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The Usage of Renewable Energy Sources in the Arctic: The Role of Public-Private Partnership

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Abstract. Sustainable development of the Arctic regions of the Russian Federation requires reliable energy supply, which is possible to achieve through searching for new environmentally clean energy sources. The Russian part of the Arctic possesses a great potential of renewable energy sources (RES), and it has required prerequisites for their accelerated development. In these conditions, the transition to renewable energy sources allows not only the provision of required energy resources to the region, supplement and partial substitution of the usage of expensive imported fuel, but the minimization of environmental damage and the preservation of natural resources for future generations. In this article, problems and prospects of the renewable energy usage in the energy system of the Arctic regions of the Russian Federation are systemized and presented. On the basis of the content analysis, the successful experience of their application in the Russian part of the Arctic is summarized, and the tasks of their promotion on these territories are shown. Besides, pros and cons of the renewable energy sources usage in the economy of the Arctic regions are defined. It is revealed that one of the most acute problems of the further development of the RES potential is related to the attraction of funding for "green" energy projects. To solve this problem, we propose the activation of cooperation between the state and business through the development of public-private partnership. We present the specifics of public-private partnership in the field of non-traditional energy and justify the importance of its application for the Arctic regions of the Russian Federation. The scientific novelty of the research is the development of theoretical provisions aimed at the cooperation between government authorities, business structures, and modern society in solving energy issues of the Russian Arctic with the goal of the sustainable development of its territories. The practical relevance of the study is the development of conditions for applying the public-private partnership mechanism to the solution of the priority objectives related to the usage of renewable energy sources in the Arctic region.

Key words: sustainable development, regional economy, the Arctic region, Northern territories, renewable energy sources (RES), alternative energy, funding, public-private partnership.

Introduction

The development strategy of the Russian part of the Arctic[1] pursues the solution of such priorities as strengthening its contribution to the economic development of the Russian Federation in general, the acceleration of economic growth of the regions and municipalities, located within its boundaries, the improving and maintaining the quality of people's life on the level not lower than the national average. Priority tasks of the Arctic's development also include protecting the vulnerable nature of the North, reducing the burden on the environment during investment projects implementation, preserving traditional culture and lifestyle of indigenous peoples. The solution of these tasks is closely connected with the development of energy sector, reliable provision of production and population with energy taking into account environmental requirements in the context of climate change managing. In the 2030 Agenda for Sustainable Development[2], adopted by the UN in 2015, one of 17 designated purposes is associated with the provision of society with clean energy at an affordable price. Scientists from different countries are actively discussing the problems of the establishment of "green" economy, which

[1] The Strategy for the Development of the Arctic Zone of the Russian Federation and National Security up to 2020. Available at: http://www.consultant.ru/document/cons_doc_LAW_142561

[2] The 2030 Agenda for Sustainable Development. Available at: https://www.un.org/sustainabledevelopment/ru/about/development-agenda/

is also closely linked with issues of renewable energy sources, the reduction of greenhouse gas emissions [1–4].

The Energy Strategy of the Russian Federation (2009)[3] provides for the development of autonomous generation systems, based on renewable energy sources. Taking into account the fact that the zones of decentralized electricity supply of the country are concentrated in the Far North, the Far East, Siberia, it could be argued that the development of renewable energy facilities is particularly important for these areas. Energy system of constituent entities of the Russian Federation in the Arctic zone[4], the area of which is about 3 million square km (18% of the country) and the population of which exceeds 2.5 million people, is mainly based on imported fuels: petroleum, coal, liquefied gas, and nuclear fuel processing at nuclear power plants. Taking into account climate, the volume of required fuel is very considerable, and the infrastructure, providing this volume, is limited by natural reasons (remoteness, permafrost, lack of personnel for maintenance, etc.). In this regard, an important economic and social challenge is a reliable energy supply to remote settlements of the Arctic. For example, currently, in the Arctic regions of the Sakha Republic (Yakutia), more than 150 thousand people live in the settlements where energy is supplied by physically and mentally outdated diesel power plants, and the electricity is available with long-term disruptions. The price of electricity for consumers is 15 times higher than the average rate. Thus, the task of implementing renewable energy sources in the Russian Arctic becomes more urgent every day. One of the most promising financing mechanisms of investment projects on renewable energy is a public-private partnership (PPP).

The purpose of this article is to study the possibility of applying the tools of public-private partnerships in order to develop the potential of renewable energy sources in the energy systems of the Arctic regions. In other words, we analyze two related issues: the meeting of energy needs of socio-economic systems of the Arctic zone of the Russian Federation and the greening of energy sector. The emphasis is put on the usage of energy resources of the zone that will act as a trigger of its rational exploration and development. The scientific novelty of the research is connected, first, with the compilation of scattered information on the actual usage of renewable energy sources in the Arctic zone of the Russian Federation, which gives a valuable testimony in favor of the effectiveness of renewable energy resources in meeting the needs of the population and economy of this part of the country, and, second, the conceptualization of using PPP mechanisms for the sustainable development of energy systems of the Arctic regions with renewable energy resources in the framework of the economic systems greening and considering the interests of indigenous population.

