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WIND ENERGY APPLICATION IN HUNGARY

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This paper deals with green wind energy application (depends on solar energy). Nowadays global energy consumption was increased increasingly due to the growing the population and standards of living style. Moreover, with increasing the global warming and environmental pollution, the development of renewable energy sources was becoming more essential. Wind energy is one of the most promising clean and sustainable energy. Wind power plants produce electricity by having rotating three blades. It has three main in its energy chain: wind turbine, gear box and electric generator. A wind turbine turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing. If wind flows across the blades, the air pressure on one side of the blade decreases. The difference in air pressure across the two sides of the blade creates both lift and drag forces. The force of the lift is bigger than the drag and this causes the rotor to spin. The rotor connects to the generator, either directly (if it's a direct drive turbine) or through a shaft and a series of gears (a gearbox) that speed up the rotation and allow for a physically smaller generator. This translation of aerodynamic force to rotation of a generator creates electricity. The total capacity of wind power capacity is 329 MW in Hungary. Number of operating wind farms are 39, with 172 wind towers. Most of wind farms are in the Kisalföld region in Hungary. Current legislation in Hungary does not allow the installation of new wind power station. My work shows that there is a justification for the use of wind energy in Hungary.

***Keywords**: wind power, wind turbine blades, lift force, generator, wind farms in Hungary, clean energy.*

INTRODUCTION

Within green energy, renewables are enjoying a renaissance. This is due to the climate change as well as the rapid decline of fossil energy carriers (coal, oil derivatives) and rising extraction costs. One of the largest problems of renewable wind energy that depends on many factors for example: meteorological conditions, geographical location, wind condition, etc. The storage of the green electricity generated by wind farms is currently not yet fully solved problem.

Renewable energy is a reliable energy source that includes solar, wind, geothermal, hydropower, biomass and tidal energy (Figure 1).

The utilization of renewable energies mean a sustainable solution to many urgent problems, there are energies environmentally friendly, since there is no emissions during use. There are two known options for the utilization of renewable energies:

- passive, and
- active utilization.

Aside from geothermal and tidal energies, renewable energy sources are replenished constantly by sunlight.

Previous wind energy studies have proven that Hungary does not have sustainable usable wind power potential due to its low annual average wind speed. Hopefully, in the near future the Hungarian government’s intention to promote increasing energy consumption will change, and a research project to investigate Hungary’s wind energy potential resources will be initiated. Measurement and analysis of air flow at the lower altitudes 90-180 m with a complex vertical profiling system.

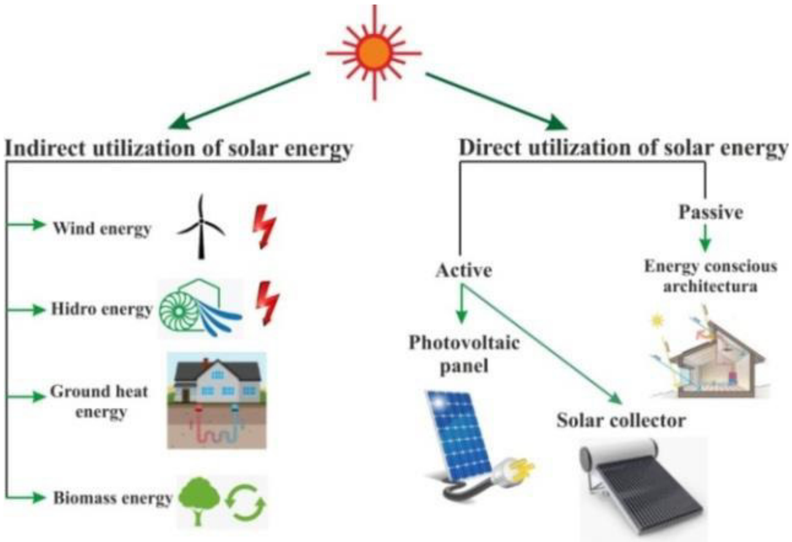

Figure 1 : Types of renewable energies

Because the installation of wind farms is prohibited by the Hungarian Government Decree 277/2016 (IX. 15.) [3]. Quote from the amendment to the law: "Within 12 000 m (12 km) of the built-up area and the boundary of the built-up area, with the exception of small wind farms of household size, no wind turbine or wind farm may be located." This situation is shown in Figure 2.

