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How to Solve Water Shortage Problem by Means of Renewable Power Generation?

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ABSTRACT

The article is devoted to one of the global humanity problems - increasing drinking water shortage. The authors analyzed statistic data of Russian federal districts and emphasized the most problem regions. The authors proposed an innovative technology of renewable power sources as a way of water supply increasing; they analyzed perspectives of renewable power engineering in Russia according to solution of a fresh water shortage problem. Development of renewable power engineering was considered as one of the ways of water supply increasing. On the basis of the research the authors formulated an economic-mathematical model. The model assessed a capacity of a water condensing combined wind driven electric plant (WDEP) under the various weather conditions - An average temperature and humidity of the air. According to the model a perspective water output under the conditions of Republic of Crimea was foreseen. The authors came to the conclusion that a combined WDEP could be used for water supply in the further-flung regions, for agriculture, production and fire extinguishment.

Keywords: Renewable Energy, Wind Driven Electric Plant, Solar Forced Circulation System
JEL Classifications: Q250, Q420

1. INTRODUCTION

Water is one of the most important resources for people survival. A human body contains 75–80% of water, so it is very significant to keep a water balance. A person can live without water only 3–10 days, depending on the environment temperature and other factors.

Water is important not only for people; it is a source of all flesh on the Earth. Inhomogeneity of water distribution can decrease life quality dramatically and lead to the social crisis.

Climatic changes, urbanization and other global problems attract more and more attention to the redistribution of water resources and to the access of pure drinking water.

The world data base Aquastat from 1991 till 2011 shows a trend of fewer water recourses per capita, it is connected with increasing population and water consumption. The growth of renewable water resources number per capita increased only in Ukraine, Belorussia, Russia, Moldavia, Bulgaria, Estonia, Georgia, Hungary, Croatia, Puerto Rico, Lithuania and Germany. In all mentioned countries except Germany it happened because of population decline. According to Country meters the Earth population was 7 billion of people on the 29th of April 2018, and despite relative stability an annual rate of population increase is 1.2% now.

UNESCO forecasts a dramatic increase of water demand for the period from 2017 till 2028 (Wastewater the Untapped Resource, 2017). It foresees higher water demand not only from agriculture, which water consumption is 70% of the world water demand, but also from production and power generation. Faster urbanization and wider net of utility systems will also play their roles in the process.

There is also a problem of water quality, being aggravated by insufficient waste water purification in agriculture and production. According to the report “Wastewater the untapped resource” (Wastewater the Untapped Resource, 2017), 92% of waste water was not purified in the countries with a low income in 2015, whereas in the countries with a high income this figure was 30%.

All these modern trends can lead to the further water quality deterioration and dwindling water supply that in their turn, will take a toll on people health, ecosystems and economic development.

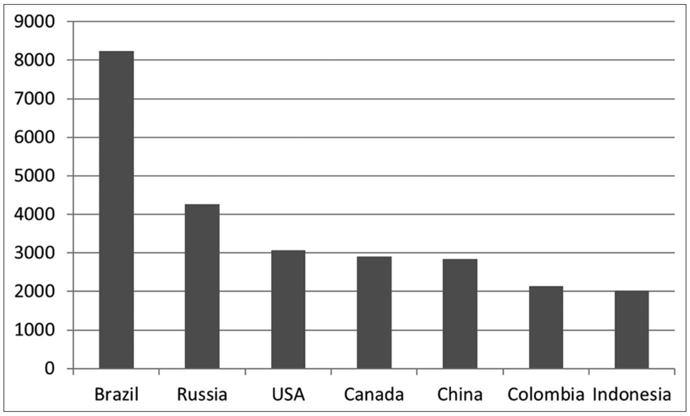
Distribution of water resources is extremely varying. The largest resources belong to Asia and South America. Countries with the largest renewable water resources are presented in Figure 1 (aquastat).

Africa and Australia have the smallest amount of water resources in the world. Russia ranks #2 internationally, its water resources are 4258.6 km^3 per year. Water resources of Russian Federation are assessed every year, the results are presented in the various reports of the state statistics. The problem of water shortage is characteristic for the south regions, including Republic of Crimea. The data of water supply per capita are presented in Table 1 (according to the State report “About conditions and consumption of water resources in Russian Federation in 2016,” 2017).

Far Eastern and Siberian Federal Districts have the largest water resources, whereas Central, North Caucasian and South Federal Districts have the smallest ones. The regions with the lowest water supply per capita are presented in Table 2 (according to the State report “About conditions and consumption of water resources in Russian Federation in 2016;” 2017).