Renewable energy sources in the Arctic regions: A theoretical overview

World and domestic experience suggest that promotion of "green" energy is one of the priorities of modern economy. In this regard, it is necessary to divide the concepts of "green energy" and "renewable energy", although they substantially overlap. The first concept refers to all activities associated with the production, transmission, distribution, and consumption of

[3] Energy Strategy of the Russian Federation until 2030: Adopted by the Decree of the Government of the RF № 1715-p, dated 13.11.2009. Available at: https://minenergo.gov.ru/node/1026

[4] On Land Territories of the Arctic zone of the Russian Federation: Decree of the President of the Russian Federation no. 296, dated 05.02.2014. Available at: http://static.kremlin.ru/media/events/files/41d4d8e8206d56fc949d.pdf

energy using the tools of greening. The second concept is more narrowed, and it refers to the usage of renewable energy sources. In recent scientific literature, the issue of renewable energy becomes increasingly urgent. Thus, B.V. Lukutin, O A. Surzhikova, E.B. Shandarova [5] propose the solution of problems of energy supply through developing renewable energy, they pay special attention to local power generation with the usage of renewable energy sources. The monograph, edited by V.V. Elistratov, N.B. Kobysheva, G.I. Sidorenko [6], is noteworthy. In this work, scientists, in addition to the studies of renewable energy technologies, assess climate resource potential of renewable energy in various regions of the Russian Federation. Energy, economic, and environmental characteristics of different RES are summarized by A.B. Alkhasov [7].

Due to the fact that a large potential of renewable energy (related to the action of solar radiation, wind, geothermal fields, etc.) in the Russian Federation is concentrated in the Arctic, the majority of scientists, who deal with renewable energy in their researches, make strong emphasis on the study of the territory. Currently, the traditional energy systems of the Russian Arctic use resources of coal, oil, natural gas, water, and nuclear power in their production process [8].

In particular, O.S. Popel', et al. in the work [9] characterize the Arctic zone of the Russian Federation from the point of view of energy consumption, and they justify the solar energy application in the region.

V.R. Kiuskina [10] studies energy security in decentralized areas with isolated generation in detail on the example of territories of the Arctic regions, and she recommends forming autonomous power supply systems in these areas using renewable energy sources in order to reduce economic, environmental, and social risks. A.L. Elyakov in his work objectively justifies the use of RES in the energy system of the Arctic regions, and he argues that the influence of the energy system on the environment and its consumers depends more on the type of used energy resources [11].

High expanses of conventional energy in this part of the country, financed from the federal budget in the form of subsidies for the Northern fuel delivery to the Arctic regions, thermal power stations operating on imported fuel oil and coal with outdated production technologies of electricity and heat, deteriorate the environment and population's health, increase the attractiveness of energy, generated by renewable energy sources, and provide substitution of the hydrocarbon fuel (in the form of diesel and gas condensate fuel, oil, natural gas, liquefied gas, and coal) with other types of energy.

Studies, conducted by the Kola Research Center of the Russian Academy of Sciences, have shown that the usage of RES is currently very important for the Arctic regions. For example, A.A. Gasnikova notes in her work that the development of alternative energy is of particular importance for the Arctic regions. This is cause by the following reasons: the presence of many small decentralized energy consumers; low transport accessibility and the associated problem of fuel supply; long duration of the heating period [12]. The author emphasizes that alternative energy in the North is based on the usage of local resources (energy of winds, energy of small rivers, solar energy), so their involvement in the regional energy system will solve the problem of fuel supply to the settlements of the Arctic regions and will enhance the Arctic territories' energy security. Technical aspects of using renewable energy sources in the Arctic regions are described in detail in the research of the Center of Physical

and Technical Energy Problems of the North, the Kola Research Center of RAS [13, 14].

According to O.B. Dubinsky, who studies the perspectives of using renewable energy sources in the Arctic zone of the Russian Federation [15], the proposals for the optimization of RES development in these regions should include the initiatives taken on the legislative level: the establishment of a fixed rate for generating facilities, based on renewable energy sources for the period of their recoupment; providing tax incentives for renewable energy power plants for the payback period; the development and implementation of programs for state co-financing of RES development projects.

The possibilities of RES application in the Arctic territories are discussed not only by Russian but also by foreign scientists. In particular, the researchers from the University of Alaska in Fairbanks E. Whitney, W.E. Schnabel, S. Aggarwal and others [16] propose a mechanism for assessing the impact of RES on food, energy, and water security of these territories when studying the conditions of human life in isolated communities in the Arctic and subarctic regions of Alaska.