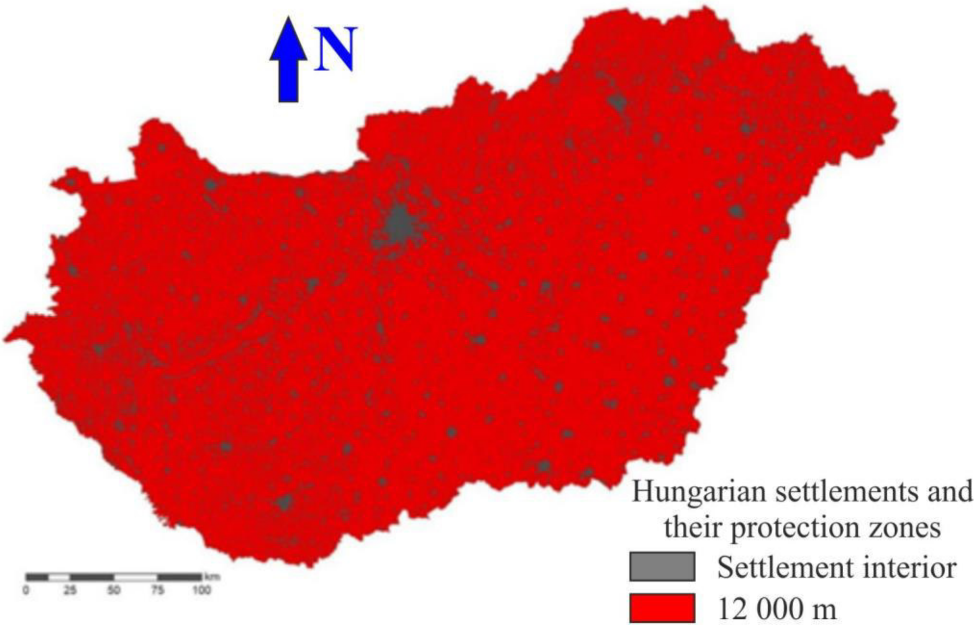

Figure 2. No possible installation site in Hungary [2]

The utilisation rate of wind power plants in Hungary exceeds that in Germany, but due to the unprecedented strict regulation in Hungary, no new wind power plants can be built today, even though the current capacity of 329 MW could be multiplied many times over with new turbines. The following research aims to demonstrate the timeliness of wind turbine expansion in Hungary.

BASICS OF WORKING METHOD OF WIND POWER PLANT

One of the most important energy generators is wind power, which uses wind turbines to generate electricity. Using wind energy is good for us and good for nature. There are many advantages - but there

are also disadvantages. Wind power is the most widely used renewable energy source in the world, ahead of hydropower and solar power. Wind is the result of solar radiation reaching the Earth's atmosphere, which reaches the surface in uneven proportions.
Because the intensity of the sun radiation varies from place to place, it is inevitable that the layers of air with strong solar radiation will be warmer, while the surrounding atmosphere will be much cooler. We know from thermodynamics that warm air travels upwards and cold air travels downwards. Therefore, cool air flows in instead of the warm layers: this is called wind.
Wind energy (like solar energy) therefore comes from the Sun. About 1-4% of the Sun's energy reaching the Earth is converted into wind energy. In terms of wind power among renewable resources, Hungary ranks 21st in the EU with a total wind power capacity of 329 MW. Table 1 shows the biggest total capacity wind farms in Hungary in MW.