As far as water supply is concerned, Republic of Crimea has the most serious problems. The peninsula has always been suffering from the shortage of fresh groundwater, the depletion happened in 1960–1970 because of over consuming. The Republic has been using internal resources of water supply since 2014, it has affected rice, corn and soy cultivation. To provide stable water supply, water from the Biyuk-Karasu was entrapped to the North Crimean channel, the horizon of geological prospecting work was widened, boreholes were drilled and water reservoirs were flushed. One of the most important ways of solving fresh water shortage problem is to decrease delivery and purification wastes. One more way to solve the problem is to desalinate seawater, but it requires energy - intensive installations, now it does not make economic sense because of energy supply problems.

Figure 1: Countries with the largest renewable water resources, km^3 per year



According to the research of Higher School of Economics, the methods of problem solving can be divided into three groups (Saritas et al., 2015):
1. Technologies, increasing productivity of systems or allowing redistributing volumes of water supply (integrated hydro - energetic and water efficient technologies);
2. New engineering solutions (new methods of desalination);
3. Infrastructure projects (multifunctional dams, small and medium water reservoirs).

New engineering solutions of water desalination are directly connected with renewable energy resources (RER) - the most rapidly growing sector of economy. According to IRENA (Renewable Energy Statistics, 2017) the capacity of power stations working on RER doubled for a 10-year period - from 994 GW in 2007 to 2011 GW in 2016. The world generating capacities increased by 161GW at the expense of RER in 2016.

One of the key market sectors with ample opportunities for RER use are some further-flung regions of the developing countries, where a traditional centralized model of power supply is economic inappropriate. Nowadays 1.2 billion of people (17% of the planet population) mainly in Asia-Pacific Region and in Africa south of the Sahara Desert don’t have an access to the electric nets.

The total capacity of decentralized RER had increased four-fold since 2007, it was 4GW in 2016. The most part of decentralized RER belongs to Asia (59%), Africa (22%) and South America (10%). As time goes, these resources play more and more important role. An average annual growth in Asia is more than 30%, in Africa - about 20%. The technologies of distributed RER allow to provide energy supply for further-flung regions of India, China, Bangladesh, Algeria, RSA and the Democratic Republic of the Congo (Global Landscape of Renewable Energy Finance, 2018).

Medium power stations on the basis of RER can solve the problem of energy supply in further-flung regions and cope with fresh water shortage.

Power generation on the basis of renewable resources are widely discussed in the scientific literature, both from technical (Zhu et al., 2018; Oh et al., 2018; Zergane et al., 2018; Willis et al., 2018; Abdulraheem and Al-Kindi, 2018), and from social-economic points of view (Daia et al., 2016; Barbosea et al., 2016; Cebotari and Benedek, 2017; Dvorak et al., 2017; Nazarova et al., 2017).

Table 1: Supply of water resources to the population of Russian federal districts

Territorial entity of the RF	Population, thous. of people	Water resources, km^3 per year	Water supply per capita, thous. of m^3 per year
Russian federation	146,519.8	4119.0	28.1
Central Federal District	39,091.2	328.2	8.4
South Federal District	14,042.9	560.6	39.9
North Caucasian Federal District	9717.5	61.4	6.3
Volga Federal District	29,668.7	1490.9	50.3
Urals Federal District	12,306.2	1206.1	98.0
Siberian Federal District	19,320.6	1975.7	102.3
Far Eastern Federal District	6194.5	2458.7	396.9

Table 2: The regions of Russian federation with the lowest water supply per capita

Territorial entity of the RF	Population, thous. of people	Water resources, km^3 per year	Water supply per capita, thous. of m^3 per year
Republic of Crimea	2327.3	1	0.4
The Belgorod Region	1549.6	2.7	1.7
The Chelyabinsk Region	3500.4	7.4	2.1
Stavropol Territory	2800.6	6	2.1
The Moscow region	7312.4	18	2.5
The Kursk Region	1119.5	3.8	3.4
The Republic of Ingushetia	473.3	1.7	3.6
The Tambov Region.	1050.4	4.1	3.9
Republic of Kalmykia	278.9	1.1	3.9
The Kurgan Region	862	3.5	4.1

Besides social - economic effects, such as power generation, decrease of CO_2 emissions, new modern productions, technologies of renewable power generation can help to solve one of the most important humanity problems - water shortage.

We would like to emphasize the research of Roblin, 2016, where the author analyzes how to use solar energy for irrigation in the developing countries. In agriculture RER can be used not only for affordable energy, but also for work of pumps in the irrigation systems. The advantage of solar energy in the arid areas is that plants get water from the irrigation systems during the hottest sunny periods, when plants need water most of all.

The importance of energy connectivity and combining use of solar energy in some regions of Africa and South Asia in spite of high capital expenditures is proved in the research of International Water Management Institute (Giordano et al., 2012). Such an approach to agriculture can improve yields in the regions by 300%.

Scientific research of such large companies as Siemens and IBC SOLAR are devoted to the development of solar pumps capable to replace diesel ones in the arid regions.

