ECONOMICAL AND ENVIRONMENT-PROTECTING QUESTIONS OF ERECTION OF WIND-POWER STATIONS IN HUNGARY
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ABSTRACT
The most frequent questions concern the connecting to the main power network, the environment protection and the economical efficiency. The present paper deals with the latter two in detail.

The protection of the environment, besides the natural environment in this case, involves the human surroundings as well. Several studies are permanently under preparation all over the world, investigating explicitly the impacts of the noise emitted by the wind-power stations and the visual effects exerted upon the human beings. Amongst all the others, these are perhaps the investigations that can hardly be determined since they include several subjective elements as well.

As against that, the economical efficiency is based on calculations containing concrete parameters from the result of which anybody can make a decision whether an investigation is profitable or not for him.

Key words: renewable energy sources, wind energy, environment, costs

1. Impact of wind-power stations exerted upon the environment
1.1. Comfort well-being and environment
During investigation of the local environmental effects of the wind energy, the impacts exerted on the well-being (comfort) have to be distinguished from the environmental effects.

The ‘comfort well-being’ includes such factors which may affect the human sensation or behaviour – e.g. visual effect, landscape, sound and electromagnetic disturbances.

According to this interpretation, the environment protection involves all direct and indirect material effects exerted on the vegetable and animal life. The birds, rare plant species, and the local hydrological, etc. conditions belong to these generally.

1.2. Avoiding CO₂ emission
In the European Union, about the one third of the CO₂ emission is derived from the energy production. Through substituting renewable energy resources for every each conventional energy producing capacity of 1 %, a decrease in CO₂ emission of 0.3 % can be achieved.

Yearly a 600-kW wind-power station protects the environment from:
- 7.1 t sulphur dioxide,
- 2.8 t nitrogen oxide,
- 1114 t carbon dioxide,
- 0.9 t carbon monoxide and
- 0.18 t suspended dust.

During its design life of 20 years it prevents about 20,000 to 35,000 t CO₂ emission in comparison with the similar energy output of the power station in Mátra (mountain).

Table 1. CO₂ emission at two technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>At fuel getting</th>
<th>At construction</th>
<th>In operating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal burning</td>
<td>1</td>
<td>1</td>
<td>962</td>
<td>964</td>
</tr>
<tr>
<td>Wind</td>
<td>Nothing</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Specific emissions of coal burning power stations and wind turbines

<table>
<thead>
<tr>
<th>Polluting matter</th>
<th>Coal burning power station (G/KWh)</th>
<th>Wind-power station (G/KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>2.5 to 16.4</td>
<td>0.087</td>
</tr>
<tr>
<td>NOₓ</td>
<td>0.89 to 5.3</td>
<td>0.036</td>
</tr>
</tbody>
</table>

1.3. Global advantages of the wind-energy utilization
In Hungary, the value of electric energy produced of renewables has been determined as 11.5 % by 2010. Of course, it is impossible to achieve that. After negotiations reasoned by calculations, according to the EU Directive No 2001/77EK, Hungary has to increase the present 0.5-% ratio of electric energy produced of renewables up to 3.6 % till 2010.

In Hungary, legal regulation (CX th law of the year 2001) guarantees – in the case of current yield produced from renewable – the obligatory accep-
Norbert Schrempf, Katalin Vágó, László Tóth

tance; the acceptance price is specified by the decree belonging to it, valid at present (No 112/2005 (XII.30.) GKM).

The estimation for the quantity of the polluting-material emission avoidable in the EU for that case if the development of wind energy would follow the trend of the European Wind-Energy Association (EWEA).