Table 1. The biggest wind farms in Hungary [6]

WIND FARM by LOCALIY	POWER [MW]
Kisigmánd	50 MW
Ikervár	34 MW
Bőny	25 MW
Levél	24 MW
Bábolna	15 MW
Nagyigmánd	14 MW
Sopronkövesd	12 MW
Csém	12 MW
Ács	12 MW
Nagylózs	11 MW

Figure 3 shows the energy chain in the wind power station. Wind turbines operate on the basic principle that the kinetic energy of wind creates lift and turns its propeller-like blades. The blades of the turbine are connected to a drive shaft that spins a generator and in turn generates electricity. The use of wind energy means using the kinetic energy of the atmosphere directly or converting it into electrical energy.

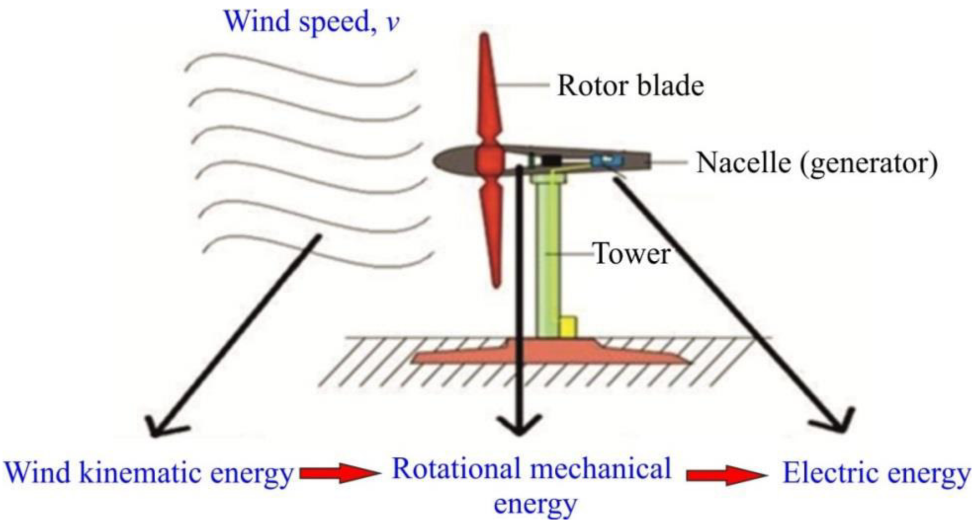

Figure 3. Wind energy becomes electric energy

The kinetic energy of an air mass moving at speed v can be written as follows

$$E = \frac{1}{2} m v^2 \tag{1}$$

where

- E kinetic energy of wind flow [J],
- m mass of the air [kg],
- v wind speed [m/s].

Wind turbines are usually characterised energetically by their power output (at rated wind speed). The relationship between kinetic energy and mechanical power can be written as follows (using Eq. 1) [1]

$$P = \frac{E}{t} = \frac{\frac{1}{2}mv^2}{t} = \frac{1}{2}\underbrace{\frac{m}{t}}_{\dot{m}}v^2 = \frac{1}{2}\underbrace{\dot{m}}_{\rho\dot{V}}v^2 = \frac{1}{2}\rho\underbrace{\dot{V}}_{Av}v^2 = \frac{1}{2}\rho A v^3 \quad (2)$$

where

- P total input wind power to rotor [W→MW],
- $\dot{m}$ mass flow [kg/s],
- ρ air density [kg/m^3],
- $\dot{V}$ volume flow [m^3/s],
- A swept area of wind turbine rotor blades [m^2].

RESEARCH OBJECTIVES AND IMPLEMENTATION

The main steps of the research were as follows:

- Wind speed map calculated for 90 m above ground level and other thematic maps to map wind energy potential.
- Delimit areas that are not suitable for wind farm development at all.
- Delineate areas proposed and potentially proposed for wind farm development. (For the county land use plan).
- Measure the wind speed at the set point.
- Conversion of near-surface data to 90 m altitude.
- Proposals for the installation of a wind farm.

Due to the location of Hungary the prevailing wind is the north-western. Based on the average wind speed, Hungary can be classified as a moderate windy region, the annual means of wind speed are varying between 2 and 4 m/s at 10 m altitude (Figure 4).

