



Visibility analysis as a tool for regional planning in the context of “repowering” (wind-turbine upgrading)

**A transferable example for
“North Sea Sustainable Energy Planning”**

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1 Context

The spatial impact of wind turbines depends, of course, on factors such as noise emissions and shadow disturbance but also, to a large extent, on its visual impact at distances far beyond the site itself. The current trend in wind energy technology is towards higher output units with taller towers and longer rotor blades. Taking a rural district in Lower Saxony, Germany, as a test case, this paper presents a new technique for using visibility analysis as a tool to aid decision-making in regional planning.

The analysis was commissioned by the district of Diepholz and carried out by GIS-Plan-Service (Jürgen Knies, Oldenburg).

There are currently (spring 2010) 314 wind turbines located in the district of Diepholz. The largest units have a nominal output of 3MW and a hub-height of 140m. The smallest ones, however, have an overall height of only 11.5m. In the future, units of 200m will not be exceptional. Compared to the first generation, today's wind turbines have a disproportionately greater impact upon the landscape.

Against this background, the regional planning department of Diepholz decided to run a study to determine if the "visual impact of wind turbines on the landscape" is an acceptable criterion for evaluating the suitability of sites for erecting such units, alongside the more concrete prohibitory factors such as proximity to housing areas. For planning purposes, it is therefore important to establish what visual impact wind turbines have on a landscape before any evaluation of the landscape can take place. This is particularly important in the context of the imminent, so-called "repowering" scheme to upgrade and renew existing wind turbines. The "repowering" scheme will allow the results of former approval practices to be rectified by dismantling as many isolated units as possible and then replacing the lost generating capacity by more high-performance units in wind farms.

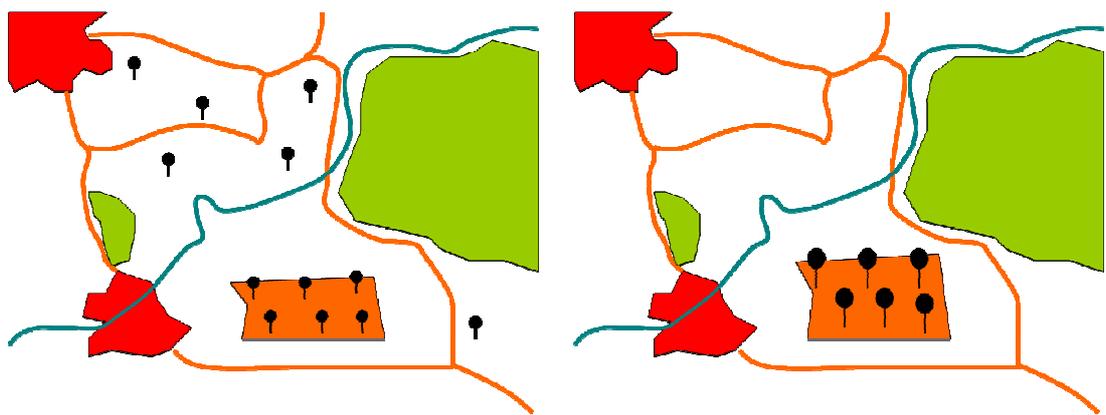


Fig. 1: The principle of repowering – Numerous isolated units are dismantled; larger and more efficient wind turbines are erected on a more advantageous site, increasing the total output (based on DStGB 2009)

The impact of wind turbines depends on several factors, not least the unit itself. The taller the tower, the further the visual impact carries. The topography of the adjacent landscape as well, is a significant factor for the





long-range impact of wind turbines. Exposed sites on the ridge of hills have a longer range impact than those located in a valley. The impact of such units depends very much on the location of the viewer. The presence of these industrial units is much more tangibly felt from close up than if they are at a distance. However, if the viewer is, for example, in a forest or a built-up area then the view of the units is masked.

It must, however, be pointed out that the visual impact does not respect administrative boundaries. It is therefore important to take a holistic, cross-boundary approach to repowering.

A so-called impact analysis, a tool which has, to date, been little used in regional planning, takes account of all of these factors.

