.25 −5.91	−247,438.95 −1.56	No longer profitable
WPP WindFarm-36	NPV, thous. RUB IRR, %	−504,874.10 −5.92	−207,654.17 −1.57	No longer profitable
WPP WindFarm-31	NPV, thous. RUB IRR, %	−550,641.04 −6.62	−281,401.88 −2.19	No longer profitable
WPP WindFarm-32	NPV, thous. RUB IRR, %	−559,761.16 −6.69	−290,514.87 −2.25	No longer profitable
Experimental WPP-67	NPV, thous. RUB IRR, %	−638,372.11 −9.67	−466,098.15 −4.57	Not profitable at the initial conditions
WPP WindFarm-41	NPV, thous. RUB IRR, %	−458,540.04 −3.85	132,214.09 0.68	Slowed down before the planned operating lifetime
WPP WindFarm-42	NPV, thous. RUB IRR, %	−458,540.04 −3.85	132,214.09 0.68	Slowed down before the planned operating lifetime
WPP WindFarm-37	NPV, thous. RUB IRR, %	−547,750.90 −4.71	−12,646.30 −0.07	No longer profitable (previously-within the limits of CSA RES)
WPP WindFarm-38	NPV, thous. RUB IRR, %	−547,750.90 −4.71	−12,646.30 −0.07	No longer profitable (previously-within the limits of CSA RES)

Table A2. *Cont.*

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
WPP WindFarm-48	NPV, thous. RUB IRR, %	−577,071.96 −5.00	−60,257.75 −0.32	No longer profitable
WPP WindFarm-49	NPV, thous. RUB IRR, %	−577,071.96 −5.00	−60,257.75 −0.32	No longer profitable
Experimental WPP-52	NPV, thous. RUB IRR, %	−691,621.83 −7.77	−347,554.44 −2.40	No longer profitable
WPP WindFarm-61	NPV, thous. RUB IRR, %	−841,593.16 −8.03	−356,649.52 −2.02	No longer profitable
WPP WindFarm-59	NPV, thous. RUB IRR, %	−964,548.84 −8.88	−490,710.27 −2.69	No longer profitable
WPP WindFarm-60	NPV, thous. RUB IRR, %	−964,548.84 −8.88	−490,710.27 −2.69	No longer profitable
WPP WindFarm-57	NPV, thous. RUB IRR, %	−964,548.84 −8.88	−490,710.27 −2.69	No longer profitable
WPP WindFarm-58	NPV, thous. RUB IRR, %	−964,548.84 −8.88	−490,710.27 −2.69	No longer profitable
WPP WindFarm-52	NPV, thous. RUB IRR, %	−728,130.61 −6.98	−196,459.64 −1.11	No longer profitable
WPP WindFarm-51	NPV, thous. RUB IRR, %	−746,161.57 −7.10	−214,473.78 −1.20	No longer profitable
WPP WindFarm-71	NPV, thous. RUB IRR, %	−674,030.50 −6.14	−69,186.53 −0.37	No longer profitable
WPP WindFarm-74	NPV, thous. RUB IRR, %	−735,677.69 −6.84	−179,437.04 −0.98	No longer profitable
WPP WindFarm-75	NPV, thous. RUB IRR, %	−897,270.83 −7.82	−340,879.42 −1.74	No longer profitable
WPP WindFarm-78	NPV, thous. RUB IRR, %	−768,637.95 −6.43	−110,657.42 −0.54	No longer profitable
WPP WindFarm-82	NPV, thous. RUB IRR, %	−931,572.94 −8.21	−402,271.95 −2.09	No longer profitable
WPP WindFarm-83	NPV, thous. RUB IRR, %	−990,635.29 −8.54	−461,279.21 −2.35	No longer profitable

Table A3. Economic efficiency of wind energy projects in the second scenario.

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
Experimental WPP-121	NPV, thous. RUB IRR, %	15,464.65 0.19	395,563.03 3.27	Within the measures of CSA RES program
Experimental WPP-127	NPV, thous. RUB IRR, %	12,115.17 0.20	297,807.34 3.28	Within the measures of CSA RES program
Experimental WPP-130	NPV, thous. RUB IRR, %	30,929.30 0.19	791,126.07 3.27	Within the measures of CSA RES program
Experimental WPP-128	NPV, thous. RUB IRR, %	17,572.35 0.19	445,286.59 3.27	Within the measures of CSA RES program
Experimental WPP-125	NPV, thous. RUB IRR, %	15,464.65 0.19	395,563.03 3.27	Within the measures of CSA RES program
Experimental WPP-129	NPV, thous. RUB IRR, %	30,929.30 0.19	791,126.07 3.27	Within the measures of CSA RES program
Experimental WPP-131	NPV, thous. RUB IRR, %	123,643.96 0.83	788,857.56 3.58	Within the measures of CSA RES program
Stavropol WPP-24	NPV, thous. RUB IRR, %	−520,520.56 −2.14	717,561.62 1.87	Sustained within the planned operating lifetime
WPP WindFarm-35	NPV, thous. RUB IRR, %	−264,693.86 −3.00	25,597.48 0.20	Sustained within the planned operating lifetime

Table A3. *Cont.*

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
WPP WindFarm-34	NPV, thous. RUB IRR, %	−331,304.92 −3.10	16,933.49 0.11	Sustained within the planned operating lifetime
WPP WindFarm-36	NPV, thous. RUB IRR, %	−277,453.06 −3.12	12,771.59 0.10	Sustained within the planned operating lifetime
WPP WindFarm-31	NPV, thous. RUB IRR, %	−323,952.32 −3,72	−61,657.09 −0.49	No longer profitable
WPP WindFarm-32	NPV, thous. RUB IRR, %	−332,345.04 −3.79	−70,093.67 −0.56	No longer profitable
Experimental WPP-67	NPV, thous. RUB IRR, %	−486,522.20 −7.05	−320,184.25 −3.21	Not profitable at the initial conditions
WPP WindFarm-41	NPV, thous. RUB IRR, %	−99,470.93 −0.80	481,113.67 2,.55	Slowed down before the planned operating lifetime
WPP WindFarm-42	NPV, thous. RUB IRR, %	−99,470.93 −0.80	481,113.67 2.55	Slowed down before the planned operating lifetime
WPP WindFarm-37	NPV, thous. RUB IRR, %	−188,681.80 −1.55	336,253.28 1.84	Slowed down before the planned operating lifetime
WPP WindFarm-38	NPV, thous. RUB IRR, %	−188,681.80 −1.55	336,253.28 1.84	Slowed down before the planned operating lifetime
WPP WindFarm-48	NPV, thous. RUB IRR, %	−218,002.86 −1.80	288,641.83 1.59	Sustained within the planned operating lifetime
WPP WindFarm-49	NPV, thous. RUB IRR, %	−218,002.86 −1.80	288,641.83 1.59	Sustained within the planned operating lifetime
Experimental WPP-52	NPV, thous. RUB IRR, %	−456,143.58 −4.93	−120,511.72 −0.86	No longer profitable
WPP WindFarm-61	NPV, thous. RUB IRR, %	−509,306.00 −4.64	−35,417.06 −0.21	No longer profitable
WPP WindFarm-59	NPV, thous. RUB IRR, %	−625,753.64 −5.50	−163,664.02 −0.93	No longer profitable
WPP WindFarm-60	NPV, thous. RUB IRR, %	−625,753.64 −5.50	−163,664.02 −0.93	No longer profitable
WPP WindFarm-57	NPV, thous. RUB IRR, %	−625,753.64 −5.50	−163,664.02 −0.93	No longer profitable
WPP WindFarm-58	NPV, thous. RUB IRR, %	−625,753.64 −5.50	−163,664.02 −0.93	No longer profitable
WPP WindFarm-52	NPV, thous. RUB IRR, %	−405,609.84 −3.73	115,399.74 0.67	Sustained within the planned operating lifetime
WPP WindFarm-51	NPV, thous. RUB IRR, %	−421,840.51 −3.84	99,065.58 0.57	Sustained within the planned operating lifetime
WPP WindFarm-71	NPV, thous. RUB IRR, %	−343,313.43 −3.00	250,580.75 1.37	Sustained within the planned operating lifetime
WPP WindFarm-74	NPV, thous. RUB IRR, %	−404,950.12 −3.61	140,340.03 0.79	Sustained within the planned operating lifetime
WPP WindFarm-75	NPV, thous. RUB IRR, %	−550,409.08 −4.60	−6046.36 −0.03	No longer profitable
WPP WindFarm-78	NPV, thous. RUB IRR, %	−421,776.20 −3.40	224,175.63 1.12	Sustained within the planned operating lifetime
WPP WindFarm-82	NPV, thous. RUB IRR, %	−584,711.18 −4.93	−67,438.89 −0.36	Sustained within the planned operating lifetime
WPP WindFarm-83	NPV, thous. RUB IRR, %	−637,876.49 −5.26	−120,943.18 −0.64	Sustained within the planned operating lifetime

Table A4. Economic efficiency of wind energy projects in the third scenario.

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
Experimental WPP-121	NPV, thous. RUB IRR, %	30,041.32 0.37	409,926.66 3.38	Within the measures of CSA RES program
Experimental WPP-127	NPV, thous. RUB IRR, %	23,048.73 0.38	308,580.98 3.38	Within the measures of CSA RES program
Experimental WPP-130	NPV, thous. RUB IRR, %	60,082.65 0.37	819,853.32 3.38	Within the measures of CSA RES program
Experimental WPP-128	NPV, thous. RUB IRR, %	33,971.12 0.37	461,445.66 3.38	Within the measures of CSA RES program
Experimental WPP-125	NPV, thous. RUB IRR, %	30,041.32 0.37	409,926.66 3.38	Within the measures of CSA RES program
Experimental WPP-129	NPV, thous. RUB IRR, %	60,082.65 0.37	819,853.32 3.38	Within the measures of CSA RES program
Experimental WPP-131	NPV, thous. RUB IRR, %	148,417.45 0.99	813,258.20 3.68	Within the measures of CSA RES program
Stavropol WPP-24	NPV, thous. RUB IRR, %	−473,427.16 −1.93	763,897.56 1.99	Sustained within the planned operating lifetime
WPP WindFarm-35	NPV, thous. RUB IRR, %	−252,540.89 −2.83	37,500.38 0.29	Sustained within the planned operating lifetime
WPP WindFarm-34	NPV, thous. RUB IRR, %	−316,697.70 −2.94	31,237.65 0.20	Sustained within the planned operating lifetime
WPP WindFarm-36	NPV, thous. RUB IRR, %	−265,277.88 −2.95	24,693.90 0.19	Sustained within the planned operating lifetime
WPP WindFarm-31	NPV, thous. RUB IRR, %	−311,791.85 −3.54	−49,747.63 −0.39	Sustained within the planned operating lifetime
WPP WindFarm-32	NPV, thous. RUB IRR, %	−320,169.96 −3.62	−58,171.45 −0.46	No longer profitable
Experimental WPP-67	NPV, thous. RUB IRR, %	−479,468.43 −6.89	−313,345.06 −3.13	Not profitable at the initial conditions
WPP WindFarm-41	NPV, thous. RUB IRR, %	−74,709.48 −0.60	505,507.52 2.67	Slowed down before the planned operating lifetime
WPP WindFarm-42	NPV, thous. RUB IRR, %	−74,709.48 −0.60	505,507.52 2.67	Slowed down before the planned operating lifetime
WPP WindFarm-37	NPV, thous. RUB IRR, %	−163,920.35 −1.33	360,647.13 1.96	Slowed down before the planned operating lifetime
WPP WindFarm-38	NPV, thous. RUB IRR, %	−163,920.35 −1.33	360,647.13 1.96	Sustained within the planned operating lifetime
WPP WindFarm-48	NPV, thous. RUB IRR, %	−193,241.40 −1.58	313,035.67 1.72	Sustained within the planned operating lifetime
WPP WindFarm-49	NPV, thous. RUB IRR, %	−193,241.40 −1.58	313,035.67 1.72	Sustained within the planned operating lifetime
Experimental WPP-52	NPV, thous. RUB IRR, %	−442,056.88 −4.73	−10,6729.94 −0.76	No longer profitable
WPP WindFarm-61	NPV, thous. RUB IRR, %	−485,546.94 −4.37	−12,057.60 −0.07	Sustained within the planned operating lifetime
WPP WindFarm-59	NPV, thous. RUB IRR, %	−602,239.73 −5.23	−140,574.81 −0.79	No longer profitable
WPP WindFarm-60	NPV, thous. RUB IRR, %	−602,239.73 −5.23	−140,574.81 −0.79	No longer profitable
WPP WindFarm-57	NPV, thous. RUB IRR, %	−602,239.73 −5.23	−140,574.81 −0.79	No longer profitable
WPP WindFarm-58	NPV, thous. RUB IRR, %	−602,239.73 −5.23	−140,574.81 −0.79	No longer profitable
WPP WindFarm-52	NPV, thous. RUB IRR, %	−382,447.34 −3.48	138,176.86 0.80	Sustained within the planned operating lifetime

Table A4. *Cont.*

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
WPP WindFarm-51	NPV, thous. RUB IRR, %	−398,639.14 −3.60	121,877.22 0.70	Sustained within the planned operating lifetime
WPP WindFarm-71	NPV, thous. RUB IRR, %	−319,588.27 −2.77	273,910.10 1.49	Sustained within the planned operating lifetime
WPP WindFarm-74	NPV, thous. RUB IRR, %	−381,224.73 −3.36	163,669.58 0.92	Sustained within the planned operating lifetime
WPP WindFarm-75	NPV, thous. RUB IRR, %	−526,335.32 −4.35	17,592.58 0.09	Sustained within the planned operating lifetime
WPP WindFarm-78	NPV, thous. RUB IRR, %	−397,702.43 −3,.17	247,814.59 1.24	Sustained within the planned operating lifetime
WPP WindFarm-82	NPV, thous. RUB IRR, %	−560,637.42 −4.68	−43,799.94 −0.23	No longer profitable
WPP WindFarm-83	NPV, thous. RUB IRR, %	−613,675.40 −5.01	−97,191.14 −0.51	No longer profitable

Table A5. Economic efficiency of wind energy projects in the fourth scenario.

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
Experimental WPP-121	NPV, thous. RUB IRR, %	−5054.19 −0.0	374,831.13 3.07	Slowed down before the planned operating lifetime
Experimental WPP-127	NPV, thous. RUB IRR, %	−3283.65 −0.05	282,248.59 3.08	Slowed down before the planned operating lifetime
Experimental WPP-130	NPV, thous. RUB IRR, %	−10,108.39 −0.06	749,662.26 3.07	Slowed down before the planned operating lifetime
Experimental WPP-128	NPV, thous. RUB IRR, %	−5511.34 −0.06	421,963.19 3.07	Slowed down before the planned operating lifetime
Experimental WPP-125	NPV, thous. RUB IRR, %	−5054.19 −0.06	374,831.13 3.07	Slowed down before the planned operating lifetime
Experimental WPP-129	NPV, thous. RUB IRR, %	−10,108.39 −0.06	749,662.26 3.07	Slowed down before the planned operating lifetime
Experimental WPP-131	NPV, thous. RUB IRR, %	84,203.75 0.56	749,044.50 3.38	Within the measures of CSA RES program
Stavropol WPP-24	NPV, thous. RUB IRR, %	−584,401.45 −2.39	652,923.27 1.69	Sustained within the planned operating lifetime
WPP WindFarm-35	NPV, thous. RUB IRR, %	−290,436.68 −3.27	−395.39 0.00	No longer profitable
WPP WindFarm-34	NPV, thous. RUB IRR, %	−362,429.54 −3.38	−14,494.18 −0.09	No longer profitable
WPP WindFarm-36	NPV, thous. RUB IRR, %	−303,414.81 −3.39	−13,443.01 −0.10	No longer profitable
WPP WindFarm-31	NPV, thous. RUB IRR, %	−349,769.09 −3.99	−87,724.87 −0.69	No longer profitable
WPP WindFarm-32	NPV, thous. RUB IRR, %	−358,305.81 −4.07	−96,307.30 −0.76	No longer profitable
Experimental WPP-67	NPV, thous. RUB IRR, %	−506,552.11 −7.31	−340,428.74 −3.39	Not profitable at the initial conditions
WPP WindFarm-41	NPV, thous. RUB IRR, %	−133,613.62 −1.07	446,603.39 2.35	Sustained within the planned operating lifetime
WPP WindFarm-42	NPV, thous. RUB IRR, %	−133,613.62 −1.07	446,603.39 2.35	Sustained within the planned operating lifetime
WPP WindFarm-37	NPV, thous. RUB IRR, %	−222,824.48 −1.82	301,743.00 1.63	Sustained within the planned operating lifetime
WPP WindFarm-38	NPV, thous. RUB IRR, %	−222,824.48 −1.82	301,743.00 1.63	Sustained within the planned operating lifetime

Table A5. *Cont.*

Project Name	Performance Indicators	DPM RES	Operating Lifetime	Commentary (Comparative DPP)
WPP WindFarm-48	NPV, thous. RUB IRR, %	−252,145.54 −2.07	254,131.54 1.39	Sustained within the planned operating lifetime
WPP WindFarm-49	NPV, thous. RUB IRR, %	−252,145.54 −2.07	254,131.54 1.39	Sustained within the planned operating lifetime
Experimental WPP-52	NPV, thous. RUB IRR, %	−482,976.12 −5.18	−147,649.18 −1.04	No longer profitable
WPP WindFarm-61	NPV, thous. RUB IRR, %	−542,203.37 −4.90	−68,714.04 −0.40	No longer profitable
WPP WindFarm-59	NPV, thous. RUB IRR, %	−660,625.08 −5.76	−198,960.16 −1.11	No longer profitable
WPP WindFarm-60	NPV, thous. RUB IRR, %	−660,625.08 −5.76	−198,960.16 −1.11	No longer profitable
WPP WindFarm-57	NPV, thous. RUB IRR, %	−660,625.08 −5.76	−198,960.16 −1.11	No longer profitable
WPP WindFarm-58	NPV, thous. RUB IRR, %	−660,625.08 −5.76	−198,960.16 −1.11	No longer profitable
WPP WindFarm-52	NPV, thous. RUB IRR, %	−437,349.87 −3.98	83,274.33 0.48	Sustained within the planned operating lifetime
WPP WindFarm-51	NPV, thous. RUB IRR, %	−453,926.94 −4.10	66,589.42 0.38	Sustained within the planned operating lifetime
WPP WindFarm-71	NPV, thous. RUB IRR, %	−375,908.70 −3.26	217,589.67 1.18	Sustained within the planned operating lifetime
WPP WindFarm-74	NPV, thous. RUB IRR, %	−437,547.41 −3.87	107,346.91 0.60	Sustained within the planned operating lifetime
WPP WindFarm-75	NPV, thous. RUB IRR, %	−586,110.79 −4.86	−42,182.88 −0.22	No longer profitable
WPP WindFarm-78	NPV, thous. RUB IRR, %	−457,477.91 −3.66	188,039.11 0.93	Sustained within the planned operating lifetime
WPP WindFarm-82	NPV, thous. RUB IRR, %	−620,412.89 −5.19	−103,575.41 −0.55	No longer profitable
WPP WindFarm-83	NPV, thous. RUB IRR, %	−674,712.87 −5.52	−158,228.62 −0.82	No longer profitable

Source: own results.

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