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Assessment of the wind power plants role in CO_2 emissions reducing and energy supply in the regions of Russia

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The article contains an analysis of the share of mayor wind power plants in regional energy mixes and evaluation of their contribution to CO_2 emission reducing, basing on the data for wind capacities construction and launch. The estimations showed that wind plants in Republic of Kalmykia could cover more than 94% of industrial and household electricity demand. Forecast evaluations for the wind plants planned to be put into operation until 2024 demonstrate a high wind potential for satisfaction of energy demand in Republics of Kalmykia and Adygeya as well as in Ulyanovsk and Astrakhan regions. The decrease in CO_2 emissions in the regions of Russia was estimated by 2024 due to the absence of emissions at wind farms in the amount of 4.5 million tons per year.

Keywords: renewable energy sources, wind energy, CO_2 emission, electricity consumption, power supply, wind power plants, capacity factor.

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1 Introduction

The tasks of renewable energy development, Russia faced in connection with global energy transit and decarbonization trends, have actively been solved over recent years. The Energy Strategy of Russian Federation up to 2035 points on necessity of increasing the share of renewable energy sources in the country's energy supply [*Energy Strategy of Russian Federation up to 2035*, 2020].

By the present time, Russia has created fully featured wind power industry with localization of 65% and rushing wind power capacities [*Review of Russian Wind Energy Market for 2020*, 2021] that goes in line with the point "29 b)" of the Doctrine of Energy Security of Russian Federation [*The Doctrine of Energy Security of Russian Federation*, 2019]. The previous researchers outlined different scenarios of future of Russia's renewable energy sector, in particular [*Proskuryakova and Ermolenko*, 2019; *Kudel and Kutcherov*, 2021]. Nowadays reality match to the greater extent the better of them, such as "new energy paradigm" [*Proskuryakova and Ermolenko*, 2019], "the slow expansion of renewable energy in Russia" [*Lanshina et al.*, 2018] has accelerated together with steadily growing investments into Russian wind power industry [*Ermolenko et al.*, 2017].

By the end of August 2021, total capacity of the network wind power plants (WPP) had reached as much as 1600 MW, besides a number of the projects at the final stages [*NP-SR*, 2021; *Overview of the Russian Wind Energy Market and Ranking of Russian Regions for 2020*, 2021]. The growth of wind electricity production in 2020 was 331% comparatively with the previous year [*Ministry of Energy*, 2021].

The aim of this work is an analysis of opportunities and prospects of renewable energy for region energy supply and decrease of carbon dioxide emission through replace of the fuel power plants by renewable capacities in Russia.

2 Object of study and methods

As a row of major WPP has been built for the last year, electricity production and capacity factors of these plants are being analyzed. There is a task to assess the probable level of energy demand coverage by wind energy both now and for the future – up to 2024, on the base of this analysis. The study

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used statistical techniques, forecast-and-analytical methods together with economy-geographical approach and expert evaluations.

The bases for the assessments were the information resources of energy producing companies, System operator of the United energy system (SO UES) of Russia, and statistical data of Russian bureau of statistics (Rosstat) and Non-commercial Partnership "Market Council" (NP "Sovetrynka").

3 Results and discussion

Operational commissioning of large WPP in Russia began at the end of 2017 in Ulyanovsk Region. The most active construction of WPP has been in the Southern regions of Russia such as Rostov Region, Stavropol Territory, Republics of Adygeya and Kalmykia. All the plants were commissioned for less a year and a half during the very difficult coronavirus epidemic period of 2020 – beginning 2021.

The growth of wind electricity production in Russia has been supplied by commissioning the WPP with total capacity of 85 MW in 2017–2018 (Ulyanovsk region), 843.8 MW in 2020, and 470 MW in eight months of 2021. The total capacity of WPP that had been built according to the DPM-1 program (capacity sourcing agreement) by 01.09.2021 were 1398.8 MW.

For the all of these WPP we evaluated their imputed average annual electricity generation, their role in the regional energy balances, and decrease of CO_2 emissions ("non-emissions") due to commissioning the environmentally clear plants instead of fuel capacities.

