Prospects for Renewable Energy Development until 2035

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Abstract The environmental agenda and the issue of electricity shortage in some regions of the Russian Federation is acute in the industrial areas of the Russian Federation. Introduction of renewable energy sources along with traditional energy sources such as coal, gas, oil, etc. can solve this problem. However, the introduction of renewable energy sources is associated with a number of difficulties and limitations existing in the Russian Federation, at the moment. The paper provides an overview of renewable energy sources, potential for their development in the forthcoming years, threats and opportunities for these technologies introduction, as well as recommendations for the possibility of renewable energy introducing and developing in the Russian Federation

Keywords Renewable energy, Clean energy, Renewable energy perspectives, Solar energy, Wind energy, Hydraulic energy, Geothermal energy.

1. Introduction

Present day energy industry is moving from traditional to digital, more modern and technologically advanced, able to provide reliable and high-quality energy supply. One of the tasks of the "new" energy is the use of renewable energy sources with energy storage systems and smart grids.

Electricity demand is increasingly growing globally, and to meet this demand the government is relying heavily on renewable energy sources. The deployment of this form of energy is accelerating dramatically throughout the world.

The amount of electricity generated using renewable energy sources (RES) is increasing every year. The world's energy systems keep to the path of digital transformation, responding to current challenges of fossil fuel limitations, need to ensure sustainable development and maintain a favorable environmental situation. New materials and technologies used to create generating capacities based on RES allow them to compete with traditional energy sources. This trend should be taken very carefully since the position of RES in Russia is very weak at the moment due to large reserves of carbon fuel. As things stand now, the need to diversify energy assets in the context of renewable energy features, such as the possibility to create distributed generating capacities based on them, is inevitable. While other countries' energy systems with high RES integration begin to actively use the advantages of environmentally friendly and safe energy sources, Russia will probably be "unprepared" for the reason of a low RES technologies support level.

Analysis specified key groups and technologies of RES the development of which is expedient in Russia at the current historical moment. The following types of renewable energy were considered: solar energy, hydropower, wind energy, hydrogen energy, biomass as a fuel, and geothermal energy. Energy industry digitalization will be considered as a tool for RES integration into the energy system.

2. Types of renewable energy sources

2.1. Solar energy

The solar energy significance is easily proven by statistical data. The amount of solar energy falling on a square meter of the Sahara desert per year is 2-3 MW*h; theoretically the desert could provide energy by several thousand times more than all generating capacities today. As for Russia, the technical potential of the Sun (in million tons of standard fuel) makes up 2.3*103. This is the largest indicator of all RES (wind is the second - 2*103). During the year, total solar radiation (on a horizontal surface) can reach 3.5-4.5 kW*h/m2 per day in some parts of the country (southern and southwestern regions); e.g, these figures are by 1.5 times higher than in Germany. [1]

The global solar energy market size amounted to US$170.55 billion in 2020. The global impact of COVID-19 was unprecedented and staggering, solar power witnessed a negative demand shock in all regions amid the pandemic. The solar energy market had a stagnant growth by 4.18% in 2020 compared to the average annual growth during 2017-2019. The solar energy market is also expected to grow from $184.03 billion in 2021 to $293.18 billion in 2028 at the CAGR of 6.9% over the period 2021-2028. The sudden CAGR increase is due to demand and growth of this market returning to pre-pandemic levels after the pandemic was over.

CanadianSolarInc., TrinaSolar and FirstSolar are currently dominating in the market. Companies are increasing their manufacturing capabilities by establishing new plants or focusing on expanding existing ones. For example, in January 2021, SterlingandWilsonSolarLimited (SWSL) successfully installed a 25MW solar project in Oman. Sonnedixhas completed the acquisition of 9 solar power plants with a total capacity of 8.2 MW [2] in July 2020. As for the Russian Federation, there are several enterprises on its territory that produce solar power plants components and all types of cable and wire products for the full cycle of solar modules production. [3-4]

2.2. Hydropower

The significance of hydropower development is stipulated by the cheapest electricity production and highest profitability of energy facilities using water as an energy source. Unlike other renewable energy sources, hydropower is flexible in management (it is possible to regulate the generated energy from minimum to extremely high with the help of turbines), and unlike thermal energy, it is able to quickly gain operating power with minimal performance.

The global hydropower market was valued at $202.4 billion in 2019 and is projected to reach $317.8 billion by 2027, growing by an average by 5.9% from 2020 to 2027. [5]

AndritzHydro USA Inc., GE Energy, CPFL Energia S.A., Sinohydro Corporation, IHI Corporation, Alstom Hydro, China Hydroelectric Corporation, China Three Gorges Corporation, ABB Ltd and Gerdau S.A. are the key players operating in the global hydropower market. The total capacity of HPPs on the territory of the Russian Federation makes up 4% of the total world capacity within a few past years; the average annual increase in capacity is 0.4%. [2] As for its hydropower potential, Russia ranks second in the world. At the moment, about 20% of the economic hydropower potential has been harnessed throughout the country. The total gross (theoretical) of hydropower potential in the Russian Federation is specified as 2,900 billion kWh of annual electricity generation. The potential of large and medium-sized rivers is 2400 billion kWh, or 83% of the hydro potential.

2.3. Biomass as a fuel

Trees and plants suitable for burning as well as crops, sewage waste, manure, and landfills are regarded as biomass. However, one should take into consideration that the difference between produced and processed biomass of the planet is about 75 billion tons. [6]

The global market size of biogas produced from waste was estimated at $52.9 billion in 2020 and is projected to reach $126.2 billion by 2030, growing by an average by 8.5% from 2021 to 2030.

Biofuel is primarily used for vehicle fuel and industrial applications such as municipal energy generation and on-site power generation. Organic nutrients collected throughout the production process enhance the circular economy effect of biogas production. [7]

As for the key players, studied and profiled in the report, are the following ones: AAT Abwasser – und Abfalltechnik GmbH, BekonBiogasEnergyInc., Biogen Greenfinch, Cargill Inc., ClarkeEnergy, Environmental Products & Technology Corp., N-bio GmbH, Siemens AG, WELTEC BIOPOWER GMBH and ZorgBiogas. The report on the global market of produced biogas provides an in-depth competitive analysis as well as profiles of these major players.

2.4. Geothermal energy

The Earth's great energy potential and advanced technologies development facilitate another type of renewable energy - geothermal energy; it gets electrical energy by converting thermal energy of the Earth's depths. Along with an almost inexhaustible supply given by hot springs, geothermal energy does not depend on weather conditions and seasons. From an ecological point of view, geothermal energy is one of the safest, however, combustible or toxic gases contained in the rocks of the earth's crust can be released through production wells. But appropriate use of geothermal energy can minimize environmental risks. [8-9]

The geothermal energy market size was US$52.87 billion in 2020. The market is expected to grow from $55.80B in 2021 to $83.27B in 2028 at 5.9% of the CAGR over 2021-2028. 12 new projects were commissioned each year in average in Europe between 2010 and 2019; in 2020, not a single project was approved in this sector. In Europe this industry development was halted in 2020, with only two existing projects completed. [10]

2.5. Wind power

Wind power is currently the world's second largest renewable source, accounting for about 6% of global generation. Therefore, wind generation today is a topical global trend in the field of electricity generation; it has a significant potential. In many developed countries, as well as in areas where centralized power supply is not available, for example, islands or, which is typical for Russia, a huge number of regions difficult to access for power supply, wind generation will be competitive. The significance of the direction is that wind power can reduce emissions; it is important as it solves problems related to environmental pollution and climate warming that, in turn, contributes to the implementation of the Paris climate agreement and other agreements related to environmental issues.

The global wind power market size was estimated at $62.1 billion in 2019 and is projected to reach $127.2 billion by 2027, increasing by 9.3% from 2020 to 2027 (Fig. 1). [11-12]

The COVID-19 pandemic has severely impacted wind turbine manufacturing in countries such as China and Germany. For example, in 2020 German Nordex SE reported negative EBITDA of $86.5 million compared to positive EBITDA of $21 million in the previous financial year. Within several months of 2020, pandemic-related restrictions disrupted supply chains, made most of the wind power workforce unavailable, delayed or canceled auctions and investment, and forced delays or cancellations of construction projects in many countries, especially in the land-based sector. Despite global health, economic and political challenges the total global wind power capacity increased by 14% by the end of the year in comparison with 2019 and reached 743 GW. Just six years earlier, at the end of 2014, this was twice the current capacity worldwide.

Vestas (Denmark), GE RenewableEnergy (GE, USA), Goldwind, Envision (both Chinese enterprises), SiemensGamesa (Spain) and Mingyang (China) were the top six turbine suppliers in 2020. They have over 63 GW of installations. Vestas remains at the top for the fifth year in a row, GE delivered record global volumes and benefited from a strong domestic market as well as Goldwind (which also delivered over 1 GW of turbines to overseas markets for the first time), Envision, Mingyang. and SiemensGamesa dropped from number three in 2019 to number five in 2020.

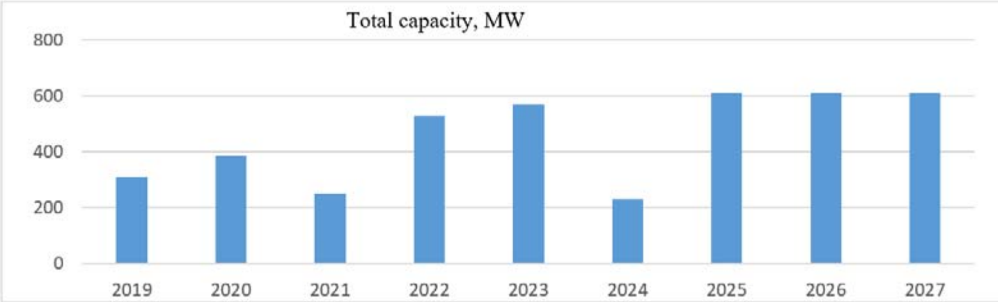

Fig. 1. Forecast values of changes in the increase in WPP capacity.

2.5. Hydrogen

Green hydrogen is produced through a process called electrolysis in which water is split into oxygen and hydrogen using energy supplied from renewable sources. Cost reducing of reusable energy and electrolysis technology will increase the demand for green hydrogen, promoting the growth of the global green hydrogen market. Several industries, including oil and gas, steel, utilities and fertilizers, are turning to green hydrogen to balance the intermittent nature of reusable resources. Electrolysis produces only about 5% of green hydrogen worldwide. Modern hydrogen production is based mainly on natural gas and coal, which together make up 95%. Today, hydrogen production from renewable energy sources is practically not carried out. However, the first industrial project LacqHydrogen, located in France and Spain, is currently operating; it is a part of the Spanish GreenCrane project for the production and export of renewable hydrogen through pipelines.

In 2021 the demand for the global green hydrogen market size and share approximately amounted to US$0.8 billion, and it will reach around US$10.2 billion by the end of 2028, registering the CAGR of 55.2% within the period (2022- 2028).

The key market players are: Green Hydrogen, Uniper SE, Nel ASA, Air Products and Chemicals Inc., Engie, Hydrogenics, Air Liquide, Toshiba Energy Systems & Solutions Corp, Linde, Siemens.

At the moment, green hydrogen readiness in the world is at TRL=8+. In Russia, the level of TRL for some technologies can reach the value of 7. IRENA calculated that the cost of hydrogen plants could fall by about 40% in the short term and by 80% in the long term (Fig. 2) (when economies of scale in technology and production are achieved).

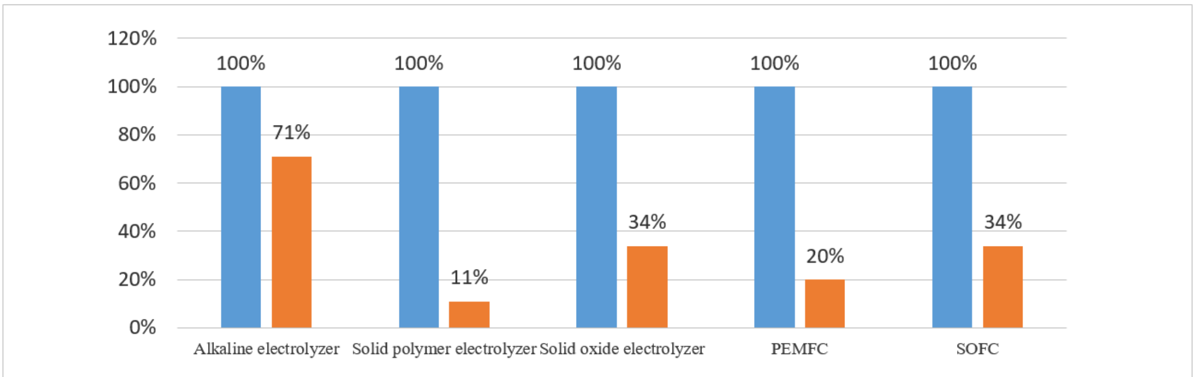

Fig. 2. Technologies with the greatest potential for cost reduction.

2.7. Digitalization technologies

The process of switching to environmentally friendly energy sources cannot be limited to the construction and launch of generation facilities. Their integration into the existing energy system is required. To ensure the reliability and uninterrupted operation of the energy system after renewable energy generation facilities introduction (with the variability of generation in view), it is also necessary to introduce additional tools capable to monitor the parameters of RES (generated energy in real time, equipment parameters) [13].

The spread of RES leads to the emergence of many small generation facilities in a large area of prosumers. Digitalization of the energy sector of the economy contributes to the reduction of barriers and energy system development based on environmentally friendly energy sources; besides it promotes RES integration into the existing energy system, and reduces pollutant emissions from already functioning traditional generation facilities. The International Renewable Energy Agency identifies the following key groups of digital technologies that contribute to the introduction of renewable energy: the Internet of Things, Artificial Intelligence and Big Data, Blockchain [14].

The global digital transformation market was valued at $998.99 billion in 2020 and is expected to reach $2744.68 billion by 2026, at the CAGR of 17.42% over the forecast period 2021-2026.

3. Setting of the problem

Based on an analysis of the current state of renewable sources in the Russian Federation under the following scenarios: negative, conservative and innovative. When conducting a scenario analysis, it is necessary to conduct a qualitative study mathematical methods to obtain more accurate data. Based on the conducted scenario analysis, it is necessary to form recommendations for each of the three scenarios for pursuing the policy within the chosen direction for the Russian Federation.

4. The theoretical part

A mathematical model has been constructed to assess the prospects for renewable energy development in Russia. The design of the model is based on multiple linear regression analysis, which involves a statistical method of estimating relationships between variables to simulate future dependence [11].

In the modelling, the task was to determine the relationship between the selected predictive value, the number of published scientific articles and the overall trend in the procurement of RE technologies. By obtaining the correlation of these three parameters, the model predicts the behaviour of one or the other criterion as a function of time. To solve this problem, the necessary amount of article and procurement data was downloaded using the parsers of the E-Library article website and the Sberbank procurement website. The data was then loaded into the model with the procurement data and the number of articles since 2010.

The technologies procured by the majority of large companies were selected to obtain the RES development trend. For each trend, a keyword relating to the digital technologies being introduced was chosen, shown in the Table 1.

Table 1. Calculation parameters for the model.

Industry	Keyword	Number of articles	Criterion
Solar energy	solar panel	1467	power
Hydropower	real time digital simulator	1296	capacity management efficiency
Biomass as a fuel	*biomass*	456	power
Digitalization technologies	digital twin	2278	accident rate
Hydrogen	hydrogen energy	798	power
Wind energy	wind generator	1546	power

The predictive ability of the model can be assessed by calculating statistical parameters, i.e. by calculating existing data and comparing it with real indicators. The model uses a time lag between the analysed and the describing indicators, the value of which is 2 years. The introduction of a lag is due to the fact that the linear regression algorithm requires a certain minimum sample size. The accuracy of the model is assessed by means of instruments such as coefficient of determination and root-mean-square error.

5. Practical significance, suggestions and case studies, the results of experiments

Based on this analysis, plausible scenarios for renewable energy development in the Russian Federation have been generated. Three possible scenarios have been identified: negative, conservative, innovative.

The negative scenario is characterized by: Lack of international linkages, development of technologies exclusively in-country, which may significantly slow down the development of technologies in-country; Only technologies with significant backlogs in-country can be developed. The leader is hydropower, which is widespread throughout the country; It is possible to develop renewable energy only at the expense of the country's own resources, which will require substantial material expenses for research and development; Possibility to develop RES only in regions with significant potential for implementation. In the case of hydropower, deployment is likely in mountainous regions, where mini-HPPs can be located without significant environmental impact.

The scenario may only be realised if international relations deteriorate and the country is fully isolated. Scenario implementation is probable, but not to a critical degree.

The conservative scenario is characterised by: Interaction exclusively with friendly countries (the Middle East, China, Belarus, etc.) and the exchange of experiences within the framework of cooperation between friendly countries; Development of currently developed technologies: Hydropower, Solar Energy, Wind Energy, partly Geothermal Energy; Development of technologies within scientific clusters and institutes within the country, gaining knowledge and experience by conducting their own tests and experiments; Lack of quality control by international organisations, need for development of normative documents), including issuance of GOSTs and TSs); Development of technologies in regions with the most favourable conditions for RES location (Rostov Oblast, Krasnodar Krai, Republic of Dagestan, etc.).

This scenario is considered by our team to be the most feasible, as it does not require additional funds, which are not easily available under the current conditions. Implementation of this scenario assumes a moderate pace of technology development inside the country and is achievable until 2035.

The innovative/positive implementation scenario is characterised by: Exchanging experience with the leading countries in the renewable energy sector (Denmark, Germany, Japan, Portugal, Sweden, Austria, etc.); development of wind energy, solar energy, hydropower, hydrogen energy, biofuels, geothermal energy without significant limitations; Training of personnel according to international standards, organization of traineeships in companies of the leading countries in the field of technologies for obtaining knowledge in the field of RES technologies; Implementation of international standards, ensuring safe and environmentally friendly energy production at RES facilities; Development of RES on a larger territory of the country through the spread of RES not heavily dependent on weather conditions (mini hydro power plants, biomass energy, hydrogen energy); Reach the maximum level of technology readiness (TRL 9) of RES on the territory of Russia until 2035.

This scenario is less likely to be implemented, as it will only be possible due to international relations, cooperation with scientific communities in leading renewable energy technologies and a substantial amount of financial resources. The 2035 scenario is unlikely, as it involves many factors that are difficult to influence domestically.

Renewable energy development is impossible without government incentives until RES becomes a competitive segment on its own. Promotion consists of financial and legal support development.

Initiatives in the field of renewable energy development, technologies, active popularization among population are essential. Availability of information on the formation and implementation of measures for renewable energy development and realization of technical and technological control and supervision over compliance with safety requirements when using renewable energy sources can contribute to its accomplishment.

Conditions for a continuous searching process and practical implementation of new scientific, technical, technological, organizational and economic solutions within the framework of nationwide regulation and a clear system of interaction between all participants in the innovation process should be created.

This strategy requires development and regular updating of power industry generating facilities layout on the basis of renewable energy sources on the territory of the Russian Federation; location of productive forces, prospects for regional socio-economic development and resource base, including projects for construction new and reconstruction of existing generating facilities operating on the basis of renewable energy sources should be taken into consideration. Favorable conditions for attracting extra-budgetary investments in order to build new and reconstruct existing generating facilities operating on the basis of renewable energy sources, and the use of venture funds to invest in renewable energy facilities ought to be established.

Furthermore, a grant system and subsidies are required to stimulate renewable energy development. Besides, close cooperation and gaining experience from such leading countries as China, India, Brazil, Vietnam, Turkey, Philippines, Mexico, Indonesia, UAE, Singapore, etc. in the field of renewable energy development are essential for successful renewable energy technologies introduction.

Clusters and educational laboratories on the basis of institutes or large energy enterprises, for example, MSTU. N.E. Bauman (Moscow), NRU MPEI (Moscow), Kazan State Power Engineering University (Kazan), IIET RAS, IK SB RAS, etc. are of great significance.

6. Recommendations for renewable energy development in the Russian federation

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7. Conclusion

RES development contributes to ensuring uninterrupted electricity transmission, environmental risks reduction (including fuel spills, emissions of harmful substances into the atmosphere, etc.), as well as cost decrease of fuel and raw materials imported into the country. On the other hand, renewable energy development requires high costs when it comes to technology introduction, equipment maintenance, personnel training, etc.

Moreover, the loyalty of the state and population is regarded as an important factor for the success of renewable energy introduction in the Russian Federation. This can be ensured by promoting emissions reduction and technological improvement of the country's industries.

At present, Russian population experience the lack of business planning culture, their intension to invest money into projects is practically at a zero level. In many cases, the formation of homeowners associations (HOA) is impossible due to general inertia and lack of financial incentives among the population. At the same time in Western countries, consortia called Local Energy provide grant support for project research, help with advice on how to get government grants, advise on asset management, present examples of successful projects, give money except to partnerships and small businesses. Funding sources for such organizations are voluntary contributions from participants and funds of charitable foundations. As for Russia, we should start with prosumer culture formation through informing the population about implemented practices; this will make people understand real mechanisms of renewable energy introduction, and will contribute to the confidence in project implementation possibility.

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