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Large-Scale Calculation of Possible Locations for Specific Wind Turbines under Consideration of Noise Limits

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ABSTRACT

The acoustical part of the study “Renewable Energy Potential NRW” [1] was conducted by DataKustik GmbH. One of the major challenges of this project was the pure data size which needed to be processed. The acoustical study comprised an area of 36,540 Km², 4.2 million receivers and 136 million high-points. The wind turbines under consideration can be operated in two different modes which differ in energy production and noise emission. The final result of this automatically processed study were the possible areas suitable for wind farms, the areas of exceeding noise levels in respect to specific noise limits and the maximum possible energy production.

1. INTRODUCTION

Many Countries target a greater portion of wind energy within their energy-mix. Especially in dense populated countries like Germany, one of the main limiting factors during the development of wind parks is the noise immission. In order to derive the maximum potential of energy which can be produced by wind farms under individual consideration of noise limits at all residential buildings, the Environmental Agency (LANUV) of North Rhine Westphalia (Germany, population 18mio.) commissioned a pilot research study. The motivation for this survey is the political requirement of the government of North Rhine- Westphalia to increase the usage of wind energy from 4 % today to at least 15 % till the year 2020. In order to support this objective and investigate potential areas for the use of wind –turbines and the potential energy production, the environmental ministry of NRW (in cooperation with LANUV) assigned the investigation “study for renewable energy potential NRW”. As one major factor restricting the installation of wind farms is the noise emission and its strict regulation, a major task consisted of the acoustical analysis. DataKustik GmbH was part of the project team and responsible for the noise survey. The major task consisted not only by calculating the noise levels caused by potential wind parks at building facades. The main job moreover comprised an optimization process which calculates automatically the boarders of potential wind parks under strict

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consideration of given frame conditions and the limiting values calculated at the nearest village. The acoustical optimization is a major element of the study which builds on different parts of the study like the calculation of wind fields. This paper provides only insights into the acoustical optimization calculation.

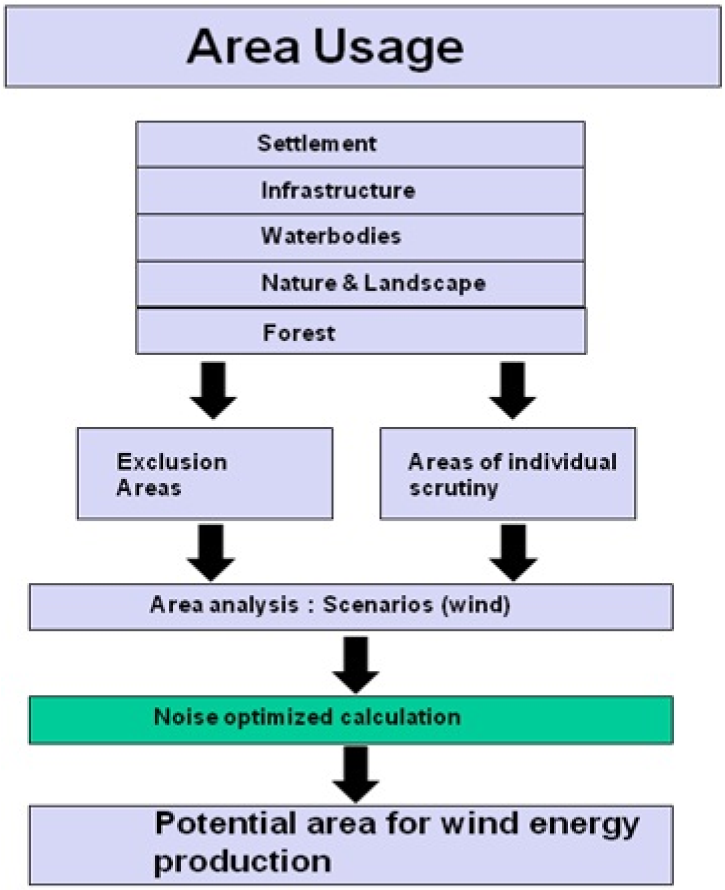

Figure 1 - Structure study for renewable energy potential NRW

The scheme depicted in Figure 1 demonstrates the central position of the noise optimization. It builds on the wind study and the analysis of general available areas and leads- after the optimization under consideration of the noise emission -to the boarders of potential wind fields.

2. Compilation of the data model – ground model

Within the frame of the project an analysis of wind fields and area usage has been conducted by distinguished experts. This analysis was performed at the whole territory of North Rhine-Westphalia with a size of 36,540 km² and driven by the objective to identify areas where the construction of wind turbines is generally possible.