Chinese researchers under the supervision of G. Zhuo [17] were studying the problems of continuous power supply of unmanned and automatic observation systems in the polar regions and simultaneously came to the conclusion that an energy system based on renewable energy sources is a perfect solution for achieving environmentally friendly and reliable energy supply in the polar regions.

In a joint comprehensive study of a group of Chinese and Pakistani scientists under the supervision of S.F. Rafik [18], the transcontinental interconnection of power system and the development of environmentally friendly energy for providing sustainability are the main objectives to be addressed within the framework of the Global Energy Association. The researchers are concerned about the depletion of fossil fuels, and they explore the opportunities for renewable energy sources in the Arctic and Equatorial zones and the methods of production and delivery of clean energy around the world within the limits of available generating capacity.

A group of scientists from Denmark, the Netherlands, Canada under the supervision of L. Mortensen [19] study the possibility of transition from fossil fuels to renewable energy in four Arctic regions: Alaska, the Canadian Arctic, Greenland, and Russian Arctic. These researchers identified the problems associated with access to fossil fuels and its deliveries to the Arctic settlements, they emphasized the importance of the global agenda concerning the climate change counterreaction and proposed the concentration of efforts in order to stimulate the introduction of renewable energy sources in such key factors as the economy and technological infrastructure.

Thus, in the course of studies on the prospects of renewable energy in the Arctic areas, most scientists came to the conclusion that the construction of new energy facilities requires substantial capital investment, the economic efficiency of which is doubtful. Moreover, in some areas, the construction of traditional energy infrastructure is impossible due to their natural characteristics (especially, the complexity of construction in permafrost conditions). In this regard, the most efficient solution for providing consumers with energy resources could be renewable energy sources.

All studied works also allow concluding that main advantages of renewable energy sources in comparison with non-renewable ones, which are actively used in the traditional energy sector, are their relative environmental friendliness

and nonterminability. Disadvantages include nonpermanent nature of presence (e.g., wind resource is available for the usage only with a wind of a specific strength and direction) and the high cost of technological development (significant investments in the development of tools of extracting energy from the source are required). In this regard, the usage of environmentally friendly energy sources is the most promising in the areas with its increased capacity and, at the same time, with a lack of usual traditional fuel resources.

Analysis of the usage of renewable energy sources in the Russian Arctic

In the current situation, energy is the basis for the state's economic growth, because it promotes the development of sectors of the economy. Energy sector's state determines the nature and pace of the development of the scientific-technical revolution. The global energy industry undergoes significant changes toward the development of renewable energy sources and technologies for their usage. This very area rapidly technologically progresses in the developed world. Renewable energy includes a wide range of primary sources of energy with specific characteristics and features. The classification of the main types of RES is presented in *table 1.*

It should be noted that, in the 1990s in the Russian Federation, there was no wide usage of renewable energy in the Northern territories of the country due to the high cost of the electrical and thermal energy produced this way. In the modern period of the Russian economy development, when the environmental laws become more stringent, the state support of renewable energy development is being implemented, the cost of produced electricity and heat energy is equalized significantly, and the prerequisites to ensure that this trend of pricing on the renewable energy market will remain in the future are formed gradually. Main reasons for renewable energy sources usage in the Arctic territories should include the depletion of natural resources, the possible prospect of a crisis of the regional energy system, the negative impact of traditional energy systems on the environment, the risk of an environmental disaster. The distinctive characteristics of traditional and renewable energy are represented in *table 2* describing the advantages and disadvantages of these two types of energy.

For many decades, the Arctic regions' energy system has been developing due to the exploitation of hydropower resources and the

Table 1. Classification of renewable energy sources

Renewable energy sources	Examples
Traditional	Hydraulic energy converted into electric power used (mostly by large hydropower stations with a capacity of 30 MW) Energy derived from biomass used to produce thermal energy by conventional methods (burning wood, peat and other fuels) Geothermal energy
Renewable	Solar energy Wind energy Energy of sea waves Energy flows Energy of the tides of the seas and oceans Hydraulic energy converted into electrical energy by small and micro hydroelectric power plants Biomass energy not used to produce thermal energy by traditional methods Low-grade thermal energy

