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Prospects for Development of Renewable Energy Sources to Preserve the Ecosystem of Arctic Zone of Russia

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Abstract

Objectives: Environmental balance of Yakutia is quite delicate, but the energy needs are growing. Therefore, the study evaluates the efficiency of employing renewable energy sources that do not pollute the environment. **Methods:** The study applies the methods of economic analysis as follows: normative method (the established maximum permissible concentrations of pollutants), economic and mathematical simulation (modeling the efficiency of renewable energy sources and estimating the economic effect of their use) and historical method (historical data on atmospheric pollutant emissions and historical prices for hydrocarbon energy products). These methods enable complex investigation of ecological and economic efficiency of renewable energy sources. **Findings:** The principal result of the study is represented by the evaluated economic efficiency of renewable energy sources, namely, productive efficiency, reduced dependency on hydrocarbon fuel supplies and lower expenses for hydrocarbons. **Applications/Improvements:** The materials of the study are of practical importance for evaluating the long-term efficiency of renewable energy sources to further promote their use.

Keywords: Economic Efficiency, Hydrocarbons, Northern Supply Haul, Power Industry, Renewable Energy Sources

1. Introduction

The Arctic and the adjacent northern regions are now the focal point of the global problems. From economic perspectives this is the area rich in mineral raw materials. Future progress of the world economy cannot be conceived without the development of the riches of the North. Consequently, the period of intensive industrial development is imminent.

The Arctic Region is the weakest component element of the biosphere, inasmuch as its ecosystems are vulnerable and are in a state of limit equilibrium. Therefore, even the slightest disturbance of the existing balance may result in destructive consequences. The weakest link of the northern ecosystem is represented by the Earth's surface that is the foundation for all wildlife. This can be explained by the nearby occurrence of permafrost.

The Arctic and the northern regions are of paramount importance for preserving the climate of the planet. Principal processes of heat- and mass-exchange between the Arctic Ocean and the northern part of Eurasia occur exactly in the territory of Russia; the Arctic Ocean

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performs the function of the climate regulation factor. This factor largely predetermines the well-being of Russia and of other northern countries. However, in these latter days there have been observed the man-induced destabilizing phenomena.

The first to mention is the pollution of the Arctic Ocean. Almost 70% of the territory of Russia is located in the river basins of the northern watershed exposure. From this vast territory all types of river contaminations go to the ocean.

The products of intensive burning of fossil fuels and other air contaminants, industrial emissions, pollutants from airliners and rockets increase the content of carbon dioxide in the atmosphere and lead to "greenhouse effect" that mostly affects the Arctic Ocean and results in deglaciation and in sea level rise[1].

The burnt fuels (coal, firewood, and hydrocarbons) now account for circa 90% of energy generation all over the world. The share of thermal sources in electric power generation is reduced to 80-85 %. Burning of fuels is the major source of energy and the main source of atmospheric pollution[1].

However, under the conditions of the Arctic regions the main source of pollution is represented by the flaring of gas in the process of oil extraction. Normally, when oil is extracted from oil-gas condensate fields the gas flaring is widely practiced i.e., burning the associated gas at the flare installed on the field in order to dispose of the gas when there is no market or when the oil company does not intend (or does not have the opportunity) to use it otherwise. Thereat, the amounts of burnt associated gas are huge: for example, in Russia in the territory of the Sakha Republic (Yakutia) circa 60% of carbon dioxide in the region is emitted as a result of burning the associated gas[2].

Thermal power stations are largely responsible for ever increasing greenhouse effect and for acid precipitation. Central Heating and Power Plants (CHPPs) together with transport account for the major part of technogenic carbon that is emitted into the air, for 50 % of sulfur dioxide, for 35 % of nitrogen monoxide and for 35 % of dust2. Thereat, the emissions from Combined Heat and Power (CHP) plants contain considerable amounts of metals and metal compounds. Expressed in terms of lethal equivalents the annual emissions from 1 million kW CHP plant contain over 100 million dozes of aluminum and its compounds, 400 million dozes of iron, 1.5 million dozes of magnesium.

At the same time, the effects produced by power industry on the environment and on the wildlife largely depend on the type of the employed energy sources. Therefore, the use of Renewable Energy Sources (RES) is most promising.

It should be noted that there are three major trends in the world power industry pertaining the development of alternative energy sources:

Fist, the majority of the developed countries aim to set the long-term quantitative milestones of the intended share of Alternative Energy (AE), thus stimulating the enactment of relevant legislation and the implementation of thereby supported technologies. Here one of the principal points is that the state is focused on environmental issues and on safety of AE rather than on economic efficiency.