2 Methodology

The impact analysis is based on a weighted visibility analysis of wind turbines which takes into account the distance from the tower to the viewer. Making allowance for the working-scale and the degree of abstraction, it is possible to make relatively accurate predictions of sight-lines/sight obstruction. The result of a visibility analysis does not provide any indication of the degree of any impairment of the landscape but it does, however, allow a first assessment of the potential visual impact to be made.

The following parameters are the basis of a visibility analysis:

- impact zone/working scale
- digital model of the terrain
- features of the terrain with visual effects
- height of the viewer

The data used were made available by the GIS department of the district. The parameters and the methodology are described in more detail below.

Impact zone / working scale: The landscape in the district of Diepholz is a patchwork of land-use types and varies between flat and rolling terrain, so it can be said that wind turbines with an overall height of over 100m are structures with a long-range visual impact. However, the actual visual perceptibility of the units depends on factors such as the transparency of the landscape and prevailing meteorological conditions. If these are left out of the assessment then the degree of visibility of wind turbines depends, to a large extent, on the given sight-lines from the viewer's standpoint.

The human eye has a vertical angle of vision of about 37° (27° of the range is above the horizontal); the horizontal angle of vision is 54°.

Accordingly, a wind turbine fills a certain part of the field of vision and will thus be perceived as either conspicuous, visually dominant or subdominant, depending on its elevation and distance from the viewer's standpoint (see table 1).



Table 1: Visual impact zones for wind turbines (WT) with an overall height of 150 m, 100 m und 80 m (Source: Schleswig-Holstein 2003)

Impact zone	Distance for a 150m WT	Distance for a 100m WT	Distance for a 80m WT	Description of the typical impact of the WT for the given distance
1	2	3	4	5
Close proximity	< 300 m	< 190 m	< 150 m	The distance is too small to allow views of the complete object; it can only be fully viewed by scanning.
I Foreground	300 m - 570 m	190 m - 400 m	150 m - 300 m	Object is conspicuous and captures the attention. WT fills half to all of the field of vision.
II Middle distance	570 m - 1.100 m	400 m - 800 m	300 m - 600 m	Full view, dominant; the complete outline of the WT can be seen in one view; it fills a quarter to half of the field of vision.
III Distant view	1.100 m – 2.800 m	800 m – 2.000 m	600 m – 1.500 m	The view is sub-dominant; WT fills 1/10 to 1/4 of the field of vision.
Far distance view	2.800 m - 40 km	2.000 m - 35 km	1.500 m - 30 km	Max. visibility zone. Only visible at max. distance in very good visibility and light conditions and if the tower is white.

A comparative study for the whole district was commissioned but the main focus of attention was on zone III and the far distance view. The working scale was set at regional level (in this case 1: 75000).

Digital model of the terrain: The digital terrain model (DTM) was taken from the official topographical cartographical information system digital. Due to the prescribed working scale DGM 25 was used. The data were converted onto a grid-based terrain model with a resolution or 5x5m (level of detail, LOD, 0)

Features of the terrain with visual effects: In order to evaluate the visibility of wind turbines, features of the terrain which obstruct the view must be taken into account as well as the digital terrain model. These include woods, housing and man-made structures. To gain a relatively accurate picture of these surface features, the computerized land registry maps were used in all areas. Each feature category was given a height based on typical values for the region so, for example, typical average heights of 20m – 25m for woodland and of 8m – 12m for built-up areas were taken, depending on type and land-use. The standardized heights for these sight-obstructing landscape features are then integrated into the digital terrain model using a resolution of 5mx5m. In this way, a digital model of landscape features is built up and this serves as the basis for further analyses (LOD1). It must be stated that accurate conclusions about specific, localized sight-lines/sight obstruction cannot be drawn from the model.