Table 2. Main distinctions between traditional and renewable energy

Distinctive characteristic	Traditional energy	Renewable energy
The exhaustion of used energy resources	Used resources are exhaustible and non-renewable	Used resources are inexhaustible and renewable
The limited use	Used depending on the conditions of the territory	Used depending on the availability of renewable energy sources and manifestations of the corresponding phenomenon in a specific locus and at a specific time
The cost of energy production	Relatively high	Relatively low
Transport component in the cost structure of energy production	High	Low
The ability of continuous energy supply to the settlements of the Arctic regions	Low	High
The influence of power objects on the environment	Relatively high	Relatively low
Potential capacity of energy produced	Very high	Low
Dependence on climatic conditions	Low	High
The reliability of the power system objects	High	Average
Legal regulation of the activities of the power systems	Full	Partial
The possibility of public-private partnership in the projects' implementation	Limited	High
Source: own compilation.		

usage of imported fuel (fuel oil, coal, diesel fuel, etc.). It should be noted that the delivery of such fuel to the Arctic regions usually depends on the navigation season for the Northern sea route, the possibilities of river communication, and the availability of winter roads, which affect the cost of the resulting electricity and thermal energy.

As noted in the draft of the Strategy for Socio-Economic Development of the Arctic Zone of the Sakha Republic (Yakutia) up to 2030[5], the climatic features of this area require increased reliability and efficiency of the engineering systems for the settlements' life activity. It is rather difficult to provide the essential services for the population due to the territory's vastness, the settlements' remoteness, low population density. The average heating period in the Russian Arctic continues for more than 9 months of the year, and it lasts for the whole year in some localities.

It should be emphasized that the Arctic regions belong to the zone of decentralized power supply on the basis of low power energy sources, mostly diesel power plants (95% in the structure of electric energy production), which significantly increases the cost of a kWh of electricity. Currently, for example, in the Arctic regions of Yakutia, there are 170 diesel and 16 solar power plants operating with a total capacity of 308 MW. The total volume of electricity supply is 334 million kWh per year, or 80% of the total for the whole of the AO "Sakhaenergo" *(Tab. 3)*. The power supply of the Cherskiy settlement of the Nizhnekolymskiy district and several settlements in the Oymyakonskiy district is implemented by the Chukotka and Magadan energy systems, respectively.

The wear of diesel generators in the power utilities of aforementioned uluses (districts) ranges from 43% in the Anabarskiy district to 85% in the Momskiy district. The buildings

[5] Strategy for Socio-Economic Development of the Arctic Zone of the Republic of Sakha (Yakutia) until 2030 (draft). Center for Strategic Studies under the Head of the Republic of Sakha (Yakutia). Available at: http://src-sakha.ru/previews/strategiya-sotsialno-ekonomicheskogo-razvitiya-arkticheskoy-zonyi-respubliki-saha-yakutiya-do-2030-goda/

Table 3. The state of the local energy sector in the Arctic zone of the Sakha Republic (Yakutia), 2019

Arctic regions	The number of DPP	The number of SPP	Electric power, kW	Including SES	Net electricity supply, thousand kWh
Total:	170	16	308 128	1 240	334 000
Anabarskaya group	5	1	9 855	40	18 200
Anabarskiy	2	0	4 295	0	8 800
Olenekskiy	3	1	5 560	40	9 400
Prilenskaya group	13	0	34 930	0	41 400
Bulunskiy	9	0	26 325	0	29 000
Zhiganskiy	4	0	8 605	0	12 400
Yanskaya group	32	6	48 835	0	53 700
Ust-Yanskiy	9	0	24 750	0	21 400
Verkhoyanskiy	20	5	20 460	1 110	28 200
Eveno-Bytantayskiy	3	1	3 625	10	4 100
Indigirksaya group	16	1	22 623	20	28 000
Allaikhovskiy	5	0	9 387	0	8 900
Abyyskiy	7	1	7 471	20	9 300
Momskiy	4	0	5 765	0	9 800
Kolymskaya group	19	0	37 821	0	50 250
Nizhnekolymskiy	4	0	12 052	0	14 200
Srednekolymskiy	10	0	11 244	0	17 000
Verkhnekolymskiy	5	0	14 525	0	19 050

Note: DPP – diesel power plants, SPP – solar power plant.
Source: Program of Optimization of the Local Energy of the Republic of Sakha (Yakutia) for the period of 2016–2025.

deterioration makes up 20% in the Eveno-Bytantayskiy ulus to 76% in the Srednekolymskiy district. More than 60% of the cost of the electricity, generated in the Arctic regions of the Sakha Republic (Yakutia), is accounted by the fuel delivered by means of water and road transport. The delivery averagely takes 2 years, the number of transshipments in different types of transport reaches 5–6 times. The savings from using solar power plants is about 450 tons of diesel fuel per year. A significant portion of the diesel fuel volume was formed at the expense of full capacity of the largest Far Eastern solar power plant of 1 MW in the Batagay settlement of the Verkhoyanskiy district.

