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Introduction

The visibility assessment of the Perenye Windpark was commissioned in 2009 by the West Transdanubian Authority for Environmental Protection. The plans of the windpark contained 11 turbines situated in an arable area near the small village of Perenye, south of the scenic Kőszegi Mountain and the Írottkő Nature Park. The height of the planned turbines was 179 meters (160 meters tower plus 19 meters rotor height). Ten of them were planned to have 2 MW energy output and one, which was offered by the investors to the local government, 850 kW.

The main reason for the visibility assessment was the need to forecast the changes the windpark will most probably induce in the well-appreciated Transdanubian scenery. According to the Environmental Authority's demand the visibility assessment had to contain a study of the main viewpoints of the area from which the windpark might appear to observers. These viewpoints were defined by the Environmental Authority itself and consisted of the traces of the two major roads running beside the site and a well-known look-out point of the Kőszegi Mountain called Szent Vid Chapel. The settlement areas of the nearby villages were not included in the Authority's request for assessment and were therefore not considered in detail. As a consequence of the visibility assessment the possible ways of minimizing the visual effects of the windpark through landscape planning methods had to be considered, and recommendations had to be given for new roadside plantings as well as for the ideal coloring of the turbines. As a result of the work the Authority accepted the plans of the windpark on the condition that all assessment driven recommendations are realized by the investor.

Background

There are well known examples of visibility and visual impact assessment studies for windparks either with GIS softwares (see e.g. Kidner and Dorey 1995, Ball and Miller 2003, Möller 2006, Aydin et al. 2010) or with CAD tools (Hurtado et al. 2004) or based on human experience studies with interviews and surveys (Bishop and Miller 2007). There are some reviews on the evaluation methods of windparks' visual-aesthetic effects on the landscape (see e.g. Berner 2002, Risser 2007), and there are numerous best-practice recommendations published by associations or governmental organizations for wind energy development (e.g. British Wind Energy Association 1994, Irish Wind Energy Association 2008, European Wind Energy

Association 2002). In Hungary there are official guidelines for the development of wind energy plants (KvVM Természetvédelmi Hivatal 2005) and also a national standard exists concerning the Aesthetic Assessment of Landscapes (MSz 20372). Though this standard is not specifically designed to aid the visibility respectively the visual impact assessment of wind turbines, it should be used officially to estimate a planned windparks' effect on the scenery.

Method

For the visibility assessment of the Perenye Windpark we chose to examine the viewpoints defined by the Environmental Authority according to a GIS methodology of viewshed generation. With this we aimed to fulfill the requirements of the national standard and the Environmental Authority. At the same time we aimed to introduce the internationally well-known and widely applied GIS based method of visibility assessment to the general professional practice in Hungary. Our assessment's key step was the creation of a digital landscape model which involved all the data and information about the site and the investment. The visibility of the windpark was assessed with the VirtualGIS Module of ERDAS Imagine software. The spatial dataset used for the viewshed generation consisted of the digital elevation model of 5 meters horizontal resolution, the most significant land cover elements – mostly forests –, and the wind power plant with the precise location and physical parameters of the turbines.

The forests near the planning area are dominated by extraneous evergreen pine trees *(Pinus nigra, Pinus sylvestris*) They bear approximately the height of 15 meters. Most of the patches are monoculture plantations of about the same age. We decided to include the forest land cover in the visibility assessment and generated viewsheds for the land surface covered by 15 meters high forests. Turbine visibility was then analyzed for three different height-ranges of the turbines (see Fig. 1 and 2.).

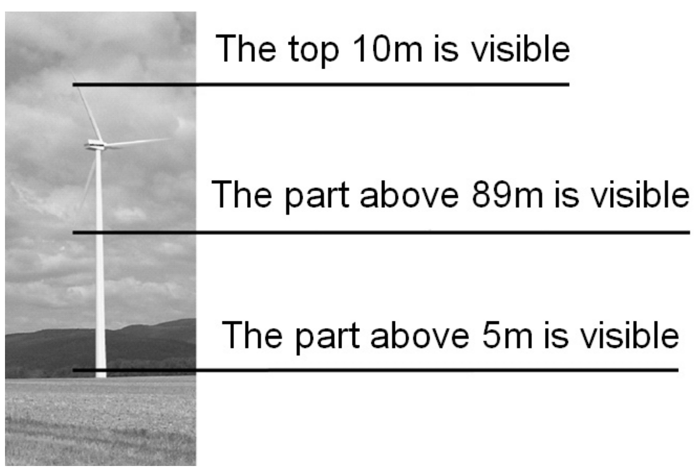

Figure 1. The three analyzed heights of the turbines.