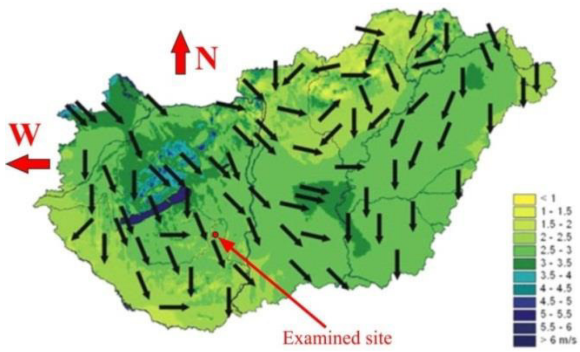

Figure 4. Wind direction and speed in Hungary at 10 m altitude [4]

The proposed wind farm (only one tower) is located in Tolna County (Fig. 4). The measurement location and GPS coordinates are shown in Figure 5.

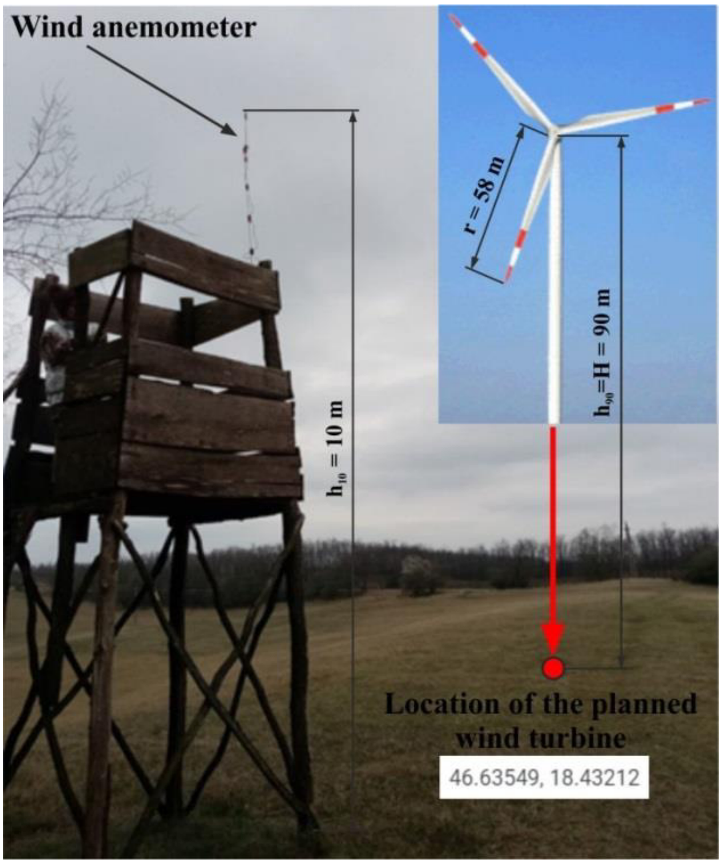

Figure 5. Planned location and measurement site

Comparative measurements were carried out at the planned site. This was compared with the measurements of the Hungarian National Meteorological Institute. Figure 6 shows the applied wind anemometer, and its position can be seen in Figure 7.

Figure 6. Used measuring instrument [3]

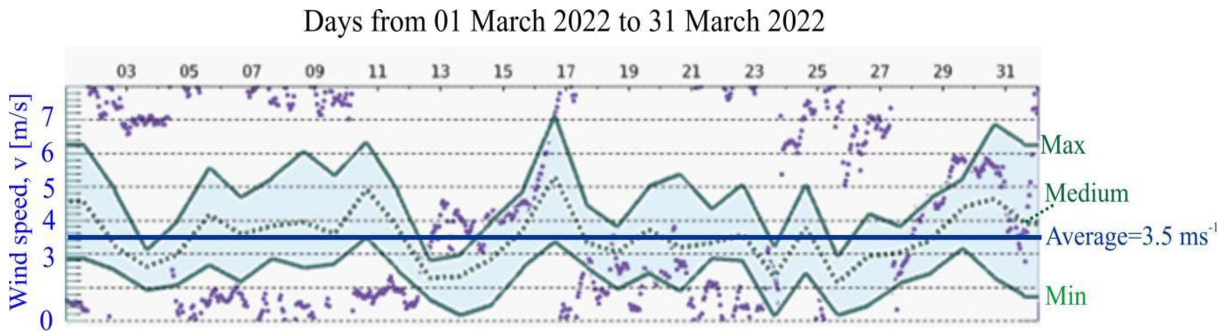

Figure 7. Minimum, average, medium and maximum wind speeds in March of 2022 in Hungary at 10 m altitude [5]

Comparative measurements were carried out in March at the planned location. The results were plotted and the average wind speeds were determined (Figure 8).

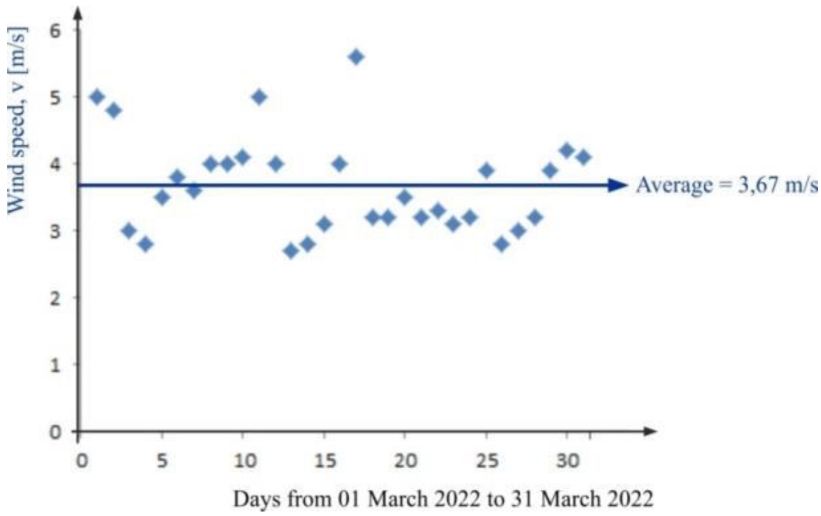

Figure 8. Results of the comparative measurement of wind speed at 10 m altitude

It can be seen from Figure 7 and Figure 8 that the average wind speeds are almost identical. We can therefore accept the meteorological service data for 2021.
The average wind speed is converted to the higher altitude of 90 metres [1], where the axis of the wind turbine's rotating rotor is located.

$$v_{90} = v_{10} \sqrt[5]{\frac{h_{90}}{h_{10}}} \quad (3)$$

where

- v_{90} calculated wind speed at 90 m altitude [m/s],
- v_{10} average wind speed at 10 m altitude [m/s],
- h_{90} 90 m altitude [m],
- h_{10} 10 m altitude [m].

Figure 9 shows maximum, medium, average and minimum wind speeds.

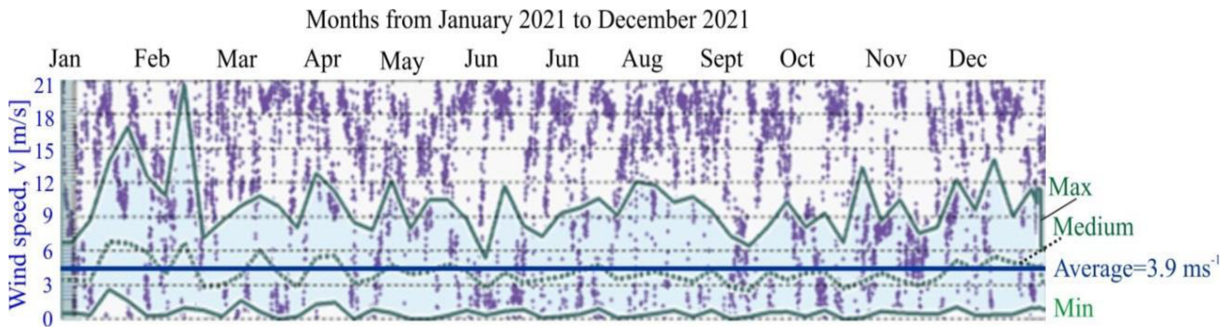

Figure 9. Wind speed for all 2021 year at 10 m altitude [5]

Average wind speed 3.9 m/s can be read from Figure 9. Applying (Eq. 3) and average wind speed

$$v_{90} = v = v_{10} \cdot \sqrt[5]{\frac{90}{10}} = 3.9 \cdot 1.55 \cong 6 \; m/s. \tag{4}$$

The real electrical output power of a wind turbine can be written according to Eq. 5

$$P_e = e_t C_F \frac{1}{2} \rho \underbrace{A}_{\frac{D^2\pi}{4}} v^3 = e_t C_F \frac{1}{2} \rho \frac{D^2 \pi}{4} v^3 \tag{5}$$

where

- P_e electric power [W→MW],
- e_t total efficiency of wind plant, about 30% [-],
- C_F capacity factor, about 0.45 [-],
- D diameter of rotor blades [m].

The designed diameter of the turbine rotor is D = 2·r = 116 m. Wind turbine type is "Alpha ventus D". Taking Eq. 4 and Eq. 5 into account, we obtain the useful electrical power

(6)

Eq. 5 shows that the electrical output of a wind turbine depends on the 3rd power of the wind speed. Taking that the average wind speed increases to 10 m/s.

$$P_e(v=10) = 0.3 \cdot 0.45 \frac{1}{2} 1.25 \frac{116^2 \pi}{4} 10^3 \cong 0.9 \; MW \tag{7}$$

From Eq. 6 and Eq. 7, we see that the power has increased by 4.5 times. Note that the capacity factor increases with increasing wind speed up to about 14 m/s.

RESULTS AND DISCUSSION

The average wind speed at the site of a potential wind farm can be used to determine the electric power output. The value of the useful electrical power (200 kW) determined from the average wind speed obtained for the measurement site is plotted in the Figure 10.

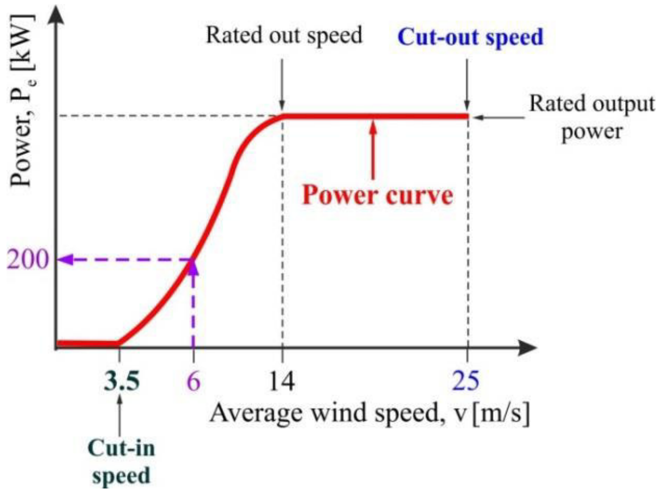

Figure 10. Typical wind turbine power output with average wind speed

Figure 10 shows that the wind turbines reach their rated power around 14 m/s. Hence, they should be installed where the average wind speed is close to 14 m/s. Assuming that the wind farm has a constant power output, the generated electricity during one year can be determined (applying Eq. 7).

$$E = P_e \cdot \underset{1\ year}{t} = 200 \cdot 10^3 \cdot 360 \cdot 24 = 1.73 \cdot 10^9\ Wh = 1.73\ GWh \tag{8}$$

The result of Eq. 8 indicates that the calculated electricity is significant. The resulting energy can replace large amounts of traditionally used fossil fuels.

CONCLUSIONS AND RECOMMENDATIONS

Most important local and global aspects are energy supply and environmental protection. The planed wind turbine is capable of producing up to 1.73 GWh every year, enough to power around 500 European homes, displacing more than 820 tons of CO_2. Based on the results, I would dare to suggest that the strict siting law for wind farms might be worth reconsidering. The engineering creations want to improve the people work and live. Of course, in addition to the many advantages, there are also many disadvantages for the living and built environment. The present study does not deal with this research field.

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