Development of electricity industry on the basis of the use of the renewable energy sources in the regional energy security system

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Abstract. In the article presented, the authors prove the objective need for the development of the electricity industry of the Republic of Crimea on the basis of the active use of the renewable energy sources, caused by the world processes of the formation of the "green" economy. The object of the study is the territory of the Republic of Crimea - a bright representative of the energy deficit region. The development of the electricity industry of the Republic of Crimea on the basis of the use of the renewable energy sources serves as the basis for ensuring regional energy security, the fragility of which was determined by the political events of 2015. The authors studied the research papers of leading domestic and foreign scientists devoted to the analysis of the renewable energy sources in order to justify the further active development of a wind energy, a solar energy as well as bioenergy and landfill gas energy in the Republic of Crimea. The development of the Republic of Crimea's electricity industry through the use of the renewable energy sources and local fuels is an essential area of modern active regional policy. It is determined by the fact that this direction, firstly, is considered as environmentally friendly generation, and secondly, contributes to a qualitative increase in regional energy security level.

1 Introduction

The Doctrine of the Energy Security of the Russian Federation, approved by the Decree of the President of the Russian Federation dated May 13, 2019 No. 216 interprets energy security as "the state of protection of the country's economy and population from threats to national security in the field of energy, in which compliance with the requirements for fuel and energy supply to consumers stipulated by the legislation of the Russian Federation is ensured, as well as the fulfillment of export contracts and international obligations of the Russian Federation" [1].

The concept of " the energy security" was first introduced into scientific and practical circulation in 1947 as part of a regulatory document adopted in the United States regulating the actions of the state in the field of ensuring national security [2]. The concept of energy security was formulated by the International Energy Agency after the oil crisis in 1973 in the

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following interpretation: energy security is "a matter of confidency that energy will be available in the quantity and quality required under these economic conditions" [3].

Theoretical and methodological aspects of the energy security study of regions with various levels are presented in the research papers of a whole pleiade of the Russian scientists [4 - 11].

The dominance of different sources of energy plays a crucial role in global industrial and technological development. In particular, the founder and the executive chairman of the World Economic Forum in Geneva, K. Schwab, mentions: "The basis of the first and second industrial revolutions were transformations in the energy sector. Initially, it was a transition to using steam energy, and then electricity itself. Now, at the beginning of the Fourth Industrial Revolution, energy is on the verge of a new historical transition: from fossil fuels to a renewable energy "[12, p. 219].

The renewable energy sources are viewed as sources of constantly operating or periodically occurring processes in nature, as well as the life cycle of the plants', animals' world and human activity.

An American scientist, recognized authority in the field of energy, international politics and economics Yergin identified seven main types of the renewable energy:

"1. A wind energy is the largest non-water renewable source, which provides energy to technologically complex plants that generate electricity, whereas the aggregate of which is called a wind farm.

2. A sunlight is captured by photovoltaic converters, mirrors or other devices that convert light and transform it into electricity.

3. A biofuel includes ethanol, bio-diesel and modern types of biofuel (from algae, cellulose or other raw materials), which substitute gasoline, diesel fuel or even aviation fuel.

4. A biomass encompasses wood or other plant material briquetted or otherwise treated and burned in a power plant; it also includes wood or manure that are burned for heating and cooking in the developing countries.

5. A geothermal energy is a hot water or steam that rises from underground to the surface and drives a turbine that produces electricity.

6. A hydropower means a falling water or pressurized one that drives turbines, but dams are increasingly criticized by environmental organizations, and therefore it is not easy to build them in many countries.

7. A passive use of solar energy (or passive solar systems) are also called "green houses" nowadays; due to their location in the natural environment, they reduce energy consumption, which echoes the concept of energy efficiency" [13, p. 487].

In addition to the seven main types of the renewable energy sources, Yergin highlights the usage of ebbs and flows' energy alongside with the waste energy generation.

The renewable energy technologies combine the following important characteristics: "They are not based on limited resources, they are not limited to any territories and, at least theoretically, do not lead to an increase in carbon dioxide emissions.