In 2018, a wind power plant was commissioned in the settlement of Tiksi; the plant is a technological complex combining wind turbines, diesel generators, and the system of electricity accumulation. The wind power plant includes 3 turbines with total capacity of 900 kW. The diesel fuel savings will amount to nearly 500 tons per year. The settlement of Tiksi is proposed to be used as a testing ground (technopark) for the development and exploitation of renewable sources of energy in the field of renewable energy sources, energy and resource saving, including for the study of joint operation of wind turbines, solar power plants, and mini-hydro power plants for heat and electricity supply of the Arctic zone of the Russian Federation[6].

Currently, the mentioned area is used for the implementation of the projects on construction of wind, solar, geothermal power plants and boiler plants using biofuels. *Table 4* represents the renewable energy projects in the Arctic regions of the country based on the analysis of Internet news resources.

[6] Available at: http://www.rushydro.ru/press/news/107013.html

Table 4. Examples of existing and upcoming RES in the Russian Arctic

Type of RES	Pilot projects	Power	Region
Wind energy	Ostrich farm "Severnoye Siyaniye" (since 2011) – up to 50% of electricity from RES	5 kW	Murmansk Oblast
	The company "Green House" producing wooden windows and doors (since 2015) – up to 20% of electricity from RES	500 kW	
	Lighting of the fishing and tourism complex on the Mudyug island (2014)	1.5 kW	Arkhangelsk Oblast
	Pilot project "Polyaris" realized in the framework of the international program *Kolarctic,* 4 wind power plants (since 2016)	200 kW	Nenets Autonomous Okrug
	Anadyrskaya wind power plant on the Cape of the Anadyrskiy district Observation, including 10 wind turbines (since 2002)	2.5 MW	Chukotka Autonomous Okrug
	Experimental wind power station in the city of Labytnangi (since 2014)	250 kW	Yamalo-Nenets Autonomous Okrug
	Wind power park "Zapolyarniy" consisting of 6 wind turbines (since 1993 to 2014)	1.5 MW	The Republic of Komi
	Installation of the wind turbine at the railway station "Tsentralnaya" (since 2013)	6 kW	
	Construction of a pilot wind power station "Bykov Mys" in the settlement of Tiksi	1.9 MW	The Republic of Sakha (Yakutia)
Solar energy	Ostrich farm "Severnoye Siyaniye" – the project of polycrystalline solar panel with high efficiency (since 2013)	N/a	Murmansk Oblast
	Project of a wind-solar installation for the supply of the office of the youth ecological organization "Etas" (since 2015)	1.6 kW	Arkhangelsk Oblast
	Wind-solar installation for the supply of a house on the Cape of Zhelaniye in the national park "Russian Arctic" (since 2015)	8 kW	
	Installation of solar photovoltaic panels to supply power to the beacons: in the Yugorsky Shar Strait and the coast of the Kara Sea (capes of Khabarov, belyi Yugorskiy, Yaraselya, Sokoliy, etc.), on the Vaygach island (Cape of Gomsasal)	No data	Nenets Autonomous Okrug
	Wind-solar generators on gas fields operated by the company "Gazprom Dobycha Yamburg". Installed more than 200 management systems on 15 fields and pipelines in the ares of Noviy Urengoy, Urengoy, Nadym, Tarko-Sale and others (since 2004)	No data	Yamalo-Nenets Autonomous Okrug
	Solar power plants in the settlements of Batamay (since 2011), Dulgalakh and Kudu-Kyuel (since2013), Kuberganya, Eyik, Dzhargalakh, Toyon-Ary (since 2014), Batagay, Betenkes, Unkyur, Stolby, Uluu, Verkhnyaya Amga, Delgey, Innyakh (since 2015)	Total about 1.4 MW	
Energy of bioresources	Boilers running on biofuel (wood waste): the settlements of Kuropta (since 1969); Luven'ga (since 2012)	1,75–3 Gcal/h	Murmansk Oblast
	The project of the Arkhangelsk pulp and paper mill on operation of 3 biomass steam boilers; the project of the company ZAO "Lesozavod" on operation of CHP plant running on wood waste	Total about 210 MW	Arkhangelsk Oblast
	PAO "Bionet" launched a plant for the production of torrefied pellets (biochar) from hydrolytic lignin in the town of Onega (since 2015)	No data	
	404 boiler houses operating on biofuel	Total about 930 MW	
	The project of boilers installation for the Syktyvkar CHP running on waste wood production of the Syktyvkar sawmill (since 2020)	240 MW	The Republic of Komi
Energy of small and medium rivers	Operation of 60 hydropower plants of collective farms (since the 50-ies of the XX century)	6.5–107 kW	Arkhangelsk Oblast
	The projects of AO "Nord Gydro" on the construction and reconstruction of small hydropower plants on the basis of water energy sources: small HPP "Lyaskelya", small HPP "Ryumyakoski", small HPP "Kalpiokoski" (since 2011)	0.63–4.8 MW	Republic of Karelia
	The projects of AO "Nord Gydro" financed by the Bank "BRIKS" on the construction of Beloporozhskiye HPPs (HPP-1 and HPP-2) on the Kem' river in the Republic of Karelia	49.8 MW	

Source: own compiled.

