WIND ENERGY CLIMATE OF THE EGER REGION IN HUNGARY

RÁZSI A. [1,2]***, CSABAI EDINA*** [1]***, MIKA J.*** [1]***, MOLNÁR ZSÓFIA***[2]***, KOVÁCS A.*** [2]

ABSTRACT. – Wind energy climate of the Eger region in Hungary. In our research, wind-climate of the Eger Energy Region (Hungary) is characterized by using the WAsP model. The map used for the research is a 30x30 km topographic map with 20 meters vertical resolution. For this model, the hourly wind-direction and wind-speed input data have been measured at the Eger Station, operated by the Hungarian Meteorological Service. This station is located in the center of the Region. Duration of these measured input data is 5 years. We estimated the potential wind energy in the area of the Region at different possible production altitudes. We have also examined, which parts of the Region are suitable for production of wind energy, considering the environmental regulations.

Keywords: wind-climate, wind energy, WAsP model

1. INTRODUCTION

One of the greatest challenges of our time is to realize sustainable development. One of the key issues of this is energy production. The use of fossil fuels can lead to numerous economical and health problems. Mining deeper and transporting the resources further can lead to increasing prices. Furthermore, sooner or later strengthening the safe supply will come to the surface. One solution for these problems could be wider usage of renewable energy.

In Hungary, it is a wide spread view, that utilization of wind energy is not economical. However, with the development of technology and the possibility of installing higher towers, we should re-examine this opinion. In our study, we examine the wind energy potential in an experimental region. We seek answers not only for economic and technological questions, but what amount of wind energy can be produced in a sustainable manner.

2. THE EXPERIMENTAL ENERGYREGION OF EGER

In October 2012, the TÁMOP4.2.2.A-11/1/KONV-2012-0016 project was launched by a consortium led by the Eszterházy Károly College. The purpose of this project is to assess the potential of renewable energy in an experimental model region (Fig. 1). Another target was to create a regional GIS database to support the research and to elaborate a conception of activities for energy-efficient economic growth in order to develop a sustainable model region (Ruszkai et al, 2014).

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[1] Eszterházy Károly College, H-3300 Eger, Leányka 6; Hungary
E-mail: razsia@ektf.hu
[2] Hungarian Meteorological Service,Hazard Warning and Service Bureau, Miskolc, Hungary

The area is located in the North Hungarian Mountains. The greater, eastern part of the region is situated in the Bükk Mountains, whereas the western part is located in the Mátra Mountains. The size of the region is 718 km^2. Population of the 23 involved settlements, including Eger, counted 92,483 inhabitants in 2009 (Mika et al., 2014).

Fig. 1. ***The Eger energy region, sample area of the research project (Ruszkai et al., 2014)***

3. WIND ATLAS ANALYSIS AND APPLICATION PROGRAM (WAsP)

The WAsP is a PC-program for the vertical and horizontal extrapolation of wind climate statistics. It contains several physical models to describe the wind flow over different terrains and close to sheltering obstacles. WAsP is an implementation of the so-called wind atlas methodology. (Mortensenet al., 1993) In an earlier testing, adaptability of the WASP model has been demonstrated also for Hungary (Bartholy and Radics, 2001). Although, the study Region exhibits mountainous relief, its topographical features nowhere reach the threshold (Dobeshet al, 1999) where the model errors are problematic.

For the modeling, five years' (2006-2010) wind-direction and wind-speed dataset with hourly resolution was used from the measurements of the Hungarian Meteorological Service in the Eger station, located in the central part of the Region. A 30km x 30km topographic map was also needed. The size of the region and the central position of the station with input data allowed covering the whole sample region by this map.

For the accurate modeling, the roughness of the neighborhood of the measuring station and location of those objects (buildings, high trees, etc.) have to be given, which may affect the wind direction and speed should have been also given.

4. WIND CLIMATE OF EGER

The first step was to examine wind climate of the measuring station. Although there is a north-western prevailing wind direction, its frequency is less than 20% (Fig. 2).This must be considered in recommendation of the possible wind farms. The distance between the wind-power turbines should be greater than five times of the rotor diameter, otherwise it will partly capture wind from each other (Mackay, 2008).

