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Realistic Potentials of Wind Energy Utilisation in Hungary

Abstract

After the demonstration of the present situation of wind energy utilisation in Hungary, those policies are analysed that determine the economical harnessing of the wind energy potential. The following aspects are examined: climatic and climate change of Hungary, facilities in Hungary's geography and land use. The relevant research is based on the last 10 years and examines the possibilities in science and science policies which are shown in greater detail. Finally, the possibilities in energy policies are investigated on the basis of Hungary's Renewable Energy Action Plan 2010–2020.

Key words

Wind energy; Hungary; Potentials in climate and climate change; Geography and land use; Science and energy policies

Introduction

In December 2011, there were 172 wind turbines in operation in *Hungary* with a total installed capacity of 329.3 MW. 90% of these are located in the northwestern part of the country. The annual electric power output of these stations is over 600 GWh. According to *Figure 1*, approximately 29% of this capacity was installed in 2010. *Hungary's* total exploitable wind energy potential is an estimate of 532.8 PJ/year (IMRE, L. 2006). This paper summarises the realistic potentials of economical wind energy utilisation in *Hungary*.

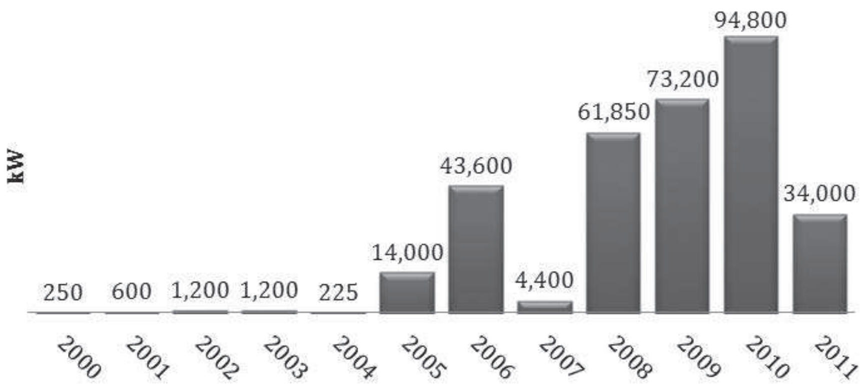

Figure 1 – Annually installed wind energy capacity (kW) in Hungary between 2000 and 2011

Source: Hungarian Wind Energy Association (MSZET, 2011); Edited by BOKOR, L. (2013)

1. Climatic potentials of Hungary

Hungary's climatic conditions demonstrate winds of far less strength that of those in *Western Europe*, but the number and distribution of old windmills indicate, unambiguously, that there is harnessable wind energy potential in the *Carpathian Basin*. Most windmills were built between 1866 and 1885. Wind conditions in the southern part of the *Great Hungarian Plain* were most suitable for installing windmills of smaller height with a typical capacity of about 20 kW. Thus, the location of former windmills defines those regions, where the utilisation of wind power is economical with high probability (KEVEINÉ BÁRÁNY, I. 2000).

The wind-climate of *Hungary* indicates that other parts of the country are also suitable for wind energy utilisation. According to the examinations by BARTHOLY, J. *et al.* (2003) and RADICS, K. *et al.* (2010), the yearly mean wind speed in *Hungary* is between 1.5–3.8 m/s at a 10-metre height *(Figure 2)*.