Besides these WPP, there are 21 plants in Russia, that were built without governmental support, with total capacity of 105.76 MW, including seven plants with total capacity of 83.8 MW in Republic of Crimea. They have much lesser capacity factor, and we leaved them out of our calculations.

The analysis of data from SO UES of Russia showed that in 2020 all the network power plants within UES produced 1,047,029.9 million kWh (decrease by 3.1% comparatively with 2019). Therefore, considerable growth of electricity production in 2020 occurred only in renewable sector and, first – in wind power segment (Table 1).

Basing on the data on wind electricity production in 2020 (1384.1 million kWh) and also nominal production of all WPP in Ulyanovsk region, Rostov region, and Republic of Kalmykia that were commissioned in 2017–2020 (that totaled 4839.5 million kWh according to our calculations), we assessed the levelized capacity factor for the WPP in 2020, that amounted to 28.6%.

For the WPP in Stavropol Territory and Republic of Adygeya (Kochubeevskaya, Karmalinskaya, and Adygeyskaya) we used the design data from the official site of Nova Wind company [*Nova Wind*, 2021]. Average annual capacity factor ranges from 32.45% at the Kochubeevskaya WWP to 26.93% at the Adygeiskaya WWP.

To estimate the share of electricity consumption coverage we compare wind electricity production in a region with energy consumption of a region according to Rosstat data [*Rosstat*, 2021]. The assessments of potential decrease of greenhouse gas emission were made basing on an assumption that average emission caused by electricity production in Russia is some 500 g of CO_2 per 1 kWh [*Gimadi et al.*, 2019].

As we can see from Table 2, in Republik of Kalmykia wind energy already covers more than 94% of electricity consumption, in Republik of Adygeya – some 25%. The leader of total wind power capacities is Rostov Region with 556.8 MW. Wind energy already supplies 7.2% of both industrial and household consumption in this large region. In the Stavropol Territory, the installed capacities of wind power plants allow generating up to 10% of electricity consumption.

Source: completed by the authors based on [*NP-SR*, 2021; *Ministry of Energy*, 2021; *Nova Wind*, 2021; *Rosstat*, 2021]

In 2013–2020 there were competitive tenders of WPP projects for Russian regions up to 2024, according to the policy of renewable energy support on the base of Capacity Sourcing Agreements.

By 2024 there has been planned (including the previous competitive tenders for WPP constracting) as much as 3569.11 MW in 13 regions of Russia. Assessments of electricity production assuming the same capacity factor for Russian wind plants, equal 28.6%, as well as the same decrease of CO_2 emission, are presented in Table 3.

Besides that, we worked out forecasting assessments of a probable share of industrial and household consumption coverage by wind energy for the regions up to 2024, assuming that total energy consumption keeps at the same level.

The assessments showed that total decrease of carbon dioxide emission due to replacing fossil fuel by wind energy would amount to some 4.5 million tons of CO_2. The share of wind in energy balances will be the largest in Republics of Kalmykia and Adygeya – some 99% and 44%, respectively. It would also be significant – more than 10%, in Ulyanovsk Region, Astrakhan Region, and Krasnodar Territory.

4 Conclusion

Assessments of wind energy role in energy supply of the Russian regions showed that it has already took its considerable place. The annual decrease of CO_2 emission due to non-emission at

Table 1: Electricity generation by power plants of various types in the Russian Federation in 2019–2020 [Uni, 2020]

Generation station type	Electricity generation, million kWh per year		Energy production change in 2020, as % of 2019
	2019	2020	
Thermal power plants	679,881.0	620,565.1	−8.7
Hydroelectric power stations	190,295.4	207,416.3	+9.0
Nuclear plants	208,773.3	215,682.1	+3.3
Wind power plants	320.8	1384.1	+331.5
Solar power plants	1,284.9	1982.3	+54.3
Total	1,080,555.4	1,047,029.9	

Table 2: Assessments of electricity production and potential decrease of CO_2 emission on the operating WPP in the subjects of Russian Federation (as on 1.09.2021)