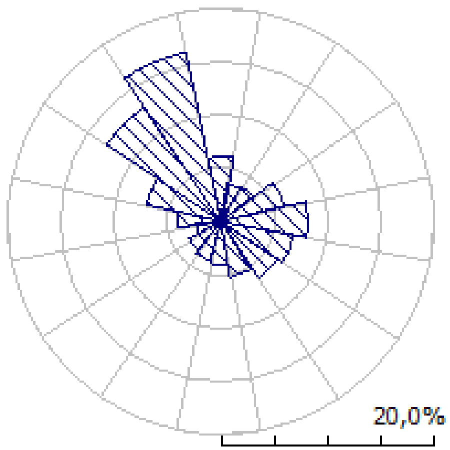


Fig. 2. ***Wind-direction frequencies in Eger***

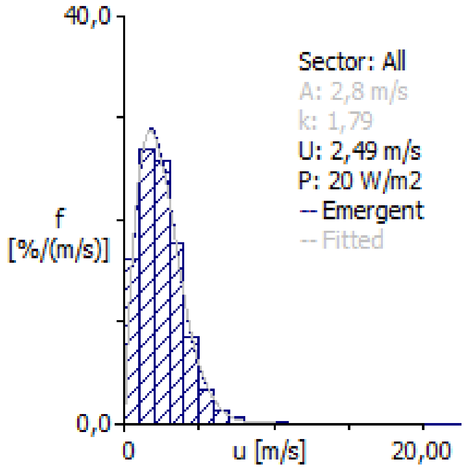


Fig. 3. ***Wind speed distribution in Eger***

Analysis of the wind speed and frequency data revealed that the average wind speed is 2.8ms^{-1}, which is a medium value. However, the frequency study also shows that significantly different wind speed from the mean wind occurs rather rarely, which is advantageous from the aspect of a stable energy supply (Fig. 3).

5. WIND CLIMATE OF THE REGION

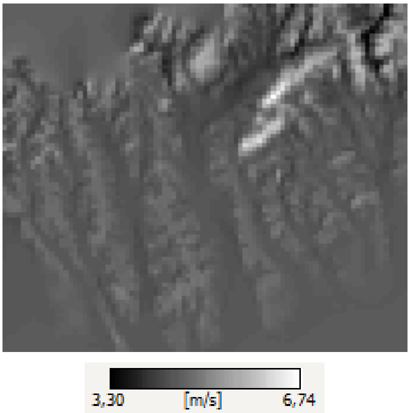
The WASP model is suitable for producing resource maps for different heights above the surface. We can get the mean wind speed and capacity density for each point of the mapped area. It is worth to enter a given rotor height of the current turbine to get immediate information on how many kWh the expected average annual energy yield could be.

Three different wind turbines have been chosen to find out what turbine should be installed in the region. The key data of wind turbines are shown in Tab.1.

Table 1.The three selected types of wind turbines was performed the calculations

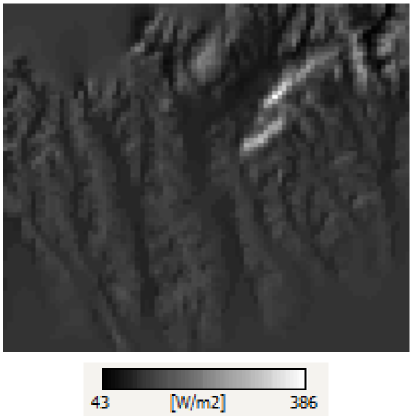
Name	Rotor height	Rotor diameter	Power
Vestas V80	67m	80m	2MW
Vestas V90	80m	90m	1,8MW
Vestas V112	84m	112m	3MW

The results of wind-speed and energy-density for the examined area in three different rotor heights are presented in Figs. 4 to 9.