A detailed review of solar forced circulation systems is presented in the work of Chandel et al., 2015. The author analyzes technologies of solar pumps, their economic practicability and obstacles for solar forced circulation systems distribution. Chandel finds out factors, influencing a capacity of a forced circulation system and photovoltaic modules break – down. The author proves that solar forced circulation systems can be commercially feasible in comparison with electric or diesel irrigation and water supply systems in rural, urban and further-flung regions, their payback time is 4-6 years.

Aliyu et al., 2018 writes about the necessity of pumps, working on RER, since there are many disadvantages of diesel pumps connected with unreliable fuel supply, high expenditures on servicing and a short period of value-added use. One of the alternatives is solar systems, used for water supply and irrigation in the further-flung regions. The author describes advantages of the solar systems – low operational fees, absence of harmful emissions and noise.

The research of Mohanraj et al. is also devoted to the solar compression heat pump (Mohanraj et al., 2018). The author emphasizes such fields of use as: Drying, space and water heating, desalinization. Mohanraj analyses key obstacles for solar compression heat pumps use and makes a conclusion about perspectives for space heating.

Current studies are mainly devoted to the solar forced circulation systems, but some companies develop water condensing wind driven electric plants (WDEP), Dutch Rainmaker BV, a Dutch company, develops a project AW-75, Eole Water, a French company * WMS1000.

In this article we analyses opportunities of combined water condensing WDEPs use, the productivity under the various weather conditions.

2. METHODOLOGY OF THE RESEARCH

To create a combined installation on the basis of WDEP USW56-100, one should modernize it, taking into account technical solutions used in water condensing WDEPs AW-75 and WMS1000.

The modernized WDEP belongs to the class of low-powered WDEPs. It has a construction with an induction generator, developed according to the classical gear scheme with the following specific features:

1. A wind wheel of the WDEP has the so - called pitch-control. Blades are located on leeward, it provides a passive mechanical orientation of a body “to the wind;”
2. A lattice-like tower of WDEP is 24 m high.

The modernized WDEP develops a nominal rating power of 110kW at a wind speed of 13m/s under the normal climatic conditions. WDEP generates electricity with ac potential 0.4 kW, it can work together with (in-parallel) other power stations on a frequency of 50 hz.

The modernized WDEP is an energetic WDEP designed to produce electricity.

The key technical characteristics of the modernized WDEP are presented in Table 3.

The WDEP gets electricity for its own needs from its own generator, if it requires. If there is no wind or when the WDEP is being repaired, it gets electricity from the electrical power system.

The WDEP own needs are the following:
1. Lighting.
2. Tools heating – up.
3. Equipment of an automatic control system.
4. Temporal electrical receiver.

One of innovative technological ways of the WDEP use is to get drinking water from the air with the use of wind energy. The point is that the special WDEP condenses water from the air, passing through it. The air contains a certain amount of water depending on the ambient temperature and humidity. This allows producing water from the air all over the world. The air always contains water practically without polluting matters unlike with wells and water boreholes.

To assess a perspective productivity of the water condensing WDEP one should perform a research in several stages.

On the first stage we gather data about an average air temperature and atmosphere relative humidity in the chosen region by month.

Table 3: Key technical characteristics of the modernized WDEP

Indicator	Indicator values
Nominal rating power	107.5 kW
Induction triphase AC generator	380 V, 50 hz
Number of blades	3
Location of fans	Lee-side
Material of fans	Fiberglass
Wind wheel diameter	17 m
Rotor rpm	72 rpm
System of wind orientation	Passive
Transmission	Dual-stage
Tower height	24 m
Capacity control method	Automatic change of blade angle of attack, pitch-control
Minimal starting speed	5 m/s
Wind speed for nominal rating power	13 m/s
Maximal working speed of wind	22 m/s
Indestructible speed of wind	56 m/s
Mass	
Body	3700 kg
Tower	4700 kg
Fans	165 kg

WDEP: Wind driven electric plant

Depending on a stage of a project and requirements to the specification or calculations results, one can use statistic data from the open data bases or results of the special - purpose research of the chosen region.

We developed an economic- mathematical model of the water condensing WDEP productivity on the basis of statistical data of the water condensing WDEP, produced by Dutch Rainmaker BV and Eole Water, and of our own scientific research of the WDEP modernization. A dependent variable is average productivity on 7500 m^3 of air per hour, l, arguments are an average air temperature and average atmosphere relative humidity. The developed model can be described by the following equation:

$$C=\exp(1.21*\log T+2.05*\log H-7.02) \quad (1)$$

Where:
T - An average air temperature, C°;
H - Average atmosphere relative humidity, %
C - Average productivity on 7500 m^3 of air per hour, l.

On the second stage of the research we assess productivity of the water condensing WDEP according to the Formula (1).