It is necessary to add another technology in this list - batteries for electric vehicles or an electric grid... They can be considered as a renewable source of energy only in the case if the electricity to which they are recharged is the product of both a wind or a sunlight "[13, p. 488].

The renewable energy application enables to solve the following global problems [12, 13, 14]:

- to overcome the dependence on fossil fuels determined by the First Industrial Revolution;
- to reduce the cost of energy production (excluding initial costs), resulting in price reduction;
- to reduce budgetary subsidies for energy supply to small towns;

- to weaken the negative impact of energy on the natural environment;
- to create an additional incentive for the high technology's development
- to improve the population comfort in territories at various hierarchical levels;
- to create a sustainable future for the rich and poor, for the urban and rural population.

As a part of the technology disclosure of the Fourth Industrial Revolution, its ideologist K. Schwab formulates the following key conclusions in terms of the process transformation of the energy production, as well as its storage and transfer as a result of the renewable energy sources usage:

"The Fourth Industrial Revolution could stop the world's dependence on fossil fuels and the greenhouse gas-related energy production process that had emerged from previous industrial revolutions. Nowadays this challenge is more urgent, because a climate change becomes more visible due to the world's population and the economy industrialization growth; as predicted, a global energy demand is projected to double by 2040. "[12, p. 229].

" In order to accelerate the growth rates and embrace more sectors of the economy, it is worth providing the transition to the renewable energy needs. Today it is necessary to make long-term investments in order to take advantage of the results in the coming decades, especially for the fast-growing regions [12, p. 230].

"New technologies in the energy sector are being explored - from the use of tidal energy to thermonuclear fusion, as well as advanced materials and nanotechnologies" [12, p. 230]. According to the scientist, this will increase efficiency and reduce the energy losses. "Intelligent networks complemented by artificial intelligence capabilities, as well as dynamic redistribution of electricity and the use of battery-powered vehicles will provide an opportunity to ensure widespread efficiency improvements at all levels" [12, p. 230].

However, according to K. Schwab, the renewable energy development can have negative consequences: "A large-scale transition to the renewable energy gives rise to fear for the fossil fuel industry, as well as creates a threat to the relevant long-standing geopolitical structures" [12, p. 230].

The renewable energy in today's society is viewed as a key solution to power supply, energy security and climate change.

Moreover, Yerging cites vivid examples of government decisions: the head of the People's Republic of China declared that China should "take advantage of the opportunities opened at a new stage of the world energy revolution. The European Union has set a goal of reaching a 20% share of the renewable energy sources by 2020, providing the status of the greenest government in the history. In 2015, the Brazilian President D. Rousseff and the US President B. Obama announced that their countries are committed to increasing the share of non-water renewable sources in electricity generation to 20% by 2030 "[13, p. 488]. According to B. Obama, "A country that is the world leader in creating new sources of energy will lead the global economy of the 21st century." [15]

Raising prices for traditional energy resources, which began in 2003-2004, narrowing the cost gap between the renewable and traditional energy sources, as well as the global problem of climate change, have become the significant factors in the energy policies of the developed countries of the world, increasing investments in the renewable energy sources. As a result of venture capital influx, the renewable energy sources have been called "clean technologies."

There are attempts to estimate "the scale of the renewable energy in monetary terms. Global renewable energy investments reached $200 billion in 2014, up four times since 2005. Today, the renewable energy accounts for about 12% of the world's energy generation capacity. But their share in the newly introduced generating capacities is growing rapidly - in 2011-2014 it amounted to more than a third "[13, 505]. All this enables to argue that the renewable energy sources are becoming a significant high-tech industry.

However, nowadays the high capital costs of the renewable power plants, the probabilistic nature of generation and the low value of installed capacity utilization do not completely replace the traditional energy sources.

2 Materials and methods

The above mentioned theoretical and methodological aspects of the renewable energy sources' investigation are of great relevance justifying development directions of the electricity industry of the Republic of Crimea, since this territory is an energy-deficient region. The attempts to make it non-volatile have been made since the Soviet times, but even in the XXI century the peninsula suffered from the lack of its own capacities.