RF subjects, WPPs	Commissioning date	Capacity, MW	Average annual production, million kWh	Electricity consumption in the region in 2019, million kWh	Share of wind in energy mix	Annual decrease of CO_2 emission, thousand tons
Ulyanovsk Region, total		85.4	214.0	5581.8		107.1
WPP - 1	28.12.17	35.0	87.7			43.9
WPP - 2	28.12.18	50.4	126.3			63.2
RostovRegion, total		556.8	139.0	19324.1	7.2%	696.7
Sulinskaya	28.02.20	98.8	247.5			123.8
Kamenskaya	28.04.20	98.8	247.5			123.8
Gukovskaya	25.05.20	98.8	247.5			123.8
Kazachya	23.11.20	50.4	126.3			75.1
Azovskaya	29.04.21	90.0	225.5			112.1
Marchenkowskaya NovaWind	28.06.21	120.0	300.7			149.5
Republic of Kalmykia, total		216.6	542.5	573.2	94.6%	271.3
Yustinskaya	29.10.20	15.0	37.5			18.9
Salynskaya	19.11.20	100.8	252.5			126.2
Tselinskaya	27.11.20	100.8	252.5			126.2
Republic of Adygeya, total		150.0	354.0	1434.6	24.7%	177.0
Adygeyskaya Nova Wind	28.02.20–27.04.20	150.0	354.0			177.0
Stavropol Territory, total		390.0	1038.0	10354.9	10.0%	519.0
Kochubeevskaya Nova Wind	28.12.2028	210.0	597.0			298.5
Karmalinovskaya Nova Wind	29.03.21	60.0	147.0			73.5
Bondarewskaya WWP Nova Wind	27.08.21	120.0	294.0			147.0
Russia, total		1398.8	3543.5			1771.1

Source: completed by the authors based on [*NP-SR*, 2021; *Ministry of Energy*, 2021; *Nova Wind*, 2021; *Rosstat*, 2021]

WPP would amount to 4.5 million tons annually. By 2025, the share of wind in electricity balances will be the largest in Republics of Kalmykia and Adygeya, 99% and 44%, respectively. It will also be considerable – more, than 10%, in Ulyanovsk Region, Astrakhan Region, and Krasnodar Territory. Besides that, it is necessary to note, that Republic of Kalmykia has a low energy consumption – less than 600 million kWh annually. Renewable plants that are to be built there by 2024 – 164.5 MW of photovoltaic plants together with 226.1 MW of wind power plants, would make Kalmykia an energy surplus region of Russia with wind electricity that would entirely cover both industrial and household consumption.

Construction of major network WPP will enhance reliability of energy supply in the several Russian regions, improve environmental condi-

Table 3: Regional distribution of WPP projects construction in the Russian Federation in accordance with the results of the 2013–2020 "Competitive selection of investment projects for the construction of RES generating facilities": windenergy share prospects in energy balance of the Regions in 2024

Region of the Russian Federation	WPP projects up to 2024, MW	The estimated potential of electricity generation million kWh per year	Energy consumption in 2019, million kWh per year	Assessed wind share in energy balance in 2024	Predicted CO_2 emission decrease, thousand tons per year
Astrakhan Region	183.00	458.4	4370.2	10.5%	229.2
Volgograd Region	77.40	193.9	16,238.9	1.2%	97.0
Krasnodar Territory	1052.50	2635.3	24772.2	10.6%	2317.6
Rostov Region	503.69	1261.7	19,324.1	6.9%	630.9
Republik of Adygeya	250.00	626.3	1434.6	43.7%	313.2
Republik Kalmykia	226.10	566.4	573.2	98.8%	283.2
Stavropol Territory	173.95	435.7	10,354.9	4.2%	217.9
Ulyanovsk Region	316.00	791.6	5581.8	14.2%	395.8
Republik Tatarstan	100.00	250.5	30,952.5	0.8%	125.3
Murmansk Region	350.97	879.2	12,727.6	6.9%	439.6
Orenburg Region	75.60	189.4	16,413.8	1.2%	94.7
Perm Territory	189.90	475.7	26,207.2	1.8%	237.9
Kurgan Region	40.00	100.2	1353.5	7.4%	50.1
Total	3569.11	8941.9			4471.0

Source: completed by the authors based on [*NP-SR*, 2021; *Ministry of Energy*, 2021; *Nova Wind*, 2021; *Rosstat*, 2021]

tions, and provide decrease of CO_2 emission that is particularly important for the Southern recreationally oriented regions of the country.

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