**Table 3. Polluting-matter emissions avoidable through the planned wind-energy use in the EU**

<table>
<thead>
<tr>
<th>Year</th>
<th>EWEA’s objectives for installation of wind-energy capacity (TWh/yr)</th>
<th>Production (TWh/yr)</th>
<th>Decrease in CO₂ (t/yr)</th>
<th>Decrease in SO₂ (t/yr)</th>
<th>Decrease in NOₓ (t/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>20,000</td>
<td>40</td>
<td>34,200,000</td>
<td>114,000</td>
<td>95,000</td>
</tr>
<tr>
<td>2010</td>
<td>40,000</td>
<td>80</td>
<td>64,800,000</td>
<td>216,000</td>
<td>180,000</td>
</tr>
<tr>
<td>2020</td>
<td>100,000</td>
<td>200</td>
<td>134,400,000</td>
<td>480,000</td>
<td>400,000</td>
</tr>
</tbody>
</table>

*Ref.: European Wind-Energy Association*

1.4. Land-area use

The 99 % of the land area in which the wind-power park is located is physically available alike as before. The wind-power-tower bases of about 10-m diameter are placed under the ground under normal conditions so they allow the agricultural cultivation right up to the column.

There is no evidence of that that the wind-power parks would in a higher degree disturb the agricultural activity or the animal farming.

1.5. Visual effect

The reaction to the vision of a wind-power station is highly subjective. Many people consider them as a symbol salutary to the clean energy while some others count them to be unfriendly accessories of the landscape.

A photomontage of computer has been made to demonstrate the visual effect.

It is well documented that the decisive majority of the visitors of the wind-power parks gain a pleasing impression. The designed wind-power device is mounted on a long (high) conical steel tower which appeals more to the most people.

The effects of the periodical reflection or interruption (shadow vibration) of the sunshine were taken into consideration at the surface treatment of the blade wheel. At the designed tower of 80 to 100 m, these effects do not operate over the distance of 400 m.

The following figure shows an example of calculating the shadow effect. Since the village is in the direction north-north-west from the power station, the shadow effect cannot appear in highlight case and, in the case of diffuse light, it can be supposed to be one to two hours in a year that it is not longer than 4 to 5 minutes even in the most disad-

![Figure 1. Calculation of shadow effect]
vantageous period.

1.6. Noise effect

The modern wind turbines are silent. The sound is measured in decibels (dB), using a logarithmic scale. The decibel is the measure of the sonic pressure level – the order of the pressure variation in air. A 3-dB increase is equal to doubling the sonic pressure accordingly it is already a significant changing in volume of sound. A 10-dB increase is such an effect in general as the doubling of the ‘loudness’. The measurement of the noise level of the environment is effected in dB(A) which includes the correction of sensation of the human ear as well. The sonic-pressure level is 50 to 60 dB(A) at the distance of 40 metres from the designed wind-power station – in general, it is as of level as that of a conversation. At a house at the distance of over 400 metres, when the wind blows from the direction of the turbine towards the house, the level of the sonic pressure is 30 to 35 dB(A) which corresponds to that in a quiet building. When the wind blows towards the counter direction, the level of sound decreases significantly – by even 10 dB(A).

![Figure 2. The infrasonic pressure (dB(A)) as a function of the frequency at 10 m away from the tower (values cannot be detected at 600 m distance)](image)

![Figure 3. Audible sound effect edging away from the column](image)

1.7. Electromagnetic disturbance

The experiences show that the wind-power park does not cause disturbance of any kind in the communication systems. The glass-reinforced polyester used for the modern blade wheels is partially subtranslucent for the electromagnetic rays therefore it is in the medium range on the scale of electromagnetic disturbance.

However, there are consultations with the civil and the military authorities for determining if electromagnetic disturbances are to be expected.
1.8. Impact upon birds

Birds frequently collide with such constructions which they can see hardly – especially high-tension transmission lines, masts, columns or windows of buildings but moving vehicles also kill them in the road traffic. The behaviour of the birds, according to species and locations, shows a specific trend.

Wind turbines rarely disturb the birds. Radar tests concerning Tjaereborg on the western shore of Denmark – where a 2-MW wind-power station with a rotor of 60-m diameter is erected – show that the birds are apt to change their flying route; to pass the turbine at a safe distance of 100 to 200 m away above or beside it. According to the observations, this behaviour is as consequent by night as by day. There are several examples of that as well in Denmark that falcons nest in cages mounted on the towers of wind turbines.

1.9. Other environmental effects

The effects exerted on the environment are primarily the results of the construction activity, excavation of soil and hydrologic erosion. The abraded soil is quickly restored by the surrounding system in several places. Evidences imply that the wind-power park affects neither the wild nor the domestic animals.

- Personal safety. There is not such a registered case with personal injury which would be caused by blades or loosened ice. The International Committee of Electric Engineering issued an international standard on the safety regulations of wind turbines.

1.10. Environmental considerations

- Visual aspect (public forum makes the decision).
- Due to the suitable distance, the wind turbines do not disturb the environment of the dwelling-houses by shadow vibration, vision or reflected light.
- Ecology. There are not protected – not even in-season – species in the area.
- There are not civil or military airfields about. Despite of that, consulting the aeronautic authority about the project is necessary.
- There are not restricted areas (military, telecommunication etc.) about.

<table>
<thead>
<tr>
<th>Irregularity class of the terrain of the wind-power station</th>
<th>Electric-energy production of the wind-power station (MWh/yr)</th>
<th>Primary energy consumption of a coal burning power station (MWh/hr)</th>
<th>Energy use of the wind-power station (MWh)</th>
<th>Return rate of energy use of the wind-power station (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>1393</td>
<td>3202</td>
<td>821</td>
<td>3.1</td>
</tr>
<tr>
<td>Class 2</td>
<td>1130</td>
<td>2598</td>
<td>821</td>
<td>3.8</td>
</tr>
</tbody>
</table>

These are conservative assessments as the estimated values of energy consumption concerning the coal burning power station includes only the direct costs of the fuel (energy content and transport of coal). At the same time, they do not contain the construction and the costs of the coal burning power station (that may be over 50 %) or the indirect energy use in the course of coal burning. Additionally, the comparison supposes a 45-% thermal efficiency that is far above the average value experienced in the coal burning power stations operated in the EU. In general, the time of return of the wind-power station will be even shorter. The transport of the wind turbines through a long distance (to the spot) causes a little difference in comparison with the above values. E.g. even if a 65-t wind turbine has to be transported to a distance of 10,000 sea-miles, this will increase the net energy requirement by only 1.5%.

1.11. Material required

The table shows the weights of the materials for the different part units of the wind-power park. Below an alternative, the breakdown by materials can be seen.

On the base of those above, it is obvious that, amongst the materials required for the wind-power park, the concrete used for the base of the turbine and steel for making the column are the dominant.

<table>
<thead>
<tr>
<th>Unit of wind-power park</th>
<th>Mass/power (t / 1000 kW)</th>
<th>Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>turbine</td>
<td>108</td>
<td>17</td>
</tr>
<tr>
<td>base</td>
<td>444</td>
<td>73</td>
</tr>
<tr>
<td>other infrastructure</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>total</td>
<td>612</td>
<td>100</td>
</tr>
</tbody>
</table>
1.12. Environmental statement

On the base of the Environmental Statement, the local building and other supervising authorities have to agree to every question and according to the documents there is no objection to the plan.

1.13. Disassembly and re-cultivation

The all elements of the device can be cleared away and the original conditions can be restored. The most of the cost of disassembly can be recovered from the metal-utility-waste value of the turbines. The possibility of the simple hazard-free disassembly of the wind-turbines – in comparison with other energy generating technologies – is the considerable advantage of the wind energy.

1.14. Recycling

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass/power (t / 1000 kW)</th>
<th>Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>456</td>
<td>74</td>
</tr>
<tr>
<td>Steel / Iron</td>
<td>134</td>
<td>22</td>
</tr>
<tr>
<td>Glass-Reinforced Polyester</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Copper</td>
<td>3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Gravel</td>
<td>3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Aluminium</td>
<td>&lt;2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Lubricants</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Polyethylene (Pet)</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Polyvinyl Chloride (Pvc)</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Others</td>
<td>&lt;&lt;1</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>612</td>
<td>100</td>
</tr>
</tbody>
</table>

Blade wheel: Glass-reinforced polyester in destructor (waste burner)

Bases: Steel in steel-works. Rubble (broken matter)

Tower: Steel, concrete-reinforcing steel as new concrete, in deposing site

Copper: Copper in copper works (cast-house)

For the easy demolition of the bases, there are shot holes in the bases.