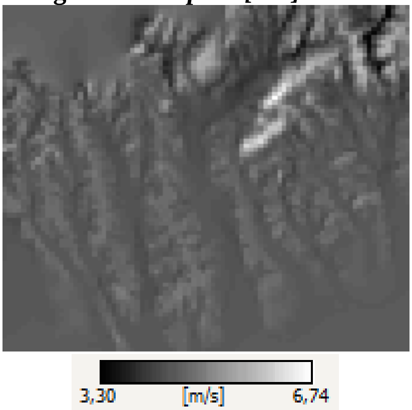
Max: 6,66 m/s	Min: 2,95 m/s	Mean: 4,3 m/s

Fig. 4. ***Mean speed [m/s] at 67m***



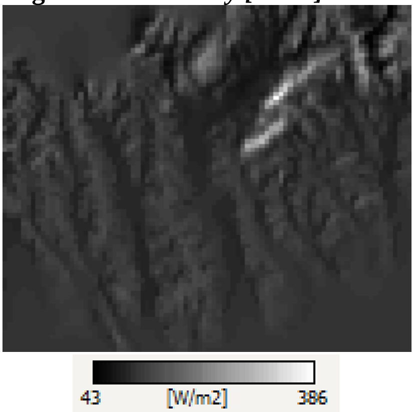
Max: 380 W/m^2	Min: 33 W/m^2	Mean: 98 W/m^2

Fig. 5. ***Power density [W/m^2] at 67m***



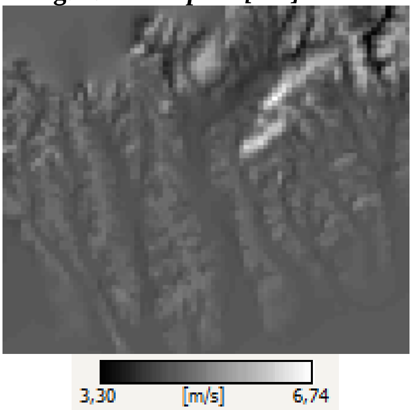
Max: 6,59m/s	Min:3,25m/s	Mean:4,50m/s

Fig. 6. ***Mean speed [m/s] at 80m***



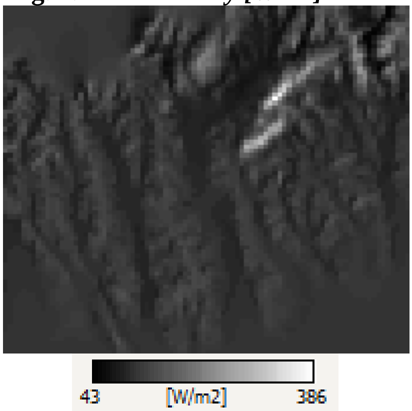
Max: 364 W/m^2	Min: 40 W/m^2	Mean: 109 W/m^2

Fig. 7. ***Power density [W/m^2] at 80m***



Max: 6,74 m/s	Min:3,30 m/s	Mean: 4,56 m/s

Fig. 8. ***Mean Speed [m/s] at 84m***



Max: 386 W/m^2	Min: 43 W/m^2	Mean: 112 W/m^2

Fig. 9. ***Power Density [W/m^2] at 84m***

From the results it is seen that the energy density can be increased with the height of the turbine. It is obvious that the total annual yield can be further increased by increasing the rotor diameter. So, increasing the rotor height leads not only to higher energy density, but it opens possibility to use larger rotor, as well.

In the following, we examine that how much wind energy purchase can be obtained in the areas which are suitable for wind energy production in the region.

6. SUSTAINABLE WIND ENERGY POTENTIAL IN THE REGION

The energy produced from wind power plants is renewable energy, but before the installation, we should pay attention to several environmental aspects, defined by the legislative regulations. According to them, wind turbines may not be installed in the following areas and in their immediate vicinity:

- -Roads,
- -Railway,
- -Transmission line,
- -Populated area,
- -Forest,
- -Surface water,
- -Landscape protection area,
- -Protected areas.

Kertész et al. (2014) edited a map indicating these areas where it is allowed or prohibited to install wind turbines. It demonstrated that only 4.5% of the energy Region is capable to install wind turbines (see in Fig. 10).

Fig. 10. ***Unsuitableareas for wind turbineinstallation (shaded area) due to environmental limitations, and those small niches where it is allowed. The three selected hypothetical points (1, 2 and 3) are chosen in the latter part of the region.***

The WAsP model allows us to carry out calculations for a particular type of wind turbine located on a particular point. In the following, three points were selected where no limitations by the above-mentioned factors occurs (Fig. 10).