Second, in many areas the government has delegated the private sector to select AE technologies that would make the foundations for the balance of energy.

And, finally, the third trend is represented by the fact that many developing countries have understood the urgency to join the global trend for increasing the share of AE in order to avoid the formation of the new fundamental technological lag that would in future result in sanctions on the manufacturers that employ less environment-friendly energy sources[3].

The businesses that are associated with modern renewable energy sources predominantly develop in the areas of the wind farms, in the sphere of producing ethanol and diesel fuel from biomass, and, to a lesser extent, in the areas of geothermal sources, solar farms and solar-thermal plants. Other areas, such as construction of tidal power plants, employing the energy of cold or using the hydrogen based fuel elements are still at the design stage, but in future they can occupy a considerable share of the world energy balance. (Table 1)[4].

Table 1. Electric power generation by countries in 2015, GW. Source: REN21's Renewables 2016 Global status report[4]

Country	Generation growth, GW	Total, GW
China	16.1	296
Brazil	2.5	92
USA	0.1	80
Canada	0.7	79
Russia	0.1	48
India	1.9	47
Turkey	2.2	26
Vietnam	1.0	15
Malaysia	0.7	5

Given the above, the alternative sources of energy have to be employed to reduce the emissions of carbon dioxide, to resolve the problem of power supply to the isolated regions and also to reduce the dependency of the economy of the region on the costs for hydrocarbons.

The most promising option is to employ the energy of the wind and the sun. Solar energy represents a practically inexhaustible source. Thereat, it can be used as the source of both thermal and electric energy. The use of solar heat is the simplest and the least expensive way to solve some certain energy-related problems. The solar heat is accumulated by the collectors. These are quite simple devices for gathering, accumulating and storing the heat.

To transform solar energy into electric power the photocells are applied. Notwithstanding the low efficiency of these devices, they are feasible because of their long operating life and because there are not any movable parts. The principle problems of their implementation are that they are expensive and require large areas for their installation. However, over the last several years the share of electric power generated by solar stations in the total amount of RES-generated power has been fast increasing year over year with simultaneous improvements of the efficiency and with the development of new solar power plant technologies focused on cost reduction.

The alternative to solar energy is represented by wind power. In the regions where the air movements are intensive the wind power plants are quite capable of meeting the local energy needs. However, the use of large wind farms is not feasible because of the expensive structures, strong vibrations, noises and frequent failures in cold atmospheric conditions.

Employing the technologies including but not limited to those described above will make it possible to reduce greenhouse gas emissions by 5 million tons within the first 20 years in the course of the implementation of the program; it will reduce the costs of electric power in isolated regions and the dependency on fuel costs[2].

In the English-language literature two approaches are traditionally used to evaluate the efficiency of RES technologies: economic cost models and financial models[5]. One of the principal indicators for estimating RES efficiency is represented by the Criterion of Leveled Cost of Energy (LCOE). It is calculated taking into account all expected expenses over the whole operating life (including construction, funding, fuel, technical maintenance, taxation, insurance and benefits) that are divided by the amount of the electric power to be generated over the whole period of operation (kWh). All estimated costs and profits are adjusted for inflation and are discounted in order to take into account the time value of money. As a financial tool, LCOE index is very helpful for the purposes of comparing different options of production. Relatively low LCOE means that the electric power is generated at low costs and it is more likely to bring profit to the investor. If LCOE generated with renewable resources is at the same low level as the cost of energy generated with traditional resources then it can be said that "grid parity" has been reached.

Thereat, according to one of the studies[6], neither of the approaches takes into account the risks associated with the selection between traditional and alternative energy sources or when the choice is made between different types of the alternative sources.

2. Concept Headings

The alternative energy technologies develop very fast reducing the prime cost of the energy generated thereby. In the course of further technological development such energy sources will be applied widely, especially in the northern regions where transport and logistics are complicated and the climate is harsh. Therefore, the principal objective of this study is to evaluate the efficiency of employing renewable energy sources that do not contaminate the environment.

Northern regions of the Sakha Republic (Yakutia) strongly depend on the fuel supplies that not only upset environmental balance of the region but also involve considerable expenses. Under such conditions the use of RES seems to be very promising as they do not depend on fuel supplies and can continuously generate sufficient amount of energy in the long run.