It is worth pointing out that "the energy system of the Crimean Peninsula began to take shape quite late, i.e. in the 30s of the XX century. Before that, a light was supplied only to the Livadia Palace of the imperial family and to the houses of several wealthy residents of the city of Simferopol - the first power station in the region was built for them in 1896.

Four thermal power plants (CHP) were built for industrial needs in the period from 1936 to 1961, which still remain the main sources of power.

In the 1950s, the Ukrainian SSR began to implement its concept of the Crimean energy system development, resulting in construction of four power lines, which connected the peninsula with the continent. There were plans to build its own nuclear power plant, but the plans have never come true due to the Chernobyl disaster.

For a while, the CHP energy and megawatts coming from the Kherson region were enough, because the industrial production in Crimea was declining.

The issue of the energy deficit was raised again in the 1990s. At the same time, it was decided to rely on an alternative energy – a wind and solar power plants, which, despite all the pluses, can hardly become the basis of the energy system "[16].

With these problems, Crimea existed until the reunification with Russia in 2014. After this historical event, reserved autonomous capacities were transferred to the peninsula, which previously provided reliable energy supply to the Sochi Olympics.

It should be noted that energy is a large branch of the modern economy of the Republic of Crimea. The peninsula possesses substantial energy reserves and the renewable potential. Gas and oil production is carried out, as well as the production of electric and thermal energy. Crimea's energy system is heavily dependent on the external supplies of electricity and petroleum products.

The analysis of the absolute values dynamics in terms of electricity production in the Republic of Crimea demonstrates a significant increase, which amounted to 1835.4 million kWh for 2017-2019. (Table 1).

Table 1. Dynamics and structure of electricity production in the Republic of Crimea

	2017	2018	2019	Indicator Change 2019 in comparison with 2017
Electricity, million kW. h	1868,8	2212,4	3704,2	+ 1835,4
including:				
electricity produced by thermal power plants	1349,6	1687,7	3199,5	+1849,9
electricity from renewable energy sources	519,2	524,7	504,7	-14,5
share of electricity from renewable energy sources in total output	27,8	23,7	13,6	-14,2

Power generation from the renewable energy sources in 2019 amounted to 504.7 million kWh or 13.6% of total production. The share of the renewable energy sources for 2017-2019 has decreased by 14.2% due to the high dynamics of electricity production from the thermal power plants.

The high dynamics of power generation worked out by the thermal power plants is determined by the implementation of the Federal Target Program "Socio-economic development of the Republic of Crimea and the city of Sevastopol until 2024," approved by the Decree of the Government of the Russian Federation from August 11, 2014 No. 790, within the framework of which one of the goals is "lifting infrastructure restrictions in order to provide sustainable economic development" and defined tasks - "eliminating restrictions and improving the quality of energy supply in the region," "formation and development of energy, transport, social and telecommunication infrastructures."

The FTP developers in section "1. Analysis of the socio-economic situation of the Republic of Crimea and the city of Sevastopol" specify that on the territory of the Republic of Crimea: "The existing natural resource potential is irrationally used, taking into account recreational, bioclimatic, mineral and raw materials' potential alongside with the energy, primarily in the field of unconventional sources application of the renewable energy (wind, solar, geothermal); there is a complete lack of systemic environmental measures to preserve the unique flora and fauna of the Crimean peninsula.

The key constraints to the socio-economic development of the investigated territory are defined as: "the insufficient resource and infrastructure supply of the region with vital sources of energy, water, food, including restrictions on the provision of water resources for drinking and productive consumption, including the lack of round-the-clock water supply for certain areas"; "a high level of energy dependence of the economy." When designing objects within the framework of the Program, it is planned to provide: "the implementation of energy- and resource-saving technologies as well as environmentally friendly ones."

3 Empirical model

The Scheme and Program for the Development of the Electricity Industry of the Republic of Crimea for 2019-2023 was developed and realized on the territory of the Republic of Crimea, according to which both a solar energy and a wind one is of the greatest importance among the renewable energy sources (Table 2) [14].

