Regional Disparities and Features of Solar and Wind Energy Potential of Bulgaria

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Abstract. Global climate fluctuations and projections of deteriorating sustainable human development since the beginning of the 21st century have highlighted the need to look for alternative energy sources to carbon fuels. The utilization of solar and wind energy has become a challenge for engineers and technologists to develop new technologies for more efficient development of renewable energy sources. The purpose of this paper is to present the territorial features in the utilization of renewable energy sources - solar radiation and wind in Bulgaria. The study focuses on the regional features of the solar- and wind energy potential. Based on statistical data, the utilization of the RES potential is considered through a review of the installed capacities

Keywords: RES, Climate, Adoption, Energy potential.

1. Introduction

After recent years, the introduction of energy sources (RES), mainly solar radiation and the introduction of all others have entered as an alternative to fossil fuels - coal, oil, natural gas and others. On average, the reasons are: 1. Attempted human creation to reduce CO₂ emissions into the atmosphere, identified as a major cause of climate change on the planet; 2. Limiting the influence of global and regional powers (USA, Russia, China, Middle East countries, etc.) on the world economy by introducing a monopoly on the prices of coal, oil and natural gas on the world market and 3. Attempt to solve the global energy crisis caused by the depletion of fossil fuels. The European Union has a leading role in the introduction of renewable energy sources in the global energy system. At the end of 2019, a new composition of the European Commission took a general decision to move to a radical reduction of carbon emissions by limiting energy production from the introduction and improving and expanding the construction of solar and wind energy parks (Directive (EU) 2018 / 2001). The purpose of the present study is to present the results of the analysis of regional differences in the absorption of wind energy and solar radiation the territory of Bulgaria, by comparing the established energy potential with operating installed capacity.

2. Methodology and Information

RES zoning is based on the territorial differences of solar- and wind energy potential. For this purpose, cartographic data from Geographical atlas of Bulgaria made by a team of the Department of Geography to NIGGG - BAS in 2010, as well as data from the Ministry of Energy of the Republic of Bulgaria for the installed capacities from renewable energy sources as of December 31, 2019. Problems with the development of "green" energy are subject to and subject to a number of scientific studies. Geographical features related to climatic factors and environmental conditions (relief, exposure, land cover) are revealed in the research of Mateeva, Dimitrov (1999), Mateeva, Filipov (1999, 2009, 2010, 2012, 2013, 2015, and 2016). The economic and social aspects are developed in research by Grigorova (2010), Peshev (2013), Ivanov (2014), Koleva, Mladenov (2014), Nikolova (2018), Nikolaev, Konidari (2017), Tsankov (2018) and others. Essential for the absorption of solar energy are the duration of the sunshine, the clouds and the angle at which the sun's rays reach the underlying

surface. There are disparities between the maximum values of radiation and minimum values of cloudiness and active electricity consumption, as this phenomenon is typical for the winter period. Forming turn, this has a positive effect on the energy balance during the summer season, when the electricity system is loaded by the mass use of air conditioners. The problem with the angle of the radiation beams is technological solution by means of automatic systems for tracking the "position" of the solar disk on the horizon. The wind energy potential is determined by the density of the air and the speed of the wind. In terms of altitude profile, the change in wind speed depends on the roughness of the underlying surface, the vertical stratification of the atmosphere and other local factors. Cyclonic and anticyclone activity in the country is characterized by variable intensity, and the underlying surface - with exceptional wide variety of shapes, orientation towards air transport, type - land or water, etc. For this reason, the wind speed in Bulgaria fluctuates too much wide limits - from "quiet weather" to very strong winds. Along with these assessments elegant for the whole territory of the country, for the purposes of wind energy are necessary and more detailed studies of each individual locality or even point object (Mateeva, Filipov, 2010). Regardless of the available potential for development of renewable energy sources, there are a number of restrictions of an ecological nature - these are the first place territories falling within the scope of Natura 2000 (Fig. 3). According to the Directive on conservation of natural habitats and the Wild Birds Directive, there are areas where it is not possible to install capacity for production of energy from renewable sources, and falls under the protection of these sites about 37,400 km² or 34% of the country's territory.

3. Result and Discussion

3.1 Territorial Features of Solar Energy Potential

The solar energy potential is represented by the spatial distribution of the production of electricity from 1 kW installed power (PV-modules), such as the values for the territory of the country vary between 1100 and 1350 kW / year. They integrate data on the total solar radiation, air temperature, transparency of the atmosphere and the orographic openness of the horizon. The internal annual course of the radiation balance has a maximum in July and a minimum in December and January. The annual values in the mountainous regions of the country fluctuate around 1800 MJ / m², as with increasing altitude the values decrease: at 1200 m are about 1700 MJ / m², and above 2200 m - below 1200 MJ / m². Average for the year from 55 to 65% of the radiation balance are spent for evaporation, and the remaining 35 - 45% - foreground air heating (Mateeva, Filipov, 2010). Measured values of the solar intensity on the territory of the country is determined by several regions with maximum solar energy potential, which in turn is a prerequisite for zoning of the country according to this indicator. On this basis, in our opinion, they can be differentiated:

1. Northeastern region including Primorska Dobrudja, Central Dobrudja and the Ludogorsko plateau; 2. North Central region; 3. South Central region and 4. Southwestern region with the southern slopes of Rila and the valley of the river Struma (**Fig. 1**). Based on data from the Ministry of Energy at the end of 2019 on with respect to the installed capacities, the following situation is observed (**Fig. 3**). The Southern Rhodope region has the most installed capacity - 175 MW, the northern region is 166.7 MW, the southwestern - 152 MW and the northeastern 49.2 MW. Well-defined differences are also observed in the regions themselves - in the Southern Middle Rhodopean region capacities are concentrated in the central parts - Stara Zagora (89 MW), Plovdiv (102.2 MW) and to the east: Burgas (68 MW) and Sliven (73 MW). From the main important for this distribution is the presence of well-developed energy infrastructure in the central and eastern parts of the region. Solar energy potential is relatively well absorbed with opportunities to expand RES infrastructure, as very good conditions from a natural point of view are on the south slope of Stara Planina. As of the end of 2019, 850 photovoltaic power plants are operating in Bulgaria

(FEC) with a production capacity of up to 1 MWh with a total capacity of 121 MWh and 246 over 1 MWh with a capacity of 911 MWh. Wind power plants (WPP) up to 1 MW / h are 56 slower 26 MW / h, over 1 MW / h are 22 with power 681 according to the data of the public RES register. The total production of electricity from renewable sources at the end of 2019 is 1, 739 MWh, with FEC emitting 1,032 MW h and WPP 707 MWh. The total number of There are 1274 "green" power plants, 1096 are photovoltaic and 178 are wind the submitted report shall take into account the installed capacities above 1 M. The main reason for this choice is that these facilities are of industrial importance. A well-developed energy infrastructure supports the absorption the solar energy potential and in the northern region, where it is observed more evenly location of the constructed capacities - Vidin - 25.2 MW; Vratsa - 18 MW; Montana - 14 MW; Lovech - 7 MW, Pleven impresses - 58.5 MW. The northern region too has good digestibility. The south-western region represents the absorption of the solar energy potential the strongest through the capacities built along the valley of the river Struma - 24 MW and the westernmost parts of the Upper Thracian lowland - 63 MW. Opportunities for expansion of RES the infrastructure is mostly in the Sandanski-Petrich sub-region. Least assimilated solar energy potential is observed in the northeastern region, but the reasons here are mainly economic interests, as well as the restrictions imposed by the use of large areas for agriculture, and the construction of solar parks requires large areas free from agricultural activity.

Figure 1: Solar energy potential and installed capacities.
(By Mateeva, Filipov, 2010)

3.2 Territorial Features of Wind Energy Potential

The respective wind energy potential varies on average from low - below $150 \text{ W} / \text{m}^2$, satisfactory - $150\text{-}250 \text{ W} / \text{m}^2$, moderate - $251\text{-}550 \text{ W} / \text{m}^2$, high $551\text{-}1050 \text{ W} / \text{m}^2$, up to very high - over $1051 \text{ W} / \text{m}^2$. The wind energy potential on the territory of Bulgaria has a localization character. When grouping the localities according to our opinion, the following areas with maximum values can be defined: 1. Northeast - with Primorska Dobrudja; 2. Central - on the ridge and northern slopes of Stara Planina; 3. Southwestern - this area includes sub regions within the scope of Vitosha, Eastern Rila and Western Rhodopean and 4. Southeastern - The Upper Thracian lowland and the southern Black Sea coast (**Fig. 2**). As separate localities with values close to the maximum values are separated from East Stara Planina with Cape Emine, the Southern Black Sea coast, Sakar Mountain and the Valley of Rusenski Lom River. It should be noted that the first two regions coincide with the migratory zones of wintering birds, which in turn represents restriction of an ecological nature. The main facilities were installed in the period 2008 - 2010 with a total capacity of 678.5 MW. Of these, the largest installed power over 500 MW is in the northeast - Primorska Dobrudja with the largest wind energy Park in Bulgaria "Kavarna", there is the largest production - 1,160,000 MWh. There are separate installed capacities in areas with specific localization: East Stara Planina - Sliven with an installed capacity of 13,900 MW and production of 22,667 MWh; Burgas, respectively 12,575 MW and 14,541 MWh; Yambol, respectively, 8,400 MW and 8297 MWh. In the northeastern locality the values are the following: Targovishte 1 250 MW and 1,377 MWh and Ruse 0.095 MW and 22 MW respectively. From the presented data can be summarized that the highest utilization of wind energy potential is in northeastern region. With relatively high utilization, is the eastern Stara Planina locality with specific natural-geographical and orographic conditions. The least developed is the southwestern region, which at the time of the research is defined as ineffective by investor interests.

Figure 2: Wind energy potential and installed capacities.
(By Mateeva, Filipov, 2010)

Figure 3: Natura 2000 protected areas.

4. Conclusion

The results of the present study show clearly defined disproportions of the potential of climate renewable energy sources. For its part there is an overlap of territories in terms of solar and wind energy potential and most of all this applies to the northeastern region - there is accordingly the highest utilization of the renewable potential. Among the main reasons for insufficient absorption are administrative obstacles, but also and not very high investor interest. They are extremely important limiting factors - natural: habitats of certain biological species, air routes of migratory birds (**Fig. 3**) and economic: agriculture, lack of well-developed energy infrastructure. In conclusion, it should be noted that at the present stage at the technological level of RES development are not yet able to provide the base capacity of the national energy system. These sources should be considered as complementing the energy load balance at peak load similar to HPPs

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