On the last stage we generalize attained results and make conclusions about perspective volumes of water production.

So the recommended stages of the research are the following:
1 Stage - gathering of information about an air temperature and atmosphere relative humidity in the researched region;
2 Stage - assessment of data according to the developed model;
3 Stage - aggregation of the results.

3. THE RESULTS OF RESEARCH

We calculated a perspective productivity of the modernized combined water condensing WDEP on the basis of the model (1) and gathered data of an average air temperature and atmosphere relative humidity in Republic of Crimea. The results of the performed research for Republic of Crimea are presented in Table 4 and in Figure 2 (calculations were made by the authors).

According to our calculations, the modernized WDEP can produce 172 m^3 per year, the maximal productivity is likely to be during the period from April till September (Figure 2).

The importance of the WDEP is obvious. It can be used for water supply in the further-flung regions without any infrastructure. The WDEPs have lots of opportunities of practical use in agriculture, production, for fire extinguishment in the fire-dangerous regions. Such a technology is universal and can be used in the various world regions, under the various weather conditions.

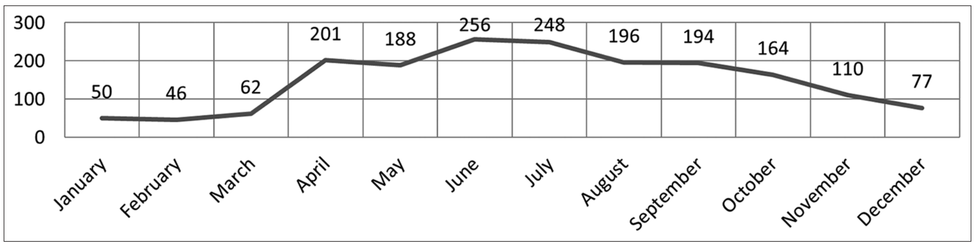
4. DISCUSSION

The analyzed variant of the modernized WDEP can provide great benefit – it will give people, living in the further-flung regions, an access to fresh drinking water during the whole period of a working lifespan (more than 20 years).

Table 4: Productivity of the combined water condensing WDEP under the weather conditions of republic of crimea

Indicator	By month											
	01	02	03	04	05	06	07	08	09	10	11	12
An average air temperature, C°	4.8	4.9	6.7	11.3	16.8	22.2	25	25.4	20.4	15	10.3	6.9
Average atmosphere relative humidity, %	82	78	75	98	75	74	68	60	68	75	77	82
Average productivity on 7500 m^3 of air per hour, l.	50	46	62	201	188	256	248	196	194	164	110	77
Theoretical productivity, l	4770	4414	5943	19338	18041	24575	23851	18810	18657	15733	10545	7395

Figure 2: Average productivity on 7500 m^3 of air per hour, l of the combined water condensing WDEP in Republic Crimea



Independence and compactability of the WDEP of a rather small capacity (30–100 kWt) allow locating it in any region with a necessary wind power potential. Natural irregularity of a wind power and corresponding variations of the WDEP capacity are not a problem for such an installation, and its influence on the environment is minimal.

A permanent magnet generator is a part of the WDEP construction, so it can be used both on its own and together with other resources of power.

This research is theoretical, practical technical modernization of the WDEP requires additional scientific-research and pilot-plan works.

The attained results can be a basis of the WDEP economic effectiveness assessment. Economic viability should be proved by the additional research.

5. CONCLUSIONS

In our research we have:
- Proposed variants of use of generating objects on the basis of a renewable power source to solve the problem of fresh water shortage;
- Formulated ideas of modernization of a WDEP us w56–100 to condense water;
- Developed an economic-mathematical model, assessing a generating system productivity on the basis of an average air temperature and average air humidity;
- Foreseen a theoretical capacity of the modernized WDEP under the conditions of republic of crimea.

We came to the conclusion that Russia - one of the leaders of water supply had a problem of fresh water shortage in the south, North Caucasus and central region. Republic of Crimea has the lowest water supply according to the statistic data.

We proposed to modernize a present WDEP with account of innovative technical solutions to solve a water shortage problem. We used the economic-mathematical model for a theoretical assessment of the modernized WDEP capacity under the weather conditions of Republic of Crimea.

According to our assessment, the capacity can be more than 172 m^3 peryear, the water can be used for irrigation and for water supply in the resorts, since the highest capacity is foreseen for the period from April till September.

Additional research is needed to clarify the WDER water productivity, taking into account its power capacity and wind speed.

This research can be a basis for the development of innovative projects that will help to solve the problem of water shortage. The economic – mathematical model can be used for assessment of the water condensing WDEP capacity for any world regions with various data of an average air temperature and air humidity. This assessment can be useful for a cost-benefit analysis of regional water resources programs.

6. ACKNOWLEDGMENT

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