Table 2. Renewable energy objects in the Republic of Crimea

	Number of objects, units	Installed capacity, MW
solar power stations	5	296,98
wind farms	7	88,563
total	12	385,543

Solar power in the Republic of Crimea is represented by five solar power plants with a total installed capacity of 296.98 MW. (see Table 2).

The installation of solar power plants is cost-effective in such a case if the number of hours of sunshine in the territory under consideration is at least 2000 per year, and the sunlight intensity is at least 5,000 MJ/m2.

Solar radiation is distributed equally throughout the Republic of Crimea. During the year, the sun shines on the Kerch Peninsula and on the South Bank within 2250-2300 hours, in the flat Crimea 2250 hours, in the Western part of the Republic of Crimea it ranges from 2250 to 2400 hours or more per year. Thus, on average, in Crimea the sun shines 5-7 hours a day during a year.

A study of information on the distribution of solar radiation and the duration of sunshine

per year in the territory of the Republic of Crimea showed that this territory is economically viable for the development of solar generation, especially in the Western and South-Western territories of the Crimean Peninsula.

In particular, on August 1, 2015, the Nikolaevka solar power station, located in the Simferopol district of Crimea, began to supply electricity to the grid [17]. The construction of the solar electric station Vladislavovka, localized on the territory of the Vladislavovsky rural settlement of the Kirovsky district of the Republic of Crimea, is considered as promising. In fact, the Vladislavovka solar power station is an object that consists of five separate stations.

A wind power in the Republic of Crimea is represented by seven wind farms with a total installed capacity of 88.563 MW (see Table 2).

Existing wind farms are localized in the Eastern, Western and Southwestern parts of the Crimean Peninsula, depending on the direction of a wind. "During the year, winds of the North-East, South-West and North-West directions prevail in the Republic of Crimea. In winter, the repeatability of the North-East winds is 45%, the South-West winds embrace 25%, while the South winds - up to 20%. During late autumn and winter, very strong Northeast winds often last about 270-325 hours a month.

The territories with the highest indicator of wind energy potential of the Republic of Crimea are located primarily in the coastal zone of the Crimean Peninsula: North, North-West, East and South-West coasts "[14].

Data exploration on long-term average wind speeds in the territories of the Republic of Crimea showed that such cities as: Armyansk, Yevpatoriya, Kerch, Saki, Sudak, as well as the territories of the districts: Leninsky, Razdolnensky, Saki, Soviet, Kirov, Black Sea and the territory of the Ai-Petri highlands possess the potential needed for operating the wind-generating plants.

In the territories favorable for the introduction of wind generation, the development of a wind power in perspective is planned through the construction of new wind power plants and the reconstruction of the existing ones.

The attractiveness of the wind energy development in the Republic of Crimea is confirmed by the following fact. The founder of the German group of companies Winkler intends to invest in the Crimean wind energy. In July 2019, the investor with his partners "registered the New Energy Plus company in Feodosia with an authorized capital of 1 million rubles. In October 2019, zWe announced that since this summer it has been actively working in the Russian Federation and, together with its partners, is preparing to produce turbines for the wind plants in the West of the country. In particular, the company develops isolated solutions with small turbines and batteries for the rural areas, as well as large wind plants. "New Energy Plus" negotiated with Crimea on the modernization of windmills, which were nationalized after the region joined Russia "[18]. Many of them have been in operation for more than 20 years and the technologies are outdated.

According to the experts' opinion, the Republic of Crimea benefits from a huge potential in the solar and wind power: "A unique solar and wind power industry is presented in Crimea, being one of the first regions in Russia in terms of the amount of the renewable energy sources' generation. A special attention should be paid to the wind and solar energetics." [19] According to the specialists' calculations, a solar and wind energy are the cheapest in the Crimea territory. In addition, alternative sources of electricity can save natural gas, which has to be either purchased on the mainland or produced on the territory of the Republic of Crimea, that is much more expensive than a solar energy itself.

4 Results and discussions

To a lesser extent, the remaining types of the renewable energy sources are represented in the territory of the Republic of Crimea.

In the Republic of Crimea, a ***hydropower*** is not introduced practically. This is due to the fact that the Crimean rivers have a low water consumption, which complicates significantly the operation of the hydroelectric power plants.

Currently, there is one mini-hydroelectric power station in the Simferopol district on the Partizan reservoir in the Republic of Crimea with the capacity of 250 kW. "The development of potential small rivers potential and the use of free head in the existing water supply and sewerage systems of the Crimean cities using small hydropower plants helps solve the problems of improving the energy supply of numerous consumers and their environmental safety" [14].

The territory of the Republic of Crimea includes the Black Sea coast, therefore the development of the renewable energy sources based on the energy of *tides*, i.e. *tidal power plants*, may be promising. However, this type of power plant has a significant disadvantage namely its power variation during a day. It requires the mandatory operation of the power plant in parallel with the power system or the redundancy of the power plant by the operation of other power plants and, as a result, an additional network construction, which increases the cost of erecting the station and its infrastructure and reduces the benefit from the cheapness of the energy generated by the station.

The next interesting direction in the framework of the renewable energy sources research is ***bioenergy*** as an actively developing direction of the unconventional and renewable energy. Bioenergy covers several independent areas of energy production at once: biogas energy; Corn Waste Energy (DAR); peat energy and other types of energy.

A detailed analysis of bioenergy potential of the Republic of Crimea is presented in a research study of the Sevastopol State University scientists, such as Starchenko M.A. et al. [20]. The authors considered the possibility and feasibility of using biogas plants for heat and electricity supply in rural settlements. The authors' main conclusions are as follows: "The use of bioenergy plants in the Crimea is promising, since there are many livestock farms on the peninsula, poultry farms, and a third of the population lives in the rural areas; The use of bioenergy plants is an effective way of providing local electricity and heat in the rural areas; This technology also has a favorable impact on the environment, since a livestock waste, especially in large farms, produces a surface and groundwater pollution.... Bioenergy contributes to developing the energy market as a whole, which has a positive effect on the economy of the region "[20, p. 97].

The energy potential of agricultural production wastes of the southern regions of Russia namely in the Volgograd region and the Republic of Crimea is disclosed in details in a scientific study by Andreenko et al. [21]. The authors evaluate the resource base for the development of bioenergy, paying special attention to the study of the energy potential of bioenergy not specially produced biomass, but organic waste generated in crop production and animal husbandry of these territories. As a result of the study, the territorial distribution of energy potentials of agricultural waste was designed to municipalities namely districts and urban districts.

As part of the renewable energy sources analysis, ***a landfill gas*** is separately investigated as a biogas formed in the result of anaerobic decomposition of organic waste at landfills of solid domestic waste (MSW).

Any solid waste landfill is a large biochemical reactor, in the bowels of which biogas is formed during operation during several decades after its closure as a result of anaerobic decomposition of waste in terms of plant and animal origin. "Biogas is a mixture of methane and carbon dioxide in approximately equal proportion. Biogas inevitably enters the

atmosphere, which causes a number of negative consequences. The accumulation of gas in the body of the landfill often causes a spontaneous combustion of solid household waste. The combustion process is accompanied by the formation of toxic substances, in particular dioxins. The negative impact of biogas on the environment has led to the widespread use of biogas collection and disposal systems in MSW landfills in most developed countries. "[14]

The production and further use of this type of gas solves several problems at once: "preventing atmospheric pollution (also, methane has a strong greenhouse effect); reducing the risk of fires and explosions at MSW landfills; obtaining an experience in operation of an electric power production facility using an unconventional energy source.

During the construction of an electric station on landfill gas, released in the body of the MSW landfill as a fuel, it is necessary to specify that it is supplied to the place with installed block-modular equipment based on the usage of the landfill gas collection system. To provide the electric station with a fuel, a complex of specialized equipment for the production, purification and supply of landfill gas is installed. This complex includes: a gas collection station connected to wells drilled in the body of the landfill; a gas compressor station providing gas supply; a high-temperature flare for burning a gas volume excess; a Gas Purification Unit (OGD) "[14].

The Republic of Crimea has a great potential for the implementation of projects for the construction of generating facilities using landfill gas. In particular, the first biogas station generating electricity from landfill gas was launched in the village of Turgenevo, the Belogorsky district of the Republic of Crimea.

Thus, a biogas energy can develop rapidly and solve the problem of electric and heat supply in agricultural settlements, as well as in large enterprises.

Wood waste, pellets are "an environmentally friendly type of fuel obtained from wood raw materials with a help of pressing. This fuel is produced from wastes of logging and woodworking industry without application of any sizing substances. The main raw materials from which pellets are made are chips, sawdust, shavings, wood dust and tree bark. But there are also other types of raw materials, such as peat, straw, nut shells, reeds, etc.

In the finished form, pellets are granules with a diameter of 6-10 mm and a length of up to 50 mm. Several important problems are solved at once by the production of pellets: fire hazardous waste is processed and high-calorie fuel is produced.

Pellets as a type of fuel have appeared relatively recently, but due to their high calorific and natural properties, they have become popular in Europe, Japan and North America. The increase in their consumption is determined by the possibility of using pellets in industrial thermal power plants and in installations intended for private use "[14].

Such type of fuel as pellets can be used widely under the conditions of a timber industry development in the Republic of Crimea.

5 Conclusions

A recognized authority in the field of energy, international politics and economics, D. Yergin notes that energy, like no other sphere, is ready for innovations, although "it took more than a decade to develop and introduce technologies. In addition, some questions about the scope and cost have not been answered yet. "[13, p. 505] Today, the renewable energy industry attracts the attention of modern theorists and practitioners at an international scale [22, 23].

In addition, Yergin emphasizes the revolutionary and evolutionary nature of the transition of modern society to the renewable energy sources: "if the transition to the renewable energy sources is really large-scale, it will be equal to the oil transition in the 20th century, according to geopolitical, economic, and environmental points of view. However, this path is likely to be long. As history proves, transitions to new energy sources usually take decades" [13, p.

505]. The scientist highlights that by 2030, the renewable energy sources will not be considered as the main energy source, wherein their share in the global energy balance depends on political, economic and innovative factors.

The founder and permanent chairman of the World Economic Forum, Schwab, makes an important conclusion to complete our study: "Clean energy technologies and better energy storage capabilities go from laboratories to production and conquer markets... The universal availability of clean, affordable energy resources will have a positive impact on the environment, and in particular on the population of developing countries where electricity systems are not reliable or do not exist completely. In addition, the use of environmentally rational energy technologies can reduce costs for companies and consumers and overcome the negative impact on the environment resulting from industrial pollution of the last century" [12, p. 219].

The Russian Federation and the Republic of Crimea have all the prerequisites for being included in the objective world trends of the Fourth Industrial Revolution, regional aspects of which are described in our scientific papers [24, 25]. The development of the Republic of Crimea's electricity industry through the use of the renewable energy sources and local fuels is an essential area of modern regional policy. This is due to the fact that this direction, firstly, is environmentally friendly generation, and secondly, it contributes to a qualitative increase in the level of regional energy security.

The importance of the high level of regional energy security in the territory of the Republic of Crimea was clearly demonstrated by the events of 2015, caused by the Ukraine's disconnection of the regional energy system from supply sources. Currently, the Government of the Russian Federation has created all the conditions for preventing the recurrence of these events.

The development of the Republic of Crimea's electricity industry through the use of the renewable sources of energy should take place in parallel with the development of efficient energy, based on the traditional energy resources, which enable to neutralize the existing disadvantages of the first sources.

The scientific study and practical implementation of the renewable energy sources is the regularity of the modern world community development, which is focused on the development of a "green" economy. Nowadays there is no other way for a mankind.

6 Acknowledgment

The study was carried out with the financial support of the RFFI Grant "Incremental Approach to the Formation and Implementation of Strategies for the Socio-Economic Development of Regions of Various Hierarchical Levels of the Russian Federation: Unified Rules for Strategy" (project No. 20-010-00824).

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