Another area of renewable energy development is the project for pellets production and conversion of boilers to biofuel. The organization of such kind of plants for the production of biofuel (pellets, briquettes) and the modernization of boilers for their partial conversion to bio-fuels in the Arctic regions will contribute to the protection of the environment and the improvement of human settlements by processing the wood waste (driftwood, wood chips, construction waste), the optimization of costs on the expensive imported fuel consumption. In addition, the implementation of projects for the production of biofuel, the pellets, will contribute to the development of small and medium businesses and partial substitution of imported fuel and energy with local energy sources.

Thus, the regions of the Arctic zone of the Russian Federation have already been using the power plants for the exploitation of local renewable energy which contributes to the alleviation of the annual problem of "Northern fuel delivery", the reduction of electricity generation cost, the increase of the reliability of local consumers' energy supply, and the improvement of the population's life quality. The usage of RES in the Arctic regions does not mean that it is possible to completely abandon the traditional capacity on these territories. On the contrary, it is necessary to double the renewable energy capacity by the capacity of traditional energy, so that, in case of the fall-down (termination) of energy production from a renewable source, it would be possible instantly switch to the backup power supply [12].

On this basis, we can formulate a list of tasks for the development of renewable energy in the Arctic zone of the Russian Federation which includes the actions for the involvement of renewable energy sources in the energy balance of these territories with the reflection in regional programs, the increase of the share of renewable energy sources in the region's energy balance, the saving of expensive diesel fuel.

Advantages and disadvantages of using renewable energy in the Arctic regions

It is obvious that the adoption of renewable energy sources in the Arctic are influenced by various conditions. First, it is a climatic factor which implies seasonal and weather dependence of the RES efficiency. The climatic design of the equipment should meet stringent requirements, so, for example, the building-up of snow on the solar panels would be prevented. It is also important to take into account the permafrost and its melting due to the possible climate warming in the Arctic, which, respectively, will require the construction of expensive foundations and involving of special machinery to the construction. Second, the logistics factor, which involves seasonal dependence of the equipment delivery, the area, the availability of specialized machinery. Third, an important condition for the active promotion of renewable energy in the Russian Arctic is highly skilled RES designers and personnel trained to operate the relevant equipment. This will require corresponding training in Russian universities. Some universities already have a successful experience of such training.

The modern period of using renewable energy in the country is characterized by its weak development in the Arctic regions. However, the importance of renewable energy in the Arctic is increasing right now, when the raw model of the economy creates additional load on the environment. It is obvious that, in order for a number of projects in the field of renewable energy sources in the Arctic zone of the Russian Federation to increase every

Table 5. Advantages and disadvantages of using renewable energy sources in the Russian part of Arctic

Advantages	Disadvantages
- Relative inexhaustibility of energy. - Lack of dependence on transport costs for fuel supply to the settlements of the Arctic regions. - Relatively low cost of produced electricity and thermal energy. - Reducing the negative impact on the environment. - Use in conjunction with traditional sources of energy. - Reduction of tariffs on electricity and thermal energy. - Attractive for small consumers (small towns, small farms).	- Dependence on natural, climatic and weather conditions of a particular locality. - Relatively small potential capacity of the energy produced. - High initial costs for the construction and installation of power facilities and the payback period of the project. - Lack of domestic equipment and dependence on imported components. - The inability to support smooth operation of power facilities without a backup power supply. - Gaps in the legal regulation of energy facilities' activities, lack of tax preferences and exemptions to the participants of alternative power market.
Source: own compilation.	

year, it is necessary to ensure a favorable investment climate, effective legal and regulatory framework, and the high level of state support. The current status of "green" energy is characterized on the basis of the analysis of its advantages and disadvantages *(Tab. 5),* and it allows outlining specific actions to increase the share of renewable energy in the energy balance of the Arctic constituent entities of the Russian Federation.

The presented analysis allows us to make a basis for the further development of renewable energy in the Russian Arctic and to define a basic set of actions for the application of "green" technologies in its regions. It is particularly important to pay attention to the following circumstance. The formation of "green" energy, including RES-based, is not only an attempt to diversify energy resources, but also a tool for greening the energy sector in the studied area. However, such measures cannot prevent large-scale natural changes in the Arctic caused by global climate change, which, in turn, is a consequence of the international economic system's functioning. If this is true, then the attempts of greening the human activity in the Arctic zone of the Russian Federation will encounter a serious obstacle in the form of environment transformation. The latter implies a qualitative change of renewable energy sources. In particular, the ice sheet's shrinking in the Arctic ocean will increase the width of the "open sea" and the duration of the season, during which it is possible to use the corresponding resources (for example, wave activity). However, this will require restructuring of technologies used to generate this kind of energy. Wind power generating is doubtful, because the speed and direction of prevailing winds can also change with climate transformation. The initiatives in the sphere of the regional and local development of renewable energy should definitely take into account these kinds of risks. In other words, it should be realized that its development makes the population and the economic system of the Arctic zone of the Russian Federation much more dependent on the global environmental factor.