Figure 4. Aspect picture of a planned wind-power station from north-east direction (Hungary, Erk)

2. Economical efficiency of wind energy

The economical efficiency basically determines the volume of project. However, for a long term, it has to be taken into consideration that it can be counted the cleanest one amongst all the energy resources since it does not emit waste of any kind. In the European countries, the carbon-dioxide is limited one by one and, in terms of this, its usability increases significantly for its erection is not limited in no way, according to the international agreements.

For the compensation of the accidental losses caused by the present price conditions, the wind energy is subsidized by state almost in every country:

- Either the produced energy
- or the investment i.e. the establishment of equipment is aided.

At the same time, it can also be observed that, in many countries, the acceptance price of the wind
energy approaches the terms of energy produced by other power stations. However, in all countries, the unit price of sold by the energy suppliers to the resident population is higher by 20 to 40% than the cost of energy produced from wind. This indicates at the same time that generating energy from wind for own use is economical today already in almost all countries.

By estimations, the wind energy is already competitive in many countries in comparison with the fossil and the nuclear energy, and it is especially true if the external costs too are taken into consideration. The economical efficiency of the wind energy fed in the main power network highly depends on the aspects by which it is evaluated.

The first is the aspect of the national energetic supply. From the view-points of the economical efficiency and the reliable energy supply, the value of the energy produced in a wind-power plant, proceeding from the random nature of the wind energy in time, could be extremely low as well. In terms of the cost of energy production, there can be very great differences as well in accordance with the role of the produced energy in the entire system:

- basic energy source
- or it serves for satisfying temporary load demands.

Remember that as well that, at calculating the return rate of the energetic investments, a priori a value exceeding 10 years is taken.

As to the technical side, the cost of power generation by wind energy is determined basically by the following factors.

The total investment cost includes
- the manufacturing cost of the wind turbines and the bearer construction, the costs of connection and other additional costs;
- the costs of the project and the project-preparatory process, infrastructure etc.

2.1. Operating and maintenance cost

- The prevailing average wind velocity in the actual place
- The condition of ground i.e. – if the bases of the wind turbines and the service roads can be built economically
- Accessibility
- Technical life
- Depreciation period
- Real bank-rate

The preparatory cost of the project highly depends on the local circumstances, social approaches, the stances of locals and such other edge conditions as the condition of the soil and the roads, the distance to electric power network.

The operating and maintenance costs include the expense items of service, repair, insurance, administration, rent of land, etc. According to one of the approaches, the annual operating and maintenance cost is the 2 to 3% of the manufacturing cost; the technical life is 20 years as an average. According to the experiences, it is advisable to exchange the critical pieces under high load – such as the main bearings, gear wheels and the generator – at the half of the design life.

The annual average wind speed prevailing in the actual area has a decisive importance for the energy cost.

In Hungary, the decree of the Ministry of Economy and Transport No 1112/2005 (XII. 23.) determines the purchase prices of the electric energy. The effect of this law extends to the electric energy under obligatory acceptance, determining its price. Since 1st January 2006 the acceptance price of electric energy produced of wind power has been 23.83 HUF/kWh all-in tariff independently of time of day.

The conditions of the energy sale (the details) have to be fixed in a separate contract. The attachment of the law conceives that the prices influenced by the inflation effects that be have to be taken into consideration at calculating the price.

3. Economical conclusions

Table 7. Break-down of project costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind generator (generator, blade helices etc.)</td>
<td>70%</td>
</tr>
<tr>
<td>Feasibility studies, design, authorization</td>
<td>3%</td>
</tr>
<tr>
<td>Transport, founding, steel tower, transformer etc.</td>
<td>20%</td>
</tr>
<tr>
<td>Effecting, land area, utilities</td>
<td>7%</td>
</tr>
</tbody>
</table>

After the theoretical calculations, the final statement concerning the economical efficiency of the utilization of wind energy can be extracted. This project cannot be passed on according to an economical basis alone; it has to be taken into consideration that the production of energy gained with the help of wind takes place in an environment saving way.

The concrete calculations are demonstrated here through showing an algorithm used internationally; it, of course, is satisfactory for an orientation only.
In areas less rich in wind energy, the determination of the location and the height of the mast are very important thereby the available amount of produced energy may be increased. The figure also directs the attention to that the lower wind velocity due to the greater frictions in land conditions can be compensated by increasing the height of the tower.

References