Single, grouped and multiple visibilities of turbines were assessed in detail. Altogether more than 40 visibility maps were created. The applied system can visualize whether a piece of land is outside the turbines' viewsheds because of the elevation, the forest cover, or the 'shadow' of a nearby forest. Additional layered data of settlement borders, land ownership records, look-out points, major roads, railway and hiking trails were used during the visual analysis. The viewpoints defined by the Environmental Authority were considered in detail regarding the expected changes the windpark will induce in the scenery.

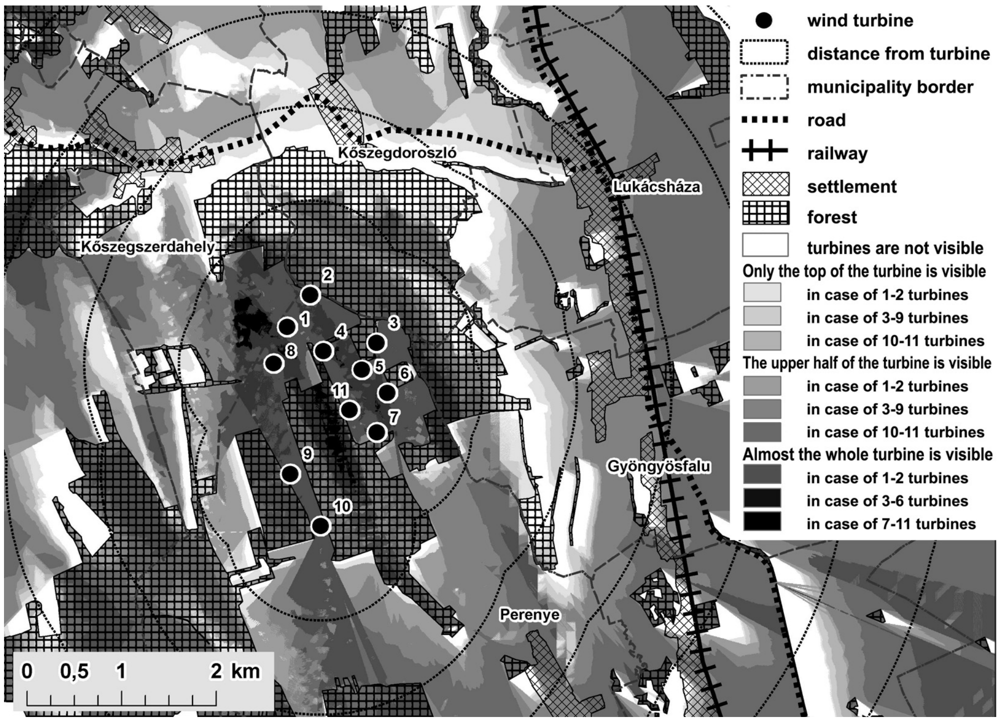

Figure 2. Complex visibility map of the windpark

After conducting the visibility assessment of the planned turbines we compared their viewsheds with alternative turbine-locations' visibility. However, when the Environmental Authority commissioned the visibility assessment the location of the planned turbines was already negotiated on the level of land parcels. Thus the method of the visibility assessment had to limit itself to this situation. As possibilities for turbine displacement we therefore investigated the lowest and highest elevation points within the planned parcels each. We measured for each possible location the percentage of the assessment area that would be affected by the view of a wind turbine. We took 5% change in the affected area as a minimum threshold for a relevant difference in visibility.

Results

The result of the comparison was that in case of four turbines the planned location's viewshed was more than 5% larger than that of the lowest location. The highest elevation alternatives' viewsheds were almost in all cases bigger than those of the planned turbines. There was only one exception to this, where minimally but the planned location gave a larger visibility area than the highest one. The difference between the highest and the planned alternative's viewsheds was mostly irrelevantly small as the planned locations were predominantly placed near to the highest elevation points (see Table 1.).

Table 1. Differences of the viewshed-areas of alternative turbine settings in percentage of the total assessed area. The alternatives were the planned, the highest, and the lowest elevation points within a parcel each.

Turbine Nr. l: low level alternative h: high level alternative p: planned location	Visually affected area (% of the assessed area)	Difference between planned and lowest elevation alternative (%)	Difference between planned location and highest elevation alternative (%)
1l	25,16	0,4	3,62
1h	29,18		
1p	25,56		
2l	25,67	7,4	0,25
2h	33,32		
2p	33,07		
3l	29,17	0,98	-0,04
3h	30,11		
3p	30,15		
4l	24,6	0,48	5,98
4h	31,06		
4p	25,08		
5l	24,26	6,15	0,13
5h	30,54		
5p	30,41		
6l	29,84	0,19	0,19
6h	30,22		
6p	30,03		
7l	22,32	6,96	0,54
7h	29,82		
7p	29,28		
8l	26,39	5,2	0,17
8h	31,76		
8p	31,59		
9l	26,06	0,6	1,21
9h	27,87		
9p	26,66		
10l	25,41	0,92	0,66
10h	26,99		
10p	26,33		
11l	22,51	1,16	6,55
11h	30,22		
11p	23,67		

The visibility analysis of the optimized turbine locations resulted that the displacement of the individual turbines inside their respective parcels does not make any relevant difference to the visibility of the windpark as a whole. The achievable visibility change consists only in the fact that from specific locations the observer can see one or two turbines less out of the whole windpark, but there were no places where this visibility decrease would mean that no turbines would be visible at all. The visibility of the whole windpark thus changes only to a small extent due to the displacement of the individual turbines. Roadside plantings, on the other hand, can substantially decrease the windpark's view, however, obviously, in this case not only the turbines but also the rest of the scenery remains covered from observers. The scenery from the popular tourist attraction, Szent Vid Chapel look-out point is affected by all of the planned turbines (see Fig. 3). There is no option to minimize the visibility of the windpark here as the turbines are in the middle of the main scenery and the look-out point provides a bird's-eye view of them. The displacement of the turbines has therefore not even a minor effect on the windpark's visibility in this case. Planting shrubs or trees would of course be counterproductive, as the vegetation would eliminate the possibility to look out on the landscape, which is currently one of the main attractions of the location.

Based on the visibility assessment, the current land use, and the ownership of the area we defined those main roadsides where the visibility of the windpark should be decreased via forest or shrub plantations. The wind turbines are of course much higher structures than trees are, nevertheless, due to the distance of the identified roadsides from the windpark, the turbines' view can be covered by the vegetation. The roadside afforestation can thus substantially decrease the visibility of the windpark. The planned roadside plantations were located on those road sections from where the whole of the turbines or at least their upper half (above 89 meters) were visible. Further, some of those road sections were included where the turbines would appear directly in front of the silhouette of the Kőszegi Mountain. The plantations were recommended for current agricultural areas where their viewshed function would be combined with wind and erosion protection.

Finally the prospective view of the planned windpark, after the realization of the above presented modifications, was illustrated by photo-realistic visualization. Different coloring possibilities, such as (white, beige to white and green to white) were used to demonstrate the further variability of foreseeable visual effects. The visibility circumstances of the different seasons were also illustrated. However, daily changes of light, and night scenes were not visualized.

Figure 3. Visibility simulation of the Perenye Windpark from the Szent Vid Chapel. The picture shows a summer aspect with a white coloring of the turbines.

Conclusion

The Environmental Authority has accepted the results of the visibility assessment as well as the recommendations which were given on its basis. The plans of the Perenye Windpark gained building permission on the condition that the proposed measures are realized by the investor. The applied methodology of viewshed generation, complemented by basic landscape planning instruments and photo-realistic visualization offered a quick and effective solution for the visibility assessment of the Perenye Windpark, and produced results, which enabled us to propose effective recommendations for decision-makers even when visibility aspects were involved in such a late phase of the windpark development.

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