The development of renewable energy in the Arctic zone of the Russian Federation should be carried out gradually and systematically. Currently, the regulatory framework in the field of RES is constantly being updated, new laws are issued almost every year, new regulations, focused on the renewable energy support measures, are adopted.

Public-private partnership in the implementation of renewable energy projects in the Russian Arctic

Currently, one of the main tools of attracting investment resources into infrastructure projects is a public-private partnership. However, as noted at the meeting of the Arctic and Antarctic Expert Council under the Federation Council of the Federal Assembly of the Russian Federation (Yakutsk, 2019)[7], the total volume of attracted private investments is rather small – only 1%, while, in many developed countries, this figure reaches 20%. In these conditions, it is necessary to encourage private investment in the infrastructure and facilities, related to the renewable energy usage, to develop the mechanism of private and public cooperation in the Arctic.

For legal and economic regulation in this sphere, it is necessary to develop and adopt changes in the legislation aimed at the development of new forms of public-private partnerships (PPPs), such as, for example, infrastructure mortgage[8] that will allow the state to buy the facilities, built by investors, through private loans that will be repaid in parts from budgets of different levels during the facility operation. The possibility of the implementation of some Arctic projects on the basis of infrastructure mortgage is currently being discussed. These projects are the construction of the North latitudinal way and the development of the Murmansk transport hub. This approach, of course, should be extended to the construction of energy infrastructure for the production and use of renewable energy sources.

It should be noted that, since 2015, special investment contracts (SPIC) have been applied[9] in order to stimulate the attraction of investments into the creation and modernization of production, to guarantee the provision of investors with industry-specific privileges and preferences, and to create a stable business environment. In our opinion, it is useful to extend SPIC mechanism not only for the industrial enterprises creation, but also for the construction of energy infrastructure. For these purposes, mechanisms of project management should be used [20].

An important area of the new technologies support, which are necessary for work in the Arctic, including the ones based on the renewable energy sources usage, is the creation of the Fund for the Development of Arctic Technologies. The Fund will intentionally support necessary for the Arctic technological, infrastructural, and energy projects, including ones at the initial phase – at the research and development stage.

Our analysis of the potential of renewable energy sources and their usage in energy systems of the Arctic zone of the Russian Federation showed that most constituent entities have sufficient quantities of renewable energy resources, and their usage is the condition for the economical and efficient spending of energy resources and the minimization of harmful impact on the environment.

At the same time, despite the considerable potential, the regions of the Russian Arctic implement a relatively small number of projects in the field of renewable energy sources. One of the main reasons, in our opinion, is the lack

[7] https://www.sakhatimes.ru/gov/news/il-tumen/v-yakutske-sostoyalos-zasedanie-soveta-po-arktike-i-antarktike-pri-sovete-federatsii-rf/

[8] https://porarctic.ru/blog/2019/04/08/arktiku-pomozhet-razvivat-infrastrukturnaya-ipoteka/

[9] Special investment contracts (SPIC). Industrial Development Fund. Available at: https://frprf.ru/gospodderzhka/o-spetsialnykh-investitsionnykh-kontraktakh-dlya-otdelnykh-otrasley-promyshlennosti/

of available sources of funding of economic entities. Therefore, in order to implement projects on the construction and exploitation of renewable energy sources in the Arctic zone of the country, it is advisable to use the mechanism of public-private partnership, which involves a legal agreement between public authorities and businesses about the construction and operation of these facilities.

A specific feature of such a mechanism in the field of renewable energy sources, in our opinion, is the fact that the agreement between public authorities of the Arctic region and business includes:

– the consolidation of private and public sources of project financing;

– the allocation of risks during project implementation;

– the attraction of additional private investments in the economy;

– the accessibility for consumers and the increase of the quality of services for the production and transmission of electric and thermal energy by RES;

– the creation of new jobs through the construction and operation of alternative energy facilities;

– mutually beneficial cooperation of public authorities and businesses during the implementation of projects on the construction and usage of renewable energy facilities in the Russian Arctic;

– businesses' usage of innovative methods, initiated and applied by the public sector, in the process of implementation of investment projects on the development of renewable energy sources in the Arctic region;

– joint implementation of projects on the construction and operation of renewable energy facilities, necessary for the Arctic region.

Another important advantage of PPP is the fact of public attention to this project. On the one hand, it emphasizes the importance of the latter (since one of obstacles, preventing RES from the wider usage, is the business representatives' narrow vision, because they consider such projects marginal ones). On the other hand, PPP is some kind of a guarantee for business, which is also important in order to ensure the willingness of the latter to participate in the implementation of technologically and environmentally innovative projects. Moreover, the state's participation will provide the attention and support of municipal authorities and local population.

According to the Analytical Center "Rosinfra" (a platform for supporting infrastructure projects), public-private partnership will be used for the implementation of the project of reconstruction of the Anadyr wind power plant in the Chukotka Autonomous Okrug in the form of a concession agreement. The implementation of this project will involve 143.3 million rubles of private funds, the return of the private partner's investment will be carried out by consumers' charge for the object usage, the project implementation timeline is 20 years (until 2039). The participants of the project are the Chukotka Autonomous Okrug and OOO "Stroyindustriya"[10]. The public partner's obligation is to ensure that the concessionaire will have necessary conditions for performing the reconstruction of the object of the concession agreement, the terms of implementation, and the assistance in the development of project documentation in accordance with the requirements of the legislation of the Russian Federation. Thus, the reconstruction and operation of the wind power plant with 2.5 MW capacity will be ensured.

[10] A platform for supporting infrastructure projects. Available at: https://rosinfra.ru/project/short-view/rekonstrukcia-vetroelektrostancii-s-dispetcerskim-punktom-v-anadyrskom-rajone-na-myse-observacii-v-cukotskom-avtonomnom-okruge

The sources of projects' co-financing in the renewable energy sector within PPP may be federal budget funds, the RF constituent entities' budgets, local budgets, and private investors. The usage of such mechanism in the field of renewable energy will allow implementing the investment projects on the construction and operation of renewable energy facilities successfully, improving the quality of services provided in the sphere of energy for the region's consumers, increasing the flows to the budgets of different levels (through the fiscal mechanism), providing employment, improving the ecological situation in the region, reducing the costs of transporting fuel to the settlements of the Russian Arctic. Therefore, the mechanism of attracting private funds with federal support in the form of tariffs' subsidizing will allow modernizing operating diesel power stations with partial substitution of diesel generation with solar, wind energy.

In order to lend financial assistance to small and medium businesses and support projects designed to increase the Arctic-produced value added, it is offered, along with the PPPs, to provide preferential financing for such projects and to use the mechanism of subsidizing interest rates on loans, which will allow attracting funds at the rate of not more than 5% per annum.

A new direction for PPP and a way of attracting investments for the implementation of environmentally and socially significant projects is the conclusion of agreements on the socio-economic development of territories between the bodies of state administration, the mining company, and indigenous peoples of the North in the implementation of projects of industrial development of the Arctic. This approach is based on the ethnological expertise of the projects in the Republic of Sakha (Yakutia), and it has been used since 2011. Its essence is that the potential losses of indigenous peoples of the North from the effects of economic and other activities' impact on their traditional occupations are defined in the framework of such ethnological expertise and compensated by the mining company [21, 22]. In the Republic of Sakha (Yakutia), the necessary legal conditions for holding the ethnological expertise and compensating losses to indigenous peoples, while implementing mining projects and mineral exploration, are created [23]. This compensation may be offered in the form of a direct payment to local people in the zone of the mining project's influence or in the form of a financial support for the development of social, transport, and energy infrastructure. For example, in the Bulunskiy ulus of the Sakha Republic (Yakutia), the implementation of the project of coal gasification at the expense of funds attracted with the help of compensation agreements is considered [24]. This approach is essentially the implementation of the concept of obtaining and using benefits in the Arctic and the interaction of concerned parties in the territory's development [25].

Conclusion

In the last decade, renewable energy in the Arctic regions has been gradually showing power growth, special programs and measures of state support, aimed at the acceleration of the development of environmentally friendly energy sources in the Arctic zone of the Russian Federation, are being developed. The development of the Arctic territories should take into account the environmental requirements and protect the habitat and traditional lifestyle of indigenous low-numbered peoples of the North.

In conditions of limited budget financing, one of the proposed sources of attracting funds for the implementation of investment projects on the usage of renewable energy sources in the Arctic regions' energy systems is the mechanism of public-private partnership, which includes

the application of project financing methods, the usage of special investment contracts (SPIC) for energy infrastructure that will stimulate the investments attraction into the creation and modernization of production, ensure the provision of benefits and preferences to the investor, and create a stable business environment.

One of the proposed sources for funding renewable energy investment projects in the Arctic regions' energy systems is the usage of part of funds paid by mining companies to indigenous peoples of the North in the framework of the ethnological expertise of projects on the territories of traditional nature use.

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