Results of the calculations are shown in Table 2.This Table and Fig. 11show that, as we expected, the energy density increases with increasing altitude and the wind speed. It is also seen that the rotor diameter has the greatest importance in the aspect of the energy production, because slightly more than double energy yield can be achieved by 40%increase of the rotor diameter (Fig. 12).

An average household needs 2,200 kWh of annual electrical energy (https://www.edfdemasz.hu). Hence, one smallest 80-meter rotor can potentially fulfill ca.2400 households' needs. The same numbers are ca. 3,200 for the 90 meter rotor and ca. 5,400 households for the largest rotor of 112 meters.

Table 2. ***Main computed wind energy characteristics in the three suitable points***

Point 1., Location: **West of Maklár** *(N47°48'23''; E20°22'38''; 172 m a.s.l.)*			
Turbin type	Mean wind speed (ms^{-1})	Mean power density (Wm^{-2})	Average annual production (GWh)
Vestas V80	4,42	105	1,795
Vestas V90	4,60	116	2,429
Vestas V112	4,65	120	4,010
Point 2., Location: **East of Maklár** *(N47°48'25''; E20°27'27''; 150 m a.s.l.)*			
Turbin type	Mean wind speed (ms^{-1})	Mean power density (Wm^{-2})	Average annual production (GWh)
Vestas V80	4,29	94	1,600
Vestas V90	4,48	105	2,214
Vestas V112	4,53	108	3,669
Point 3., Location: **South of Szomolya** *(N47°53'11''; E20°29'18''; 234 m a.s.l.)*			
Turbin type	Mean wind speed (ms^{-1})	Mean power density (Wm^{-2})	Average annual production (GWh)
Vestas V80	4,51	110	1,892
Vestas V90	4,58	114	2,396
Vestas V112	4,74	125	4,199

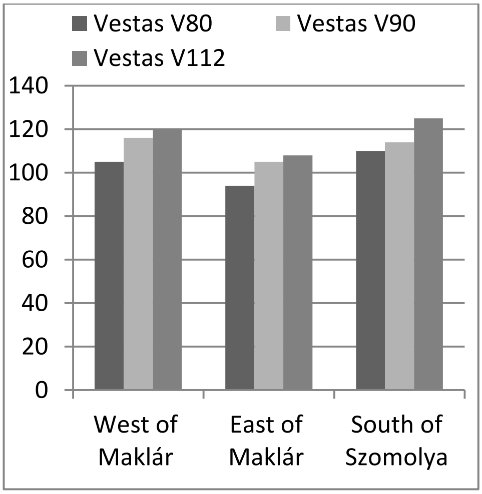


Fig. 11. ***Mean power density (Wm^{-2}) in the three suitable regions***

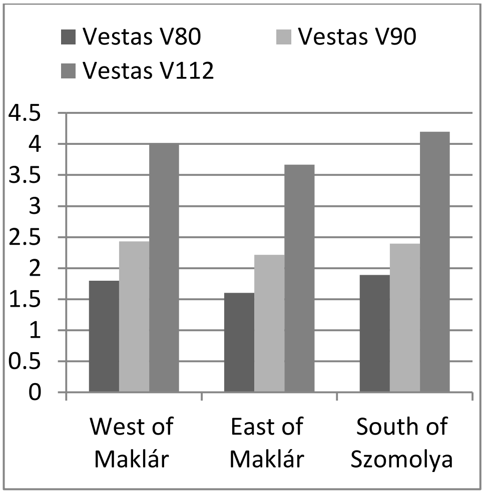


Fig. 12. ***Annual mean production(GWh) in the three suitable regions***

7. CONCLUSIONS

We examined the wind climate, the economic and sustainable wind energy potential with the help of the WASP model in the Eger Energy Region. We found that a significant part of the region is not suitable for installation of wind power plants, but there are areas where utilization of these instruments should be considered. It was found, that density of the wind energy increases with the altitude above sea level, so for further studies it is worth starting measurements at the possible highest point.

In order to effective production, the largest power plants are worth using, because there are costs that exist any type in the same way (foundation, delivery pipes, etc.), but the annual rate of return is more than double compared to the smaller plants. In 70-80% of cases, the wind speed reaches the starting threshold, so it can’t be said that the area is rich in wind energy, but it would be worthwhile to calculate when such a project will return, if having this proportion of windy days.

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