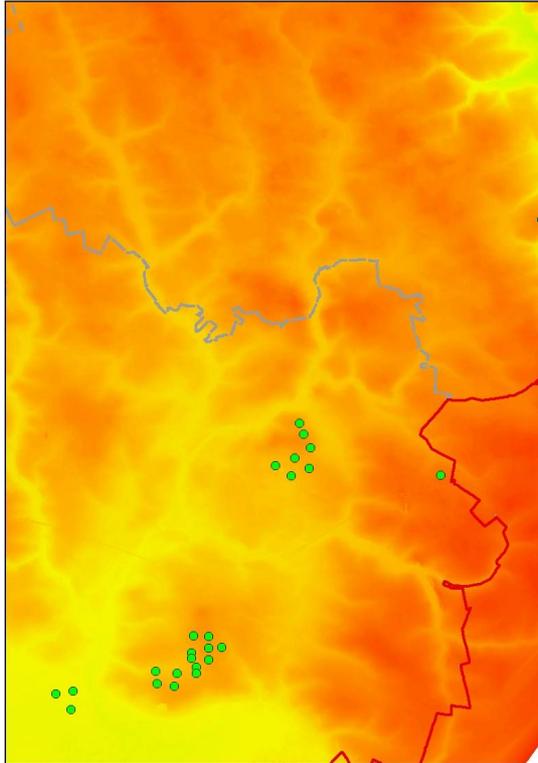


Fig. 2: Terrain model showing existing wind turbines

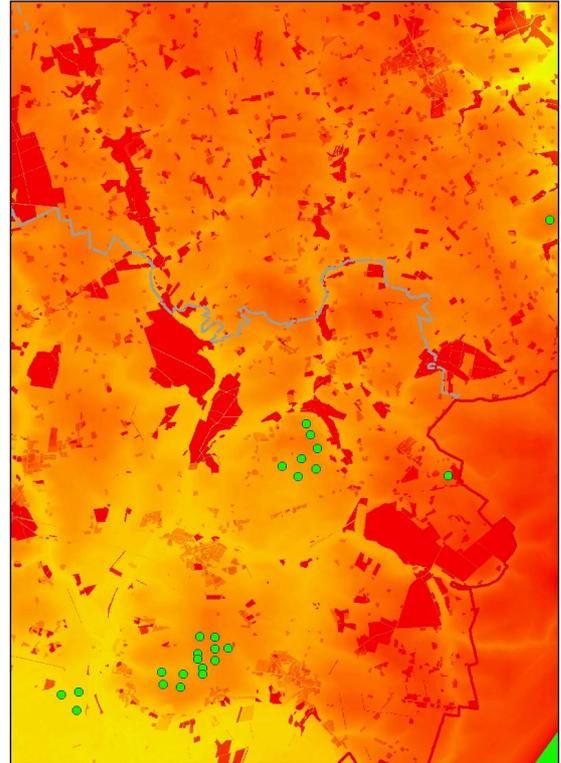


Fig. 3: Model of terrain features (terrain model including features with visual impact) showing existing wind turbines

Viewer's height: A standardized viewer's height of 2m was taken.

Method for impact analysis: The impact analysis uses radii of impact which are determined by the height of the wind turbines. Now it is possible to carry out a visibility analysis, using geographical information systems (GIS) and, at the same time, incorporating the digital model of terrain features, and taking into account the viewer's height and the extent of impact zones. To this end, the methodology was refined in that the impact zone for larger units was defined and the impact zone "distant view" more critically defined. A theoretical visibility distance of 40km is measurable but for planning purposes not practicable. Thus, distant view was defined as double the distance given for zone III after perceptibility was also factored in. This zone can thus be seen as a more accurately defined extension of zone III and the alteration can be seen as a response to the current debate on impact zones (see also Nohl 2007).



Table 2: Re-adjusted analysis zones and evaluation of impairment

Impact zone	Weighting	Distance for WT height up to 180 m	Distance for WT height up to 150 m	Distance for WT height up to 100 m	Distance for WT height up to 80 m	Distance for WT height up to 50 m
Subdominant perception (Zone III)	2	3.600 m	2.800 m	2.000 m	1.500 m	900 m
Far distance view with factored-in perceptibility (double of Zone III)	1	7.200 m	5.600 m	4.000 m	3.000 m	1.800 m

3 Results

In conclusion, the regional planning authority received maps giving an overview of the impairment to the landscape from existing wind turbines. This enables them to predict the impact of planning proposals on the landscape and, moreover, various scenarios and their consequences can be clarified, thus benefitting the communication process.

The following illustrations show the impacts arising from various scenarios. In order not to jeopardize the on-going discussions the topographical map is not included as, otherwise, project developers could draw concrete conclusions from what are only proposals.

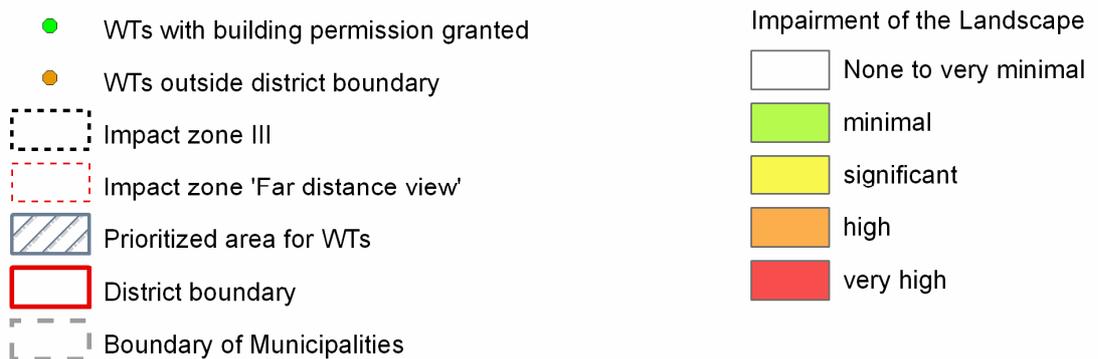


Fig. 4: Legend



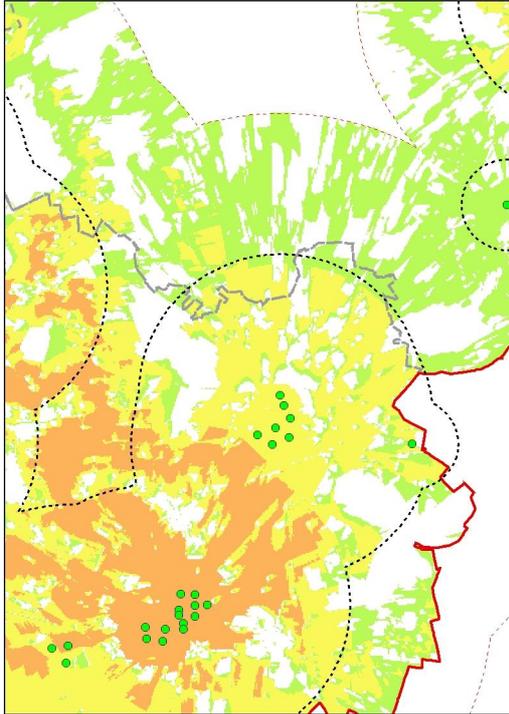


Fig. 5: Status Quo – existing WTs in wind farms and stand-alone units

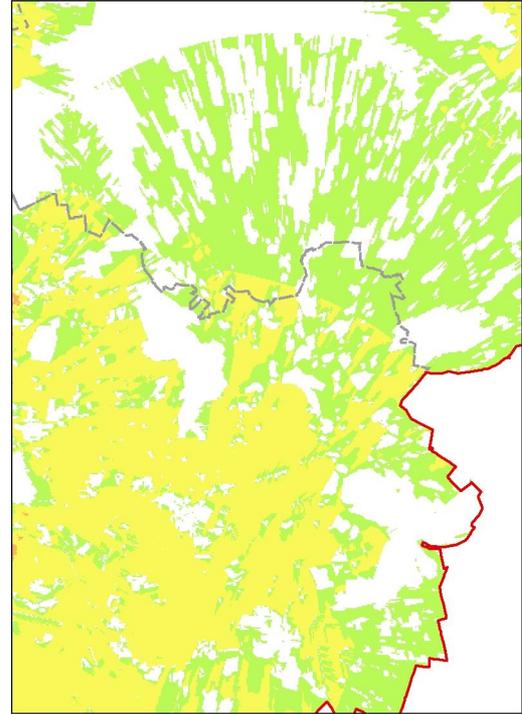


Fig. 6: Restricted development only in currently prioritized areas (tower height up to 180 m); dismantling of stand-alone units

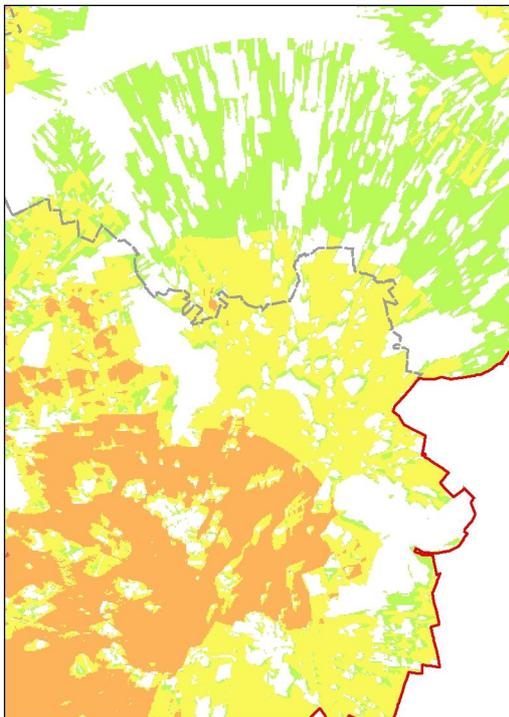


Fig. 7: Uncontrolled development (Worst Case)

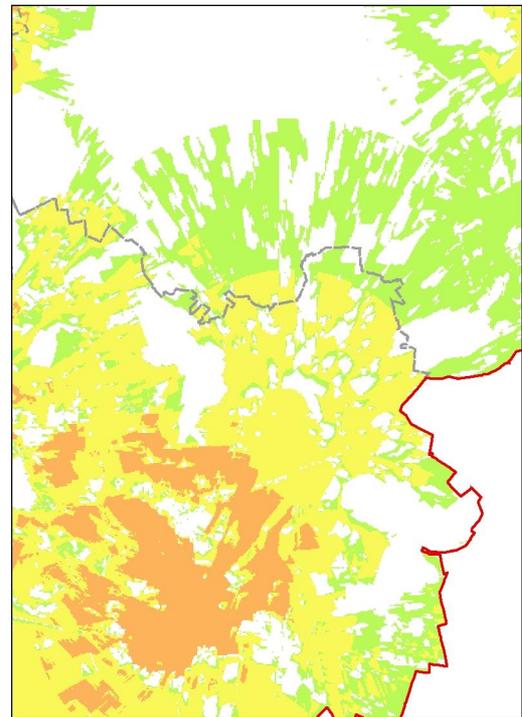


Fig. 8: Vision 2020 – co-ordinated development (expansion of prioritized areas; dismantling of stand-alone units)



4 Conclusion

Impact analysis is a tool which enables regional planners to define terrains in which the impact is extensive and also to classify other areas in which the impact is minimal or, indeed, non-existent. Random tests in the field have confirmed the impacts predicted by the analyses, even in localized situations. With impact analysis at its disposal, the district of Diepholz now has a practical tool with which to model the impact of wind turbines on the landscape in a well-founded and easily-understandable manner.

Various scenarios can, with relatively little effort, be examined and their impact on the landscape be clearly shown. For example, the impact of planned wind farms or of alterations within existing prioritized areas can be depicted by simply changing the appropriate parameters i.e. location or height of the wind turbines.

The regional planning department of the district of Diepholz uses this tool not only for the spatial evaluation of new locations but also in political forums to present the impacts of planned developments. The political decision-making process has benefitted from the possibilities offered by the visualization of the impacts and, particularly, the ability to depict a variety of scenarios.

5 Literature

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