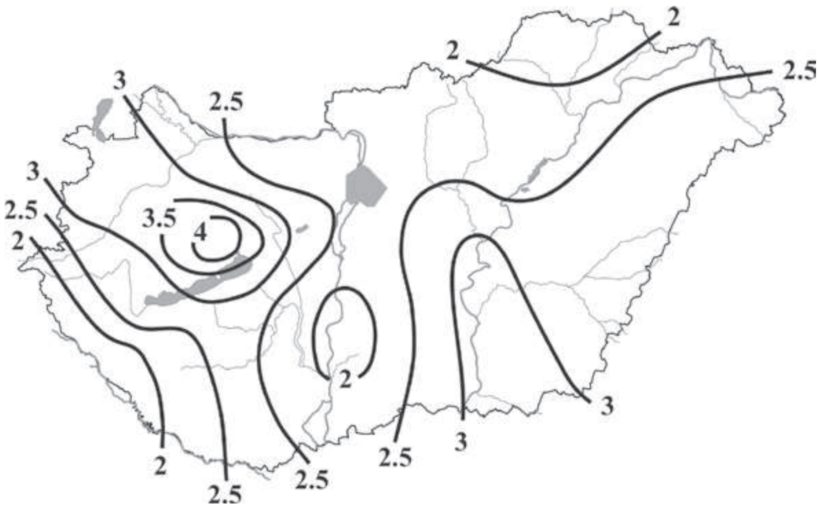

Figure 2 – The yearly mean wind speed at 10 m in Hungary
Source: BARTHOLY, J. et al. (2003)

These mean wind speeds are greater than 3 m/s in about 70% of the country's territory and they show great geographical differences at this height. The most and least windy parts are the northwestern and northeastern parts of *Hungary,* respectively. This is shown in *Figure 3* which represents the geographical distribution of wind speeds of more than 5 m/s at 10 m height.

The maximum of relative frequency is in the middle of *Transdanubia* (21.6%), its minimum (less than 4%) occurs in the axis of *Northeast* and *Southwest Hungary*. The longest duration of wind speeds is between of 1–3 m/s and between 1,500 and 3,000 hours/year.

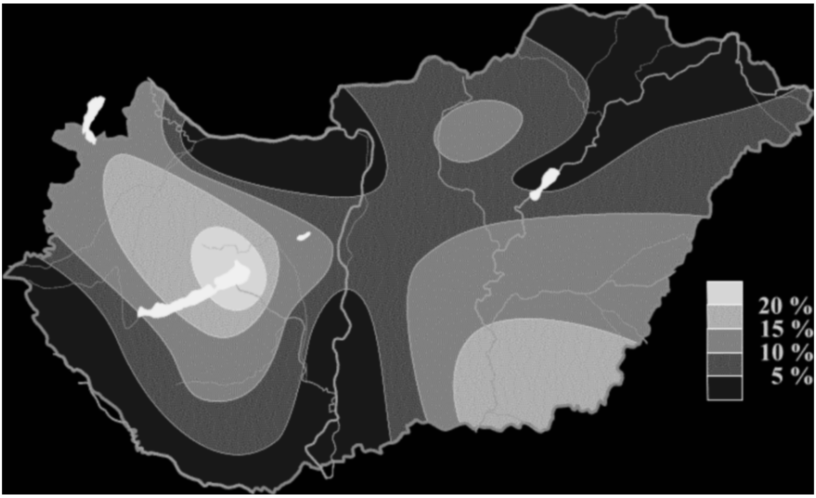

Figure 3 – Spatial distribution of wind speeds of more than 5 m/s measured at 10 m height

Source: RADICS, K. et al. (2010)

Since the cut-in wind speed of wind turbines working in *Hungary* is 3–4 m/s, the statistics of wind speeds, that are greater than this figure, is very important. According to our former research results (TAR, K. – RÓZSAVÖLGYI, K. 2008; TAR, K. *et al.* 2011), there is no orographic difference in the daily distribution of the probability of hourly wind speeds of more than 3 m/s. For example, the maximum of this probability occurs at about 13–14 o'clock and, accordingly, the daily distribution of continuously changing temporal probability results in an increase of electricity production until 17–18 o'clock.

There are neither orographic nor height-separations when it comes to the mean length of those intervals that have the wind speed of more than 3 m/s every hour. The length of these intervals determines the monthly mean specific wind power between 38% and 69%. The monthly mean specific wind power is more sensitive to the changing length of these intervals in mountainous regions than in flat plains.