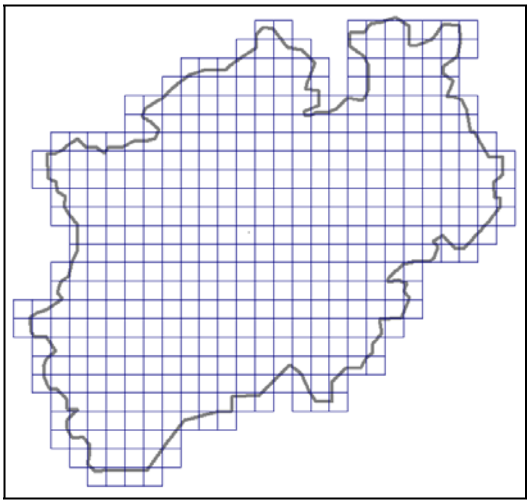

Figure 2 - Boarders of the territory (grid 10km x 10km)

The result of the mentioned previous research work are areas which were used for the acoustical study as input data. The elevation model was delivered with a heavy detailed 10m x 10 m grid and needed to be dyed out under specific certainty criteria. The remaining height points were connected to 2,603 height-lines with a total length of 1,502 km by the application of a sophisticated method which ensures that the final height deviation stays within a predefined level. The whole simplification process was processed with a height-accuracy of 2 m and resulted in 2.6 million height-points after the simplification.

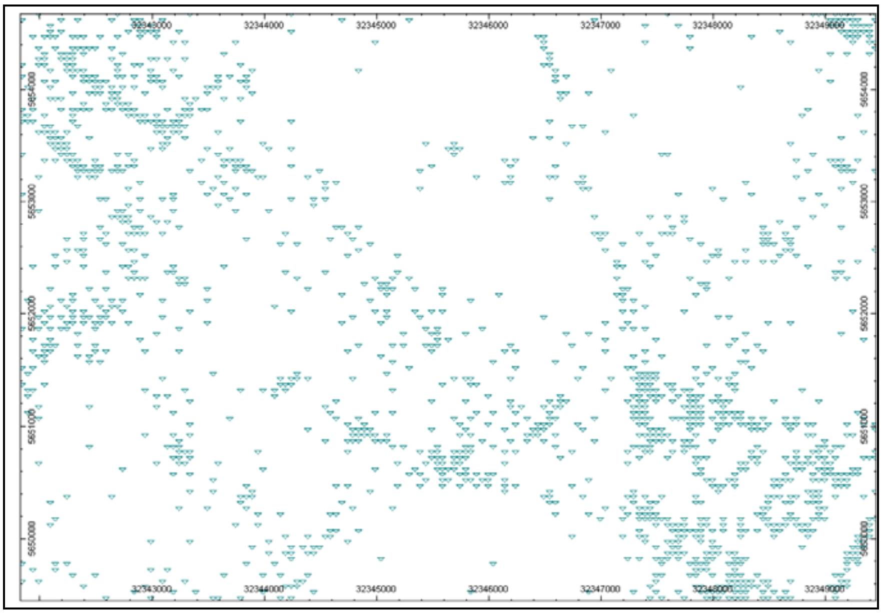

Figure 3 - Distribution of dyed out height points

3. Buildings and receiver location

According to the defined procedure an enormous number of 4,239,852 buildings were imported as polygons in x-y- projection with height information. Receivers with a height of 4 m above ground (according to DTM) were generated in the center of the houses. During the following calculations the houses have not been taken into consideration (no screening).

The limiting values of 41.4 dB(A) or 46.4 dB(A) during the day and 40 dB(A) and 45 dB(A) during the night were assigned to each receiver depending on its location relatively to the imported areas of land use.

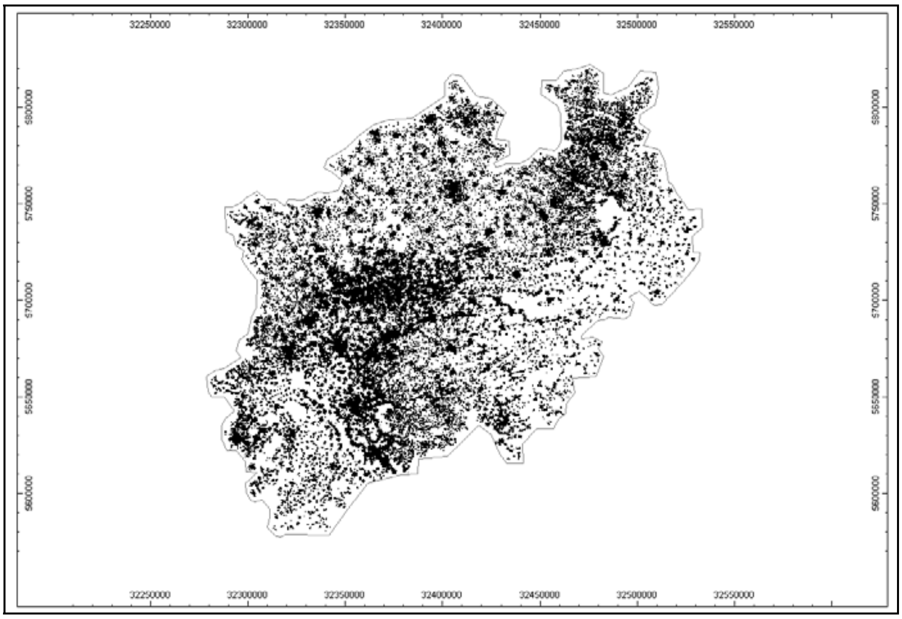

Figure 4 - The 3D ground model with 4.239.852 buildings

4. Basic conditions of the sound propagation calculation

According to the project specifications the acoustical calculations were processed according to the alternative procedure of DIN ISO 9613-2 part 7.3.2. For the propagation calculation the air absorption for 500 Hz, a temperature of 10°C and a humