Assessment of development effectiveness of solar energy in Russia

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Abstract. Non-renewable fossils are the main source of energy in modern conditions. This method of production and consumption of energy acts as one of the main anthropogenic factors that negatively impact the environment. Besides, limited energy reserves do not guarantee the sustainable development of world energy in the long term. The way out of this situation is using renewable energy sources (RES). Renewable energy sources are one of the promising and innovative areas of energy development. These energy sources allow moving to a new high-quality level of power supply and heat supply of the country and significantly improving the ecological state of settlements. The Russian Federation has all conditions for the implementation of such innovative projects aimed at using renewable energy sources. One of such promising projects is solar energy. The perspective of using solar energy is an almost inexhaustible resource, available everywhere, and also has another advantage - high environmental safety. Besides, solar energy is characterized by low indicators in terms of capital and operating costs, a lower cost of electricity compared to traditional energy as well. In this study, the perspectives for the development of solar energy in the Russian Federation are identified. The existing solar capacities in Russia are analyzed, the main developments of solar energy in the country are determined. A model for assessing the economic efficiency of floating power plants is proposed in this paper. These plants make it possible to provide electricity to entire settlements. Having been the study, conclusions are drawn about the prospects of using such power plants as sources of cheap energy and environmental compatibility.

Keywords: natural resource management, renewable energy, solar energy, sustainable development, environment, financial analysis, floating power plants, modeling, investment

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1 Introduction

The 2004 study of the International Energy Agency showed that the most promising direction for the Russian Federation could be considered the development of the grid RES market, as well as off-grid electricity supplies based on such sources of electricity. The areas' development in the electric power industry as geothermal energy, wind energy, biomass and energy of small hydropower plants has shown its perspectives in the countries of the Organization for Economic Cooperation and Development (OECD). This was facilitated by a significant reduction in the cost of electricity, which became possible as a result of the implementation of major projects in this area, the introduction of more efficient production methods, and technological improvements. Autonomous power supply based on renewable energy sources is extremely beneficial, because electricity suppliers decrease their costs due to the lack of power lines, which are not needed in this case. It should be noted that a significant number of the population lives in remote and hard-to-reach areas in the Russian Federation. This prevents them from using conventional sources of electricity. [1-3] Autonomous systems using traditional fuels are quite costly due to the high cost of both the fuel and its delivery. Therefore, renewable energy sources are the way out under these conditions.

2 Materials and methods

In this study, the method of investment assessment was applied. It is considered in the form of a dynamic process that takes place in time and subject sections. In the first section, tasks that provide the life cycle of innovative projects are examined. In the second one, solutions are directed to the investment sector securing funding for projects in different aspects are developed. These aspects primarily involve the technical base of the investment project, its social significance, and financial viability of the project, its environmental safety, organization of project management, and the sufficiency of performance indicators as well. On the basis of the proposed method, an investment project was assessed to create floating power plants in the Russian Federation. [1-2, 4-5]

3 Results and discussion

Production of electricity from renewable sources in Russia is only 0.2% and includes the following power: geothermal, wind, solar, micro hydro, tidal, biofuel. [6]

There are 7 large solar power plants (SPP) in the Russian Federation (Fig. 1):

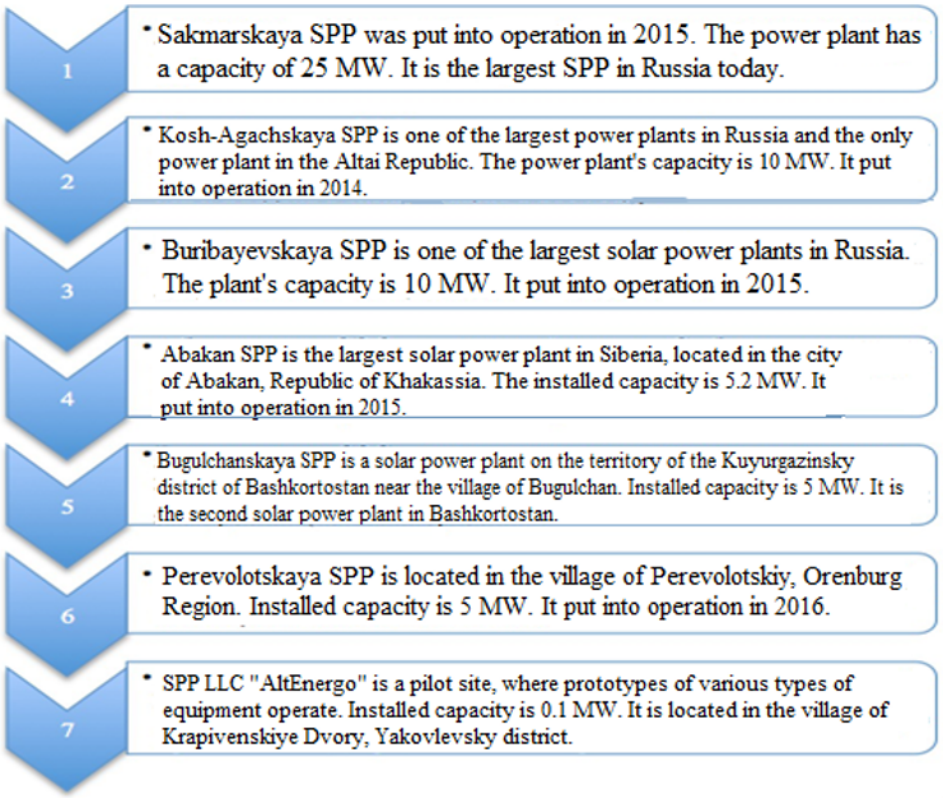

Figure 1. The largest solar power plants in Russia

The construction of solar power plants has led to a significant increase in installed capacity in the Russian Federation (Table 1).

Table 1. Growth rates of installed SPP capacities in Russia from 2014 to 2019

Year	Installed capacity by the end of the year, MW	Capacity growth compared to the previous year, MW	Growth rate compared to the previous year, %
2014	295	-	-
2015	300	5	1,7
2016	320	20	6,7
2017	360	40	12,5
2018	529	169	46,9
2019	829	300	56,7

Solar power plants in Russia have actively been constructed for the last two years. [7] Despite the increase in the capacity of solar power plants in Russia, their share in the total volume of consumed electricity is very small, which indicates the need for further development of this area. One of the innovative projects in this area is the construction of floating solar power plants.

Floating solar power plants (FSPPs) becomes more and more popular due to their unique design and the lack of the need to allocate a plot of land for their placement. [8] Besides, such stations slow down the evaporation of water, which scientists consider an advantage for the environment. And the low temperature near the surface of the sea or

ocean effectively cools the photovoltaic panels and reduces the risk of their failure. The initial data, which are given in Table 2, were used to evaluate the efficiency of investments in the construction of FSPP.

Table 2 Initial data

	Measurement units	Value
Year of construction start	year	2019
Investment period	years	25
Installed power (N_y)	MW	8
Total investment	thousand roubles	722 110
The cost of 1 kW·h electricity consumption	roubles	1
Discount rates	%	6
		8
		10
		12

The economic effect of building a floating solar power plant will be to generate "cheap" electricity. [9-11]

According to the FSPP project, its capacity will be 8 MW. According to experts, the cost of 1 kW·h of electricity from PSE is 1 ruble, and the amount of depreciation per unit of production is 0.8 rubles.

As can be seen from Table 2, the estimation is made according to four discount rates: 6%, 8%, 10%, 12%. [12]

Further, one needs to evaluate the main indicators of the efficiency of the investment project (net present value, payback period, profitability index, and internal rate of return).

The calculation results are shown in Table 3. [13-16] When calculating, an annual growth of profit is taken in the amount of 7% due to an increase in energy prices.

Table 3 Net present value, thousand rubles

Years of the investment project	Investments	Net profit from project implementation	Cash flow	Discount rate (at a discount of 6%)	Discounted cash flow	Cumulative discounted cash flow
1	2	3	4	5	6	7
2019	722110	29580	-692530	1	-692530	
2020		31650,6	31650,6	0,943	29847	-662683
2021		33866	33866,1	0,89	30141	-632543
2022		36237	36236,8	0,84	30439	-602104
2023		38773	38773,3	0,792	30708	-571395
2024		41487	41487,5	0,705	29249	-542147
2025		44392	44391,6	0,665	29520	-512626
2026		47499	47499	0,642	30494	-482132
2027		50824	50823,9	0,592	30088	-452044
2028		54382	54381,6	0,558	30345	-421699
2029		58188	58188,3	0,527	30665	-391034
2030		62262	62261,5	0,497	30944	-360090
2031		66620	66619,8	0,469	31245	-328845
2032		71283	71283,2	0,442	31507	-297338
2033		76273	76273	0,417	31806	-265532
2034		81612	81612,2	0,394	32155	-233377
2035		87325	87325	0,372	32485	-200892
2036		93438	93437,8	0,361	33731	-167161
2037		99978	99978,4	0,35	34992	-132169

2038		106977	106977	0,33	35302	-96866
2039		114465	114465	0,312	35713	-61153
2040		122478	122478	0,299	36621	-24532
2041		131051	131051	0,284	37219	12686
2042		140225	140225	0,275	38562	51248
2043		150041	150041	0,266	39911	91159

Net present value becomes positive starting in 2041. Thus, the investment is suggested to be profitable. The total net present value for the entire period would amount to 91,159 thousand rubles.

Net discounted income was estimated similarly at various discount rates (Table 4).

Table 4. Net present value for various discount rates, thousand rubles

Years of the investment project	Cash flow	Discount rate (8%)	Discounted cash flow	Discount rate (10%)	Discounted cash flow	Discount rate (12%)	Discounted cash flow
1	2	3	4	5	6	7	8
2019	-692530	1	-692530	1	-692530	1	-692530
2020	31650,6	0,926	29308	0,909	28770	0,893	28264
2021	33866,1	0,858	29057	0,751	25433	0,797	26991
2022	36236,8	0,794	28772	0,683	24750	0,712	25801
2023	38773,3	0,735	28498	0,621	24078	0,6355	24640
2024	41487,5	0,681	28253	0,564	23399	0,567	23523
2025	44391,6	0,663	29432	0,318	14117	0,5066	22489
2026	47499	0,583	27692	0,1797	8536	0,453	21517
2027	50823,9	0,54	27445	0,424	21549	0,404	20533
2028	54381,6	0,5	27191	0,3855	20964	0,361	19632
2029	58188,3	0,463	26941	0,35	20376	0,322	18737
2030	62261,5	0,429	26710	0,319	19861	0,287	17869
2031	66619,8	0,397	26448	0,29	19320	0,257	17121
2032	71283,2	0,368	26232	0,263	18747	0,229	16324
2033	76273	0,34	25933	0,239	18229	0,205	15636
2034	81612,2	0,315	25708	0,2176	17759	0,183	14935
2035	87325	0,292	25499	0,198	17290	0,163	14234
2036	93437,8	0,27	25228	0,18	16819	0,146	13642
2037	99978,4	0,25	24995	0,1635	16346	0,13	12997
2038	106977	0,232	24819	0,149	15940	0,116	12409
2039	114465	0,215	24610	0,135	15453	0,104	11904
2040	122478	0,198	24251	0,1286	15751	0,09	11023
2041	131051	0,184	24113	0,112	14678	0,083	10877
2042	140225	0,17	23838	0,109	15285	0,074	10377
2043	150041	0,158	23706	0,1015	15229	0,066	9903
Total			-57850		-243861		-271152

Since the net discounted flow is positive at the rate of 6%, the payback period of the project can be determined only at this rate:

$T_{pb} = 22 – ((-24532) / (37219+24532)) = 22,8$ years

According to calculations, the sum of discounted cash flow elements changes sign from negative to positive between 22 and 23 years of the investment period. The resulting payback period is 22.8 years.

Then, one needs to determine the internal rate of return:

IRR = 6 + ((91159 * (8-6)) / (91159+57850)) = 6,2%

The IRR indicator showed that the total discounted cash flow became negative at a discount rate of 6.2%.

Since the net present value is negative when the discount rate is above 6%, the rest of the indicators (payback period, internal rate of return) cannot be calculated.

Project performance indicators are summarized in Table 5.

Table 5 Investment project's performance indicators for the construction and operation of a floating solar power plant

	Measurement units	Discount rate, %			
		6	8	10	12
Net present value	Thousand rubles	91159	-57850	-243861	-271152
Payback period	years	22,8			
Internal rate of return	%	6,2			
Profitability index	The proportion of units	1,13	0,92	0,59	0,62

The discount rate of 6% was taken as the base one. In this case, the net discounted income will be 91,159 thousand rubles. The project will pay off in 22.8 years. A further increase in the discount rate will lead to negative net discounted income; the payback period, in this case, is longer than the project implementation period (25 years). The internal discount rate cannot be calculated, since it is higher than the pledged discount (8, 10, and 12%, respectively).

4 Conclusion

Having analyzed data, the following conclusions can be drawn:

- the development of the electric power industry based on renewable energy sources in the Russian Federation is at an extremely low level, the entire volume of generated electricity is only about 0.2% of the total volume, while the global average is about 8%;
- further development of energy using alternative sources should be based on innovative ways of developing such facilities. One of such areas is the creation of floating power plants, which can significantly reduce not only the cost of electricity but also ensure environmental safety;
- the modeling has shown that using floating power plants is one of the promising areas for the development of alternative electric power, due to the cost reduction of generated electricity. Investment projects in this area are profitable that allow using the possibilities of attracting not only public investments but also private financing, i.e. applying all the possibilities of the public-private partnership mechanism.

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