3. Results and Discussion

3.1 Development of Renewable Energy Sources (RES) in the World

Abroad RES attract large capitals: According to the data of international organization Renewable Energy Policy Network for the 21st Century (REN21), in 2014 new investments in RES and fuel amounted to USD 270.2 billion, which is by 17% more than in 2013. In terms of investments the leading countries were China, the USA, Japan, Great Britain and Germany. In 2014, RES accounted for

almost 60% of newly installed power generation facilities. Hydro-Electric Power Plants (HEPPs) included, the renewable power generation ensured 27.7 % of the total installed generating capacity in the world and 22.8 % of electric power generation. Without HEPPs RES would account for 6.2 % of electric power generation and a half of it would be wind power[7].

RES are the growth rate leaders in the global power generation sector. Concentrator Photovoltaics (CPV) generation is the fastest. Over the period since 2004 till 2012 the average annual growth of CPV generation capacity amounted to 63.0%. The leaders in terms of the installed capacity are Germany, Italy, USA, China and Japan. The second best position is occupied by wind power generation. In this sector the average yearly growth rate within the same period made 24.8%. The leaders in terms of the installed capacity were represented by China, USA, Germany, Spain and India.

In a number of countries the price of some RES can well compete with that of traditional sources or at any rate it comes very close to being competitive; and this is without taking into account governmental subsidies. In many European countries, in Japan, Australia and Brazil there are even some regions where CPV solar generation, which is one of the most expensive RES technologies, is quite competitive in terms of the associated expenses.

According to the data of International Renewable Energy Agency (IRENA), in 2014 the sector of renewable power generation employed 7.7 million people all over the world, even without taking into account such large and already well proven segment as big hydroelectric power industry. Among the renewable power industries the leader in terms of the working places is CPV solar power generation (circa 2.5 million); the leading country is China (circa 3.4 million)[8].

Notwithstanding the fact that in a number of regions of the world many RES can compete with traditional and nuclear power generation in terms of associated expenses, RES are still in need of governmental support. It should be noted that the industries of traditional and nuclear power generation get huge governmental subsidies: according to the estimations of International Energy Agency (IEA), in 2013 these subsidies amounted to USD 550 billion, which is four times more than the subsidies granted by the states to support and to develop RES. Besides, the technologies that are employed by the renewable power generation (usually excluding large hydroelectric power industry) are regarded as innovations; thus, correspondingly, the sector is associated with higher risks and with higher costs for Research and Development. Some of the important arguments for the extensive governmental support in many countries are represented by the obligations to reduce emissions of carbon dioxide (environmental factor) and by the attempts to improve national energy security through energy sources diversification.

3.2 Barriers Hampering the Development of Renewable Power Generation in Russia

Notwithstanding the great potential of RES development in Russia and regardless of the officially adopted decisions to support this sector of economy, the advisability of supporting renewable power generation is still the subject matter of disputes, and thus the implementation of the ambitious plans is very slow. Russia possesses huge technological and economic potential for developing renewable power generation facilities; however, today the share of RES in electric power consumption in Russia does not exceed 0.5%. This fact has been predetermined by a number of serious problems.

First, actual support of renewable power generation development is hampered by the inert policy when the continuing support of traditional power generation is believed to be more profitable and economically feasible; and so it is supported through tax exemptions, Research and Development funding, through the subsidies for oil and gas infrastructure construction, through geological prospecting and exploration, etc. Based on the experience of earlier development there has been a strong conviction that Russia has practically inexhaustible deposits of fossil fuel in its possession[8]. This endowment of Russia with fossil fuel creates an illusion that the energy crisis in Russia is impossible[9].

Second, a certain role is played by the issue of priorities: marginal significance of RES in Russia is usually substantiated by their low competitive power in terms of expenses as compared to fossil fuel and nuclear power. Electricity tariffs in the regions of centralized energy supplies in Russia are even now considerably lower than those in other countries which, of course, affect the price competitiveness of renewable power generation[5].

Besides, under the conditions when the budget spending is cut and the external political situation is rather complicated the development of renewable power generation facilities goes to the background.

The citizens of Russia reveal extremely small demand for the energy generated with renewable sources, and there is no interest in ecological innovations in general not only because of the specific mentality, but, in the first place, because of the insufficient awareness about the advantages of this sector and because no relevant opportunities are available[10–12].

3.3 The Need to Employ RES in the Sakha Republic (Yakutia)

Environmental situation in the Sakha Republic (Yakutia) is now in a position of a delicate balance. Any increase in pollution rates can result in drastic deterioration of the ecological conditions in the region and lead to irreversible changes. To avoid this danger, alternative energy sources have to be developed. In the long run such sources are quite feasible, insofar as they do not depend on the external fuel supplies and do not contaminate the environment. The first factor is very important for the isolated regions of the North because of their complicated accessibility.

Even today Yakutia is within an inch of ecological catastrophe. According to the statistics, emissions to the atmosphere in 2013 amounted to 165.1 thousand tones (Table 2).

Major part of the emissions has been caused by flaring of associated gas in oil-gas condensate fields.

The Sakha Republic (Yakutia) is characterized by the unfavorable specifics of climate and geographical indicators and also by the man-caused air pollution. In the territory of the republic there are over 400 industrial enterprises that are the main cause of air pollution. Major stationary sources of air pollutant emissions are represented by such industrial companies as PJSC Pechenganickel Combine and PJSC Severonickel Combine of OJSC MMC Norilsk Nickel, dressing plant PJSC "Olkon", PJSC "Yakutskenergo", JSC "ALROSA", "Aldanzoloto" LLC, State Enterprise Sakhaselkhozenergo, Central Heat and Power Plants, boiler houses, railway transport.

Presently the share of RES (including hydroelectric power generation facilities) amounts to 2.5 %[4]. Almost all this share of RES is represented by hydroelectric power generation: Russia occupies the fifth position in the world producing 48 GW of hydraulically generated power per year (Figure 1).

Given the fast progress of the technologies and further intensive development of RES, it is now very much less expensive to employ clean energy facilities. Even now in Yakutia there are solar power stations and wind farms that operate as pilot projects. If their operations prove to be successful these plants will spread over the territory of the whole region.

Table 2. Atmospheric pollutant emission. Source: Regions of Russia: population, territory, healthcare, environment 1970-2015[2]

Date	Emissions, thousand tons	Change, %
2013	165.1	2.67
2012	160.8	2.75
2011	156.5	-2.86
2010	161.1	-16.92
2009	193.9	6.01
2008	182.9	12.62
2007	162.4	1.63
2006	159.8	-1.72
2005	162.6	5.45
2004	154.2	14.82
2003	134.3	2.52

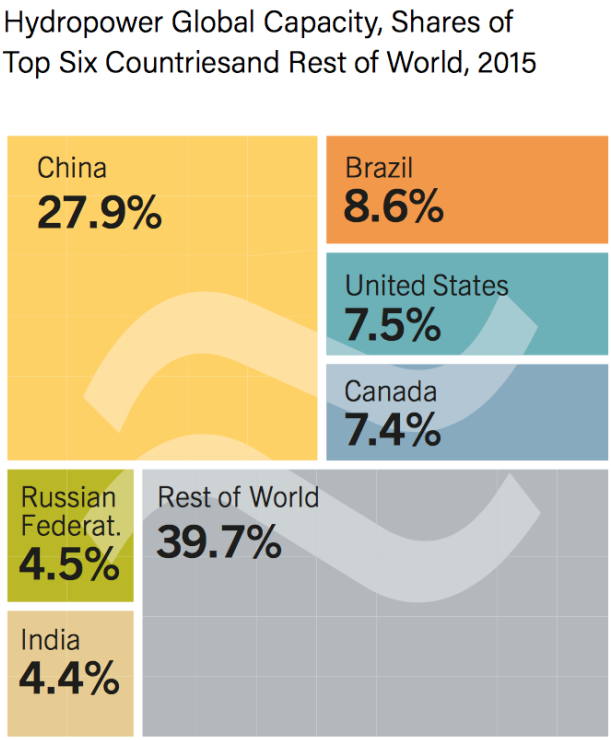

Figure 1. Structure of world hydroelectric power generation. Source: REN21's Renewables 2016 global status report[4].

3.4 Development of RES in the Arctic Zone of Russia including the Sakha Republic (Yakutia)

Now the Government of the Russian Federation lends strong support to alternative power generation sector in line with the "Strategy for Developing the Arctic Zone of the Russian Federation and Protecting its National Security for the period up to year 2020" approved by the President of the Russian Federation on February, 8, 2013, No. Pr-232 and which, according to the Federal Law dd. 03.26.2003 No.35-FZ "On Electric Power Industry" of the Government of the Russian Federation[13–17].

- Approves of the principal directions of state policy in the sphere of improving the energy efficiency in electric power industry including the target indicators of production and consumption of electric energy generated with renewable energy sources within the aggregate balance of production and consumption of electric power; the plan and the program of the activities on achieving the abovementioned target indicators;
- Lends support to the employment of renewable energy sources and stimulates the introduction of energy efficient technologies in conformity with the tax legislation of the Russian Federation.

The high-level structure of changing electric power generation by Unified Energy System of Russia split by the type of electric power plants within the period under consideration is shown in Table 3[14].

The amount of RES electric power generation has been determined based on the number of hours of operation of the newly installed facilities of WIP (wind power plants) – 2000 hours/year, SEGS (solar electric generating stations) –1800 hours/year; for currently operating RES the electric power generation within the prospective period under consideration has been assumed based on the actually achieved value (at the level of 2015).

Not withstanding the above mentioned problems associated with the progress of alternative power generation, this sector should be developed, as it is exactly this industry that would make it possible to obtain energy in the remote territories of the Sakha Republic (Yakutia) without being dependent of the external supplies of raw materials. Another important argument is represented by the delicate environmental balance of the North of Yakutia that could be easily disturbed. All these facts stipulate the necessity to implement such kind of projects.

Table 3. High-level structure of electric power generation by Unified Energy System of Russia. Source: RF Ministry of Energy. Program for the development of the Unified Energy System of Russia for 2015 - 2021[14]

	Units	Electric power generation		
		2015 actual	change in 2016 2022	2022 forecast
Total, including:	Billion kWh	1026.9	52.7	1079.6
	%	100.0	–	100.0
NPP	Billion kWh	195.3	30.0	225.3
	%	19.0	–	20.9
HEPP	Billion kWh	160.2	28.0	188.2
	%	15.6	–	17.4
CHPP	Billion kWh	671.4	–8.3	663.1
	%	65.4	–	61.4
RES	Billion kWh	0.013	3.0	3.0
	%	0.0001	–	0.3

The implementation of AE projects would be most promising within the program of streamlining local power industry in the Sakha Republic (Yakutia). This program envisages governmental support for the construction of such types of projects.

In Yakutia, several RES projects have been launched, for instance, 1 MW solar electric generating station in Batagay settlement. Commissioning activities have been accomplished over the second half of 2015; in October the performance tests of the solar plant have been carried out successfully, and in 2016 it has been put in operation. The success of this project incited the interest in implementing similar projects in other regions of Yakutia, for instance, in settlements Betenkes, Stolby, Yunkur[1].

The wind farm is scheduled to be constructed in settlement Tiksi. In September 2015 during World Economic Forum in Vladivostok a letter of intent has been signed with Komaihaltec Inc (Japan) that is supposed to result in the construction of 1MW wind power generation park equipped with the energy accumulation system in Tiksi settlement of Bulunsky District. Every year circa 8 thousand tons of diesel fuel are supplied to Tiksi. It is expected that the wind farm will save up to 300 tons of fuel annually. Upon visiting Tiksi the technical experts of Japanese

company Komaihaltec Inc. have preliminary selected the future location of the prospective wind power plant[1].

3.5 Evaluating the Efficiency of RES in the Sakha Republic (Yakutia)

The principal reason for introducing RES is the low price of the generated electric power. For example, the maintenance costs for solar power stations are minimal and their useful life exceeds 20 years. Thus, in the long run these solutions are economically feasible especially given the volatile oil and gas prices.

In Batagay settlement the first stage of 1 MW solar power plant has been accomplished already. To generate this amount of energy with currently applied Diesel Power Stations (DPS), 300 tons of diesel fuel would be required annually. There are plans to expand the station to achieve 4 MW capacities. This could save circa 1200 tons of diesel fuel each year. The principal factors that predetermined the construction of the solar power plant in Batagay settlement are the poorly developed infrastructure and complicated transportation system to deliver fuel for the power generation objects. Verkhoyansk District is the largest in terms of the number of settlements and in terms of the number of DPSs accordingly. In this District there are now 20 DPSs that largely depend on the diesel fuel supplies. Given the adverse climatic conditions and poorly developed transport and logistics infrastructure, the construction of such energy sources is both necessary and economically feasible.

Apart from the new plant in Batagay, Public Joint Stock Company "RAO Energy Systems of the East" are "employing successfully" eight solar power stations in such settlements of Yakutia as Batagay, Yuchugey, Kudu-Kyuyel, Toyon-Ary, Dulgalakh, Eyik, Kuberganya and Yargalakh.

Thus, the construction of RES facilities will make it possible to do the following:

- Reduce the dependency on hydrocarbon fuel and, as a consequence, to reduce the amount of air emissions.
- Eliminate transport expenses associated with fuel supplies.
- Reduce electric power costs for the consumers without any additional capital investments in the nearest future.

Naturally, at the first stage of introducing RES large capital investments will be required. However, considered from the long-term perspectives this projects represent the optimal option that combines the advantages of being independent on hydrocarbon fuel prices and the low-cost maintenance operations for a long time.

4. Conclusion

Notwithstanding the growing interest in the alternative power generation industry, this is not enough by far. High expenses of diesel power generation funded by the federal budget in forms of grants and subsidies for northern supply haul of fuel within the short period of navigation in the Arctic territories of the Republic and for thermal power stations that operate with coal applying the outdated power and especially heat generation technologies that damage the ecology of the environment and that are detrimental to the health of the population should become the drivers for RES power generation growth rates and for the replacement of fossil fuel and highly expensive hydrocarbon fuels represented by diesel and gas condensate fuel, oil, natural and liquefied gas.

Given the fact that electric power is prerequisite for human existence all over the world and that the northern territories also require thermal energy, it should be generated with ecologically clean types of fuel and especially employing the renewable types of energy generation to preserve the health of the population.

To facilitate the development and the introduction of RES in the world the measures should be undertaken in the areas as follows:

- In the area of mutually beneficial cooperation between countries:

The continuing activities have to be carried out to preserve and to improve the environment and to maintain life on Earth. The authors of this study believe that for this purpose the interaction between countries has to be arranged in the first place through the continuous integration of power industry and ecology to establish their synergetic interaction. It is suggested that for this purpose the state should ensure wider interaction with International Renewable Energy Agency and International Network for Sustainable Energy which would imply joint activities in such different areas as healthcare, science and power generation technologies.

The cooperation should result in joint coordination of long-term strategies and programs aimed at the implementation of power generation projects in different countries of the Arctic zone focused on employing and

developing RES. For instance, in the sphere of collecting and exchanging the information on the advanced RES technologies, on the potential prospective development of the technologies taking into account the specifics of functionality and development of power generation industries in different countries; here the people of the Arctic Region would be interested in RES technologies that would fit the extreme climatic conditions of the North.

- In the area of employing RES technologies:

Within the framework of applying RES technology it is suggested that the experience in implementing RES should be shared and the assistance should be mutually provided to facilitate the employment of highly efficient RES technologies. There is also the need for international integration in the sphere of RES technologies research and development in the countries where these technologies have already achieved some progress and keep on progressing; it would be rational to import these technologies by establishing cooperation between the industrial companies to produce RES technologies. Apart from these activities, the domestic industrial companies capable of producing and supporting RES technologies on regular basis should be developed in different regions of the country.

- In the sphere of RES implementation to create favorable conditions in Russia:

Considerable growth of the investments in electric power generation industry has to be stimulated to replace the existing outdated equipment and to install new large-scale RES power generation facilities. Energy and ecological efficiency of electric and thermal power generation should be improved considerably; the formation of the internal Russian power market has to be accomplished envisaging the prospective export of electric power. It is suggested that for this purpose a long-term Single Energy and Power Balance of Russia should be developed taking into account RES power generation.

As for this country, in order to develop RES in the Arctic zone of Russia including the Sakha Republic (Yakutia), the effective mechanisms would be required to stimulate the development of "green power generation":

- In the sphere of legislation and normative regulations.
  - Develop and approve of the Federal Law "On Renewable Energy Sources" and also introduce amendments to the Federal Law dd. 03.26.2003 No. 35-FZ "On Electric Power Industry" and to the Decree of the Government of the Russian Federation dd. 05.28.2013 No.449 "Mechanism for the Promotion of Renewable Energy on the Wholesale Electricity and Capacity Market" to establish the tools to attract investments in RES development and to ensure the return on investments by saving the electric power tariff associated expenses over the pay-back period (average economically substantiated tariff in local generation industry is 36.31 RUB/kWh).
  - Develop and adopt the priority long-term governmental program for RES development and implementation over the whole territory of Russia and in its Arctic territories.

- In the sphere of creating favorable conditions:
  - Industrial and IT-parks, Priority Social and Economic Development Area (PSED) "Kangalassy".
  - Tax benefits for the residents of PSED Areas.
  - Quota-free foreign workforce employment by the residents of PSED Areas.
  - Engaging state budget funds into RES projects within the framework of Public Private Partnership.

All these measures will facilitate the development of alternative power generation facilities in the Arctic zone of Russia including the Sakha Republic (Yakutia) and will result in the improved living standards of the population while preserving the environmental balance in the region.

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