The changes of potential wind energy in different parts of the day—which is proportional to the cubed wind speed—causes an important problem for the transmission system operation. It is necessary to supply the missing amount of electricity from other sources. According to *Figure 4–5*, the daily distribution of hourly cubed wind speeds may show a 12-hour or a 24-hour period.

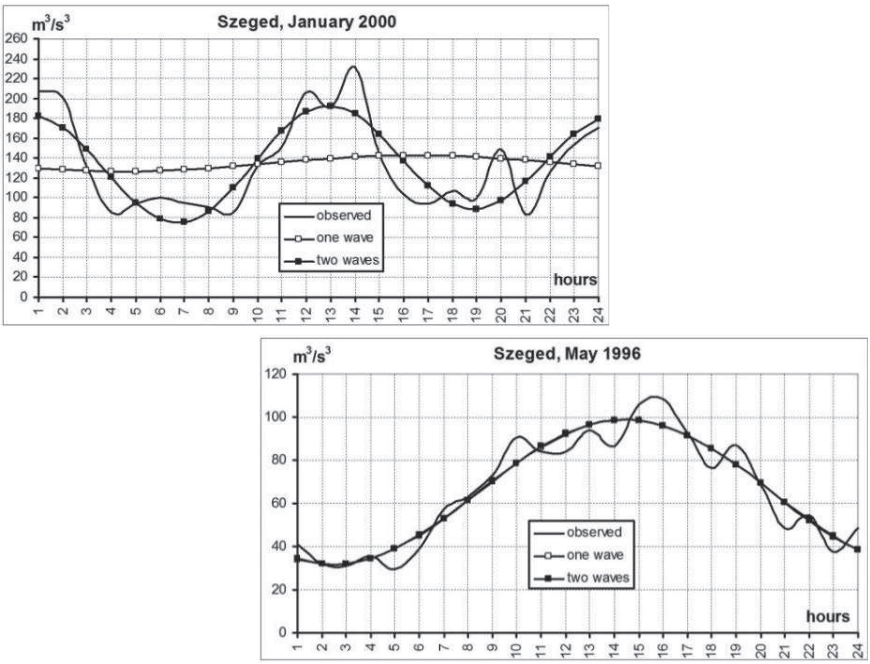

Figure 4–5 – Complex (12-hour period) and simple (24-hour period) changes in daily cubed wind speeds that are proportional to the specific wind power
Source: TAR, K. (2006; 2007)

The frequency of the wave with 12-hour periods increases during the winter, early spring, and autumn months, that is for the major part of the year. Thus, significant daily alterations in wind energy are to be expected, with minimums in the morning and afternoon, and maximums during daytime and at night. There are no daily changes in wind energy, where the 12-hour wave is random because it is dominated by the daily cycle with a single maximum around midday. The most favourable days for the transmission system operation are those, when there is no significant daily variation. Following the above case, the number of these days should be relatively small. The proportion of those months, where the daily average wind energy shows neither the daily nor the 12-hour period, is only 2%.

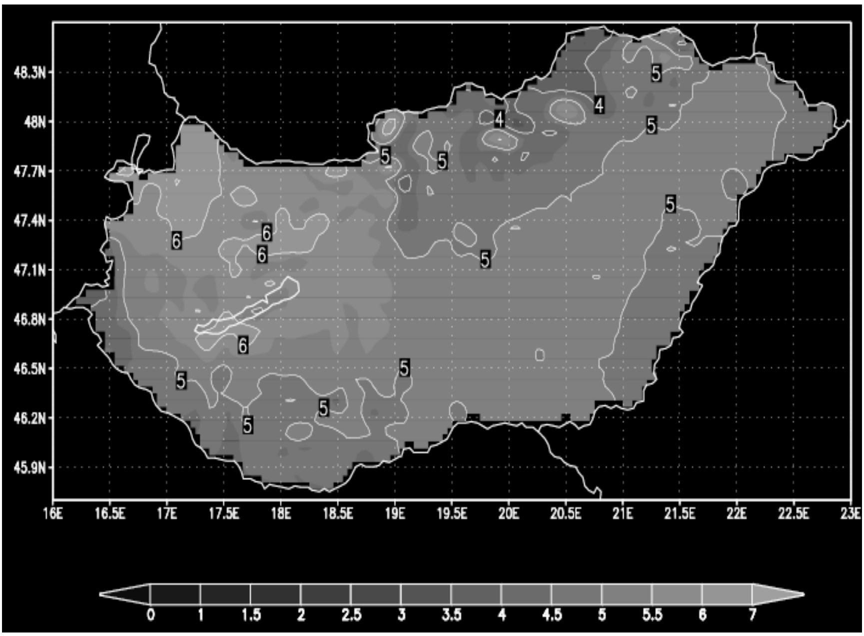

Figure 6 – Average wind speeds at 75 m height calculated by the dynamic downscaling between 1961 and 1990

Source: SZÉPSZÓ, G. – HORÁNYI, A. (2009).

Apart from the application of wind forecasts with high space-time resolution, the careful selection of the site of wind turbines is also necessary for economical operation. The selection of the optimal site can be achieved with the help of wind maps showing the mean wind speed or the mean specific wind energy during a particular time interval. In the course of a national research project, one of the important tasks of the *Hungarian Meteorological Service (OMSZ)* was to draw high-resolution wind maps that show the wind climate of the lower 100-metre-layer of the atmosphere on the historical basis in the past.

OMSZ provided more solutions to this problem. The dynamic downscaling of numeric models enables modelled wind fields near the ground to accurately reflect real stream conditions. This technique enables the production of wind direction and wind speed data at different points and heights where measured information does not exist, otherwise (SZÉPSZÓ, G. *et al.* 2006, SZÉPSZÓ, G. – HORÁNYI, A. 2009). The dynamic downscaling is never exact because it is just the best available simulation based on the laws of the atmosphere. Nevertheless, in our opinion, the produced 5 km resolution wind climatology (wind direction and speed) provides better results than the maps derived from ground-level measurements *(Figure 6)*.

2. Potentials in the change of Hungary's climate

According to the investigations of MIKA, J. (2001), it can be concluded that the decreasing barometric gradient, the increasing frequency of anticyclones and the decreasing frequency of northerly and westerly flows would result in a decrease of wind speeds and wind energy.

This result is also supported by one of our own investigations, although it covered only a short period with regard to climate change (TAR, K. *et al.* 2002). The frequency of cyclonic and anticyclonic macrosynoptic weather situations, after *György Péczely,* was determined during between 1968 and 1972, and 1991 and 1995. These situations specify atmospheric stream conditions in *Hungary*. It was found that the number of cyclonic situations, namely which have utilisable wind speed, decreased by 4% during the second period. In the case of some Hungarian weather stations, the impact of this decrease on the mean specific wind power was also investigated. The deficit was 40% for the whole period, its maximum occurred in the summer (48%), and its minimum in the winter (36%).

Based on the hourly wind speeds of the above mentioned periods, the monthly relative wind energy, i.e. the monthly proportion in percentage of the yearly sum was determined. According to *Figure 7*, the relative wind energy follows the 'traditional' yearly distribution of the wind speed: in Budapest, maximums in March, July and November; and minimums in September were detected between 1968 and 1972. However, significant changes occurred between 1991 and 1995 compared to the previous interval: extreme values changed and the third maximum in the summer, which is very important with respect to irrigation, disappeared. These are the consequences of significant alterations in the yearly distribution of the wind speed which can be likely due to the changes of atmospheric flows as a result of climate change.

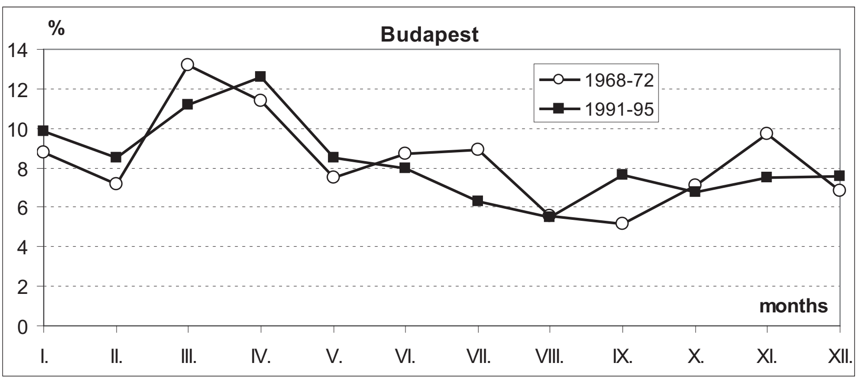

Figure 7 – Annual changes in monthly relative wind power in Budapest

Source: TAR, K. et al. (2002)

However, the results of a research-team, which has analysed ground-level wind speeds for the past three decades, show that decreasing wind speeds in the last 30 years are primarily due to the increase in vegetation covering the *Northern Hemisphere* (LÁZÁR, I. 2011). As a result, the surface of the ground has become rougher which hinders the air flow. The team has analysed the data of weather stations and found that average wind speeds on the *Northern Hemisphere* are weaker by 10% than 30 years ago. Ranking the causes, the researchers concluded that the vegetation cover accounts for 60% of the wind speed decrease. Consequently, VAUTARD, R. *et al.* (2010) states: their results are explained by global warming only by 10–50%.

In contrast, the *2007 IPCC report* says that westerly winds have become stronger in medium latitudes on both hemispheres since 1960 (ÉGHAJLATVÁLTOZÁS, 2007).

Theoretically, the investors and operators of wind turbines may worry about the decrease in wind speeds, but researchers are not able to answer the question of to what extent this phenomenon affects the wind energy utilisation in its industrial size. Ground-level wind is measured at 10 m height, so these data are used by researchers as well. However, the rotor of wind turbines is at 50–100 m height, and there is little data on air flows at this height in all parts of the *World*.

There is no direct reference to the change of the wind speed in the *Carpathian Basin* either in the above mentioned paper or in the IPCC report. According to MIKA, J. (2009), *Hungary's* wind energy will rather decrease in the future, despite the fact that the downscaling of macro-regional climate models do not show significant alteration in wind speeds.

3. Potentials in Hungary's geography and land use

The main factors in installing wind turbines are the following:

- wind conditions which mean the prevalence of permanent, strong winds that should be checked by wind energy measurements;
- environmental aspects: an area that is wide, open and free of obstacles and other surface roughness and statically possesses adequate soil conditions;
- technical factors: sufficient quality of roads, grid connection opportunities;
- environmental protection factors: noise effect, shadow effect, bird migration routes, etc.

The latter ones are the most complex; in fact, areas that are not recommended for installation or are forbidden can be deduced from these factors. These are:

Installation not recommended or forbidden:

- areas of ecological networks (protected natural areas, their buffer zones, natural areas, and ecological corridors);
- biotopes, feeding and nesting areas of protected wild animals and their migration routes;
- biotopes of protected plants and plant associations;
- protected landscape areas, areas of unique landscape values;
- areas affected by international agreements and laws (e.g. Ramsar, Natura 2000, Bio-sphere reserves)

Areas recommended for installation:

- large, contiguous agricultural areas (farmlands);
- industrial areas;
- areas degraded by open-pit mining or other factors.

Based on various statistical yearbooks, HUNYÁR, M. *et al.* (2006) identified the total area of lands that are unsuitable with high probability for installing high capacity wind turbines. Results are shown in *Table 1*.

Table 1 – Areas unsuitable for wind turbine installations

Source: HUNYÁR, M. et al. (2006)

Land category	Area (km^2)
Interior area of settlements	6,650
Water surfaces	1,753
Protected areas	8,573
Yards, vineyards, orchards	2,880
Forests	17,468
Railroads	3,949
Roads	2,205
High and Medium voltage transmission lines	15,419
Areas 400 metres above sea level and steep slopes	1,860
Total	**60,758**
In percentage of Hungary's total area	**65.3 %**

4. Potentials in science and science policies

Technological development, which is closely linked to the results of scientific research, can be observed in the change of the capacity of wind turbines. In this respect, the past 25–30 years have shown that doubled axis height and rotor diameter resulted in a 2.5 times capacity increase, while a three times change resulted in 4.3 times change in the capacity. If this tendency goes on, then by 2020, there may appear wind turbines with the 20 MW nominal capacities.

The role of science is also important. By choosing the location of high capacity, electricity generating wind turbines require serious consideration of climatological, technical, economic, social, and environmental factors. A review of the Hungarian meteorological literature shows that Hungarian meteorologists are aware of their responsibility when it comes to exploration and exploitation of atmospheric resources (SZÉPSZÓ, G. *et al.* 2006; SZÉPSZÓ, G. – HORÁNYI, A. 2009).

The results of wind climate research for energetic purposes are summarised in a paper written by TAR, K. – PUSKÁS, J. (2011). Nevertheless, there is still a lot to do in the area of detailed and accurate exploration of *Hungary's* wind energy potential in short and long-term forecasts.

During the exploitation of renewable energy, currency, acceptance and government subsidies are among the most important social factors. Research in the currency and acceptance of renewable energy has recently become the topic of socio-geographic research, and so far, the results have been encouraging (KOVÁCS, T. – PATKÓS, CS. 2011; TÓTH, J. – TÓTH, T. 2011; TÓTH, T. – KAPOCSKA, L. 2011; TÓTH, T. *et al.* 2012). The main conclusion of an extensive research conducted in the valley of the *River Hernád* with respect to wind energy is the following: *"… real substantive knowledge is minimal. Traditional sources of information (electronic and print media) do not provide a full range of knowledge on this topic. Residents should be given correct, authentic and comprehensive information which fulfils their needs as its best. Municipal leaders may play an important role in the actual implementation and information transmission process."* (TÓTH, T. *et al.* 2012).

Education is one of the key factors of success. Given the fact that the present geography textbooks used in elementary and secondary schools underrepresent the current state of renewables, PAJTÓKNÉ, T. I. (2012) introduces her own electronic toolkit developed for geography teachers and students. Moreover, it also gives examples on how to diversify the teaching of geography and other natural sciences with the knowledge of renewable energy sources.

With respect to the government subsidies, the paper by GÁCS, I. (2010) and BÜKI, G. (2010) comes to the following conclusion: *"During the exploitation of wind energy, electricity is produced which substitutes primary energy. Substituted primary energy in the Hungarian national grid can be fossil fuels (gas, coal, lignite) and nuclear energy, but because of various aspects (primarily due to the high percentage of natural gas in the structure of primary energy use), this results in the substitution of natural gas. However, the hectic electricity production of wind turbines due to wind speed fluctuations decreases the efficiency of power plants working in the network. Due to the compensation for the alternating electricity production of wind turbines, the electricity system requires a higher reserve capacity. This results in a significant decrease in the efficiency of fossil fuel power plants. Primarily, this occurs at night when the electricity demand is low. Rapid and significant changes in load increase the frequency of unstable working conditions in traditional power plants which decreases their annual average efficiency and results in more fuel consumption and greenhouse gas emissions."* (GÁCS, I. 2010, BÜKI, G. 2010).

"The savings on primary energy usage, chiefly the substitution of natural gas, provides the basis for the promotion of wind energy. Energy saving is also related to the reduction of carbon-dioxide emissions. This reduction in emissions means 2–2.5 HUF/kWh (0.007–0.009 GBP/kWh) an advantage in the present electricity system. The amount of money or part of it can be transferred to wind energy producers. In a grid equipped with more modern and more efficient gas power plants, this figure is reduced by one-third. However, a 30–40% increase in profit could be achieved by setting up pumped-storage hydroelectric power stations, but in this case (at least), the additional profit should be used to finance the construction of the power plant … More subsidies for wind turbines would be justified only if large scale wind turbine production was present in Hungary which would result in new jobs." (GÁCS, I. 2010).

Meteorologists carry out researches on wind climate and also hope that these conditions will be fulfilled soon, and that the installation of wind turbines will continue with its past dynamics. It is an encouraging sign that the foundation stone of a new wind energy generator house factory was laid on 15 October 2010 in *Tiszaújváros*.

5. Potentials in energy policies

In this respect, wind is the most authentic source in *Hungary's* Renewable *Energy Action Plan 2010–2020*. The following paragraphs contain the edited version highlighting those parts of this document which refer to wind energy.

"Wind energy is an extremely environmentally friendly, modern energy source (with practically no CO_2 emissions) which could represent one of the key elements of energy supply in the future. It is, however, a non-controllable, weather-dependent technology. Thus, the proliferation of wind energy is inhibited until the time energy storage can be ensured in an economical manner by the controllability and capacity of the electricity system. The national target for 2020 is thus aligned to the limit of the electricity system's controllability which is, to our present knowledge, capable of receiving wind energy up to an approximate total output of 740 MWe."

"Based on surveys conducted in the past few years, locations have been identified that provide economically sufficient place for the installation of larger wind turbines with respect to nature conservation and environmental protection. According to this, Hungary's total wind power potential reaches several thousand MWe." (According to IMRE, L. [2006] this is 6,489 MW.)

"In addition to larger wind energy parks, the National Renewable Energy Action Plan also factors in the spreading of smaller wind turbines (with an output of a few kW) and dwarf turbines which could generate power for the network periodically and primarily play an important part in the local autonomous energy supply. Based on experts' estimates, these can be expected to emerge at a total electricity output of approxi-

mately 10 MWe until 2020. Based on this, a realistic target of 750 MWe can be set for the creation of wind energy capacities by 2020."

"According to the Hungarian Electricity Act (article 7 – (2)) on January 1, 2008, connecting wind turbines to the grid requires formal application. The first request for tender in wind energy appeared in 2009 in the capacity of 410 MW. (Decree of the Ministry of Transport, Communication and Energetics, no. 33/2009. (VI. 30.). The frequency of tenders' occurrence depends on the controllability and safe operation of the electricity system and on the changes in technical limits which may enable the installation of the additional wind power capacity based on the results of the periodic audit of the electricity system."

"The primary goal of the priority axis 'Increasing the use of renewable energy' within the Hungarian Environment and Energy Operational Programme is to generate a favourable change in the structure of Hungary's fuel consumption, i.e. to promote the shift from fossil fuels to renewable energy. Within the construction of thermal energy and electricity, the following measures are supported: biomass usage, production and usage of biogas from green waste, exploitation of geothermal energy, installing heat pump systems, using solar and hydro power, installing wind turbines without grid connection, setting up or modernising community district heating systems using renewable energy, and preparing renewable solid fuels (e.g. pellets, briquettes). Taking the limited wind energy receiving capacity of the Hungarian electricity system into account KEOP (Environment and Energy Operational Programme) currently supports the installation of only low-capacity (max. 50 kW) wind energy parks."

6. Epilogue

"Based on large and world-wide sources, with respect to costs, the maturity of technology and limited environmental impacts, it can be stated that the use of wind power for the fulfilment of an ever growing percentage of electricity demand has a promising future in those countries that are willing to make investments." (OLÁH, GY. *et al.* 2007).

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