ANALYSIS OF ECONOMIC FACTORS AFFECTING DEVELOPMENT OF RENEWABLE ENERGY FOR POWER SERVICE OF REMOTE CONSUMERS

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ABSTRACT
The development of renewable energy sources (RES) for innovative energy supply to remote and isolated consumers is an opportunity to improve life quality of the population, which still does not have access to centralized energy supply. This paper examines the factors that affect the decisions on renewable energy technologies for high-quality, reliable and affordable power supply to remote areas. The study of economic viability is of paramount importance among all factors in conditions of limited funding. For Russia it is especially actual in connection with the peculiarities of the fuel and energy balance. The authors suggest that despite the low cost of traditional energy resources in Russia, the use of innovative technologies can be economically viable for the specific regions. At present, there are not enough studies searching for the most cost efficient and advanced economic solutions. There are no methodological and practical recommendations to foster sound decision-making. The authors analyzed a pilot program for the development of wind power in 23 communities of the Yamal-Nenets Autonomous Region. A preliminary renewable electricity cost evaluation of wind power supply was carried out. An algorithm has been developed for assessment of RES economic viability in the region, depending on the existing energy supply system and the electricity rates. The results of the studies can serve as the basis for the formation of a sound public policy in the field of development of renewable energy sources in remote regions and isolated energy systems, determining the volumes of financing and evaluating the viability of specific projects.

Keywords: remote consumers; renewable energy sources; economic efficiency, innovations, factors of development

Introduction
The market of renewable energy technologies (RES) is the fastest growing energy sector. Over the past decade, the capacity of renewable power plants has doubled from 994 GW in 2007 to 2011 GW in 2016. Thanks to renewable energy, world's generating capacity increased by 161 GW in 2016 (IRENA, 2017).

Investments in renewable energy in 2016 amounted to $ 263 billion and remained stable despite the impact of different dis incentive factors, such as: fall in global prices of all types of fossil fuels, further financial support of traditional energy, increased legislative and political instability and the integration
of expanding renewable generating capacities. Compared to 2013, investments grew by 10% (IRENA and CPI, 2018).

Remote regions of developing countries, where the use of the traditional centralized model of energy supply is inexpedient, are the main market segments, here we can find ample opportunities for use of renewable energy. Seventeen percent of the world's population (almost 1.2 billion people) do not have access to electricity nowadays, most of them live in the Asia-Pacific and sub-Saharan Africa.

The installed capacity of distributed renewable sources has increased four times since 2007, reporting 4 GW at the end of 2016. The largest share of decentralized RES facilities is in Asia (59%), Africa (22%) and South America (10%). Every year, the role of distributed RES only increasing. In Asia, the average annual growth exceeds 30% in 2007, and in Africa about 20%. The development of decentralized RES technologies allows to meet the energy needs of remote consumers in India, China, Bangladesh, Algeria, the Democratic Republic of the Congo, South Africa (IRENA and CPI, 2018).

The need to optimize energy supply in local power systems in Russia is associated with the complexity of logistics in remote areas, severe climatic conditions, the intention to improve the quality of life of people who do not have access to centralized sources of energy and heat. The greatest challenge is to provide electricity to isolated power systems of Far North, the Arctic and the Far East, where new promising deposits are concentrated, and strategic social and economic projects are implemented.

A key solution to the problem of electricity supply to remote regions is the construction of medium-capacity stations using renewable energy sources. The urgency of the study of economic factors affecting decision making process for the implementation of RES into isolated energy systems is driven by the need to assess the feasibility in terms of cost-effectiveness of various energy sources. For Russia, the cost-effectiveness of RES is of the utmost importance, considering the reserve of natural resources and the high level of conventional energy generation development, running on natural gas, the cost of which in domestic market is below world prices.

Review of relevant studies
Various research methods have been offered and applied by scholars to determine the influence of different factors on the RES development in the country. For example, in order to assess the factors of innovative energy supply in each of the selected areas, Önüt S (2008), Kablan MM (2004), Köne AÇ (2007), Ulutas BH (2005) apply the analytic hierarchy process (AHP) approach and analytic network process (ANP) approach. Another group of scientists: Oberschmidt J (2010), Kowalski K (2009), Topcu YI, Ulengin F (2004), Cavallaro F (2009) etc. propose a preference ranking organization method for enrichment evaluation (PROMETHEE) - an interactive method for solving discrete multi-factor tasks. There are some other interesting methods. For example, the elimination and choice expressing the reality (ELECTRE, “ELimination Et Choix Traduisant la REalité”), method of narrowing the Pareto set of alternatives covered by Salminen P. (1998), Goletsis et al (2003), Cavallaro (2010).

The study of publications focusing on the investigation of factors influencing on the efficiency of RES brings us to the conclusion that one- and multi-criteria models have become the most widely used.

Traditional single-criteria models for assessing efficiency are simple to use, but they do not consider the complexity of the environment for the operation of innovative power supply systems.

Multi-criteria models of efficiency evaluation, on the contrary, provide flexible scientific and technical methods and tools for processing and consolidating a wide range of factors that are expressed by variables of different types, and, therefore, create a reliable information base for comprehensive decision-making in the field of innovative energy which accounts a whole number of often contradictory aspects due to the increasing complexity of social, technological, environmental and economic factors of energy supply development.

The study of the scientific publications devoted to the research of the influencing factors on the development of innovative energy supply allows us to distinguish four main areas of application of valuation models: the assessment of factors at the planning stage and the public policies development in the field of innovative energy supply technologies; an estimation of factors of production and consumption of a certain type of renewable energy; an assessment of the implementation of innovative technologies (evaluation of the effectiveness of the project); evaluation of the development of energy supply on the basis of RES from the point of view of the impact on the environment, ecology and climate.
The key factors affecting the development of decentralized RES systems have been classified in the work of the Bondarchuk N. et al. (2017) as follows:

1) natural and climatic factors;
2) technical factors;
3) legislative and institutional drivers;
4) financial factors;
5) political
6) qualification factors;
7) factors of competition;
8) environmental factors;
9) factors of reliability;
10) cost of energy resources.

The last group of factors is crucial for ensuring global competitiveness of renewable energy technologies. According to IRENA (2018) the global weighted average total installed costs demonstrate regular decline since 2010 for concentrating solar power, solar photovoltaic, onshore wind. For comparison, the average total installed costs for solar photovoltaic in 2017 was 1388 dollars / kW, while in 2010 this value was 4394 dollars / kW, for concentrating solar power, the average total installed costs decreased from 7583 USD / kW in 2010 to 5564 USD / kW in 2017. One of the most competitive technologies of renewable energy - onshore wind, here the average total installed costs as of 2017 amounted to 1477 USD / kW, which is almost 20% lower than in 2010 (1,843 USD / kW).

Despite the fact that cost is a key factor limiting the use of renewable energy, specialized studies of factors that affect its development are not sufficient and use limited amount of data. The economic issues of RES are considered in research papers of Edenhofer, Hirth and Knopf (2013); Dvorak et al. (2017), Savinoa et al. (2017). The study by Cicea and Marinescu (2014) is about the effectiveness of investments in RES from the point of view of their impact on the environment. The work of such scientists as Dvorak and Martinat (2017), Savinoa et al. (2017) are devoted to research in the field of renewable energy. The evaluation of investments in the development of RES in the Russian Federation is presented in a study by Nazarova, Sopilko et al. (2017).

While global trends indicate the cost reduction in RES generation, the need to localize production of equipment that considers Russia's climatic and logistical features increases the cost of renewable energy. Another significant factor affecting the development of renewable energy in Russia is the considerable reserves of minerals that must be accounted even for isolated power systems. Based on the analysis of existing literature, we can conclude that the study of economic factors that determine the feasibility of RES for remote territories in Russia that address the climatic and logistical features of the territories, as well as the proximity of traditional sources, has great importance.

Research methodology
The methodological basis of this study was the assessment approaches of economic efficiency provided in “Methodological recommendations for assessing the effectiveness of investment projects” (1999) and based on the modeling of monetary projects with discounting.

The authors proposed the following algorithm for assessing the economic factors affecting the development of renewable energy in the region:

1. Identification of promising localities for possible optimization of the structure of energy supply.
2. Analysis of the current energy supply system.
3. Cost of electricity valuation according to the list of communities.
4. Construction of financial and economic models of innovative energy supply for each locality.
5. Assessment of the overall RES development program efficiency in the region.
6. Drafting recommendations on implementing of innovative technologies in the region.

The preliminary program for wind power development in the Yamalo-Nenets Autonomous Region (YNAO) was drawn up to study the economic factors affecting the application of renewable energy sources in remote areas.

As initial data, we used information on 23 communities of the Yamal region, parts of the Tazovsky and Ural regions of the Yamal-Nenets Autonomous Region.
For the research, the selected communities of YNAO were divided into two groups: the first calls for the construction of wind-diesel systems based on self-supporting off-grid diesel power stations and the second in gasified communities.

To assess the feasibility of applying RES, we calculated the following economic performance indicators: net income, net present value (NPV), payback period simple and discounted, internal rate of return (IRR).

These indicators were calculated for each human settlement on the basis of the existing electricity rates in 2016. The initial data on current electricity rates was taken from the Tariff Policy, Energy and Housing and Communal Services Department of the YNAO.

Table 1: Average single-rate tariffs for 2016

<table>
<thead>
<tr>
<th>Communities of the YNAO (villages)</th>
<th>Single-rate tariff, RUR / kW • h</th>
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<tbody>
<tr>
<td>1. Aksarka, Beloyarska, Tovopogol, Zeleny Yar, Harsaim, Vylposl, Laborovaya, Katrovozh, Shchuchye</td>
<td>19,9245</td>
</tr>
<tr>
<td>2. Tazovsky Gas-saale, Antipayuta, Nakhodka</td>
<td>11,065</td>
</tr>
<tr>
<td>3. Yar-Saale, Salemal, Panaevsk, Seyakha, New Port, Cape Kamenny (Central Power Plant + Diesel Power Station Airport), Sounai-Sale</td>
<td>23,777</td>
</tr>
<tr>
<td>4. Gyda</td>
<td>28,541</td>
</tr>
<tr>
<td>5. Harp</td>
<td>8,074</td>
</tr>
</tbody>
</table>

As technical equipment, we have chosen the installation of the NPS 100 Arctic Turbine, wind turbine, manufacturer Northern Power Systems, operating under severe climatic conditions like the Yamal-Nenets climate. The capital investments in the project were estimated considering the climatic and logistical features of the remote areas of the Yamal-Nenets Autonomous Region and amounted to $2,900 / kW.

**Results and Discussion**

As part of the study of economic factors impact, we carried out a preliminary assessment of the economic efficiency of wind power stations for energy supply of consumers in remote areas (YNAO). The purpose of the assessment was to determine the efficiency of renewable energy generation in comparison with the existing electricity rates in the region.

Our aggregated calculations for 23 communities showed the economic feasibility of implementing projects in certain specific locations at current electricity tariffs.

![Fig. 1 - The results of construction efficiency calculations for wind power stations in communities of YNAO at tariffs of 2016 (more than 20 rubles / kWh) and a discount rate of 15%](image-url)
The results of the calculations showed the feasibility and economic efficiency of wind energy generation for the selected communities with a single-rate tariff for electricity above 20 rubles / kWh, which is explained by significant investments in the construction of wind power stations in remote northern territories (Fig. 1).

However, for the second group of gasified communities with a single-rate tariff of less than 20 rubles / kWh (Fig. 2), we can state that the use of renewable sources is inappropriate.

Thus, analyzing the economic factors impacting the development of RES in the region, it is necessary to consider the climatic, logistical, technological features of the territory that affect the total amount of capital investments in the project for the construction of the RES facility, as well as the existing energy supply system.

Summing up, it can be noted that despite the urgency of the issue of stimulating of alternative energy supply for the power supply of remote territories, so far, the variety of factors influencing this process has not been sufficiently studied.

The methodological approaches proposed in this work to assess the feasibility of using innovative technologies for energy supply to remote areas of Russia will partially contribute to the solution of these problems.

In the current study, we did not pay much attention to a multifactor evaluation of the development of renewable energy in isolated energy systems in remote areas. In addition to research on economic factors, the next steps of the study should include some other criteria that may affect the performance indicators when implementing RES investment projects. In this paper, it is justified that the amount of investment in innovative sources of energy supply influences the decision-making and taking a position on the desirability of implementing an innovative project in remote areas. To assess this impact, we propose the use of approach to assessing the economic efficiency of investment along with a mandatory analysis of the current situation in energy supply and the cost of electricity in the region.

An evaluation of the efficiency of power plant construction projects for wind generation in YNAO has been carried out. The obtained results demonstrate the dependence of the expediency of applying renewable energy sources on the tariffs prevailing in the region. It is necessary to form a sound development program that would account socio-economic factors. Further prospects of the research would focus on the formation of a model which considers the factors contributing the costs of RES development depending on the size of the investment, and which would make it possible to ensure the economic efficiency of RES projects in the region. Understanding the factors influencing on innovative energy supply for remote consumers and the possibility of its quantitative and qualitative assessment will improve the quality of management of technological innovations at both national and sectoral levels. This should accelerate the replacement of traditional sources of power supply to remote consumers with better, cheaper and more environmentally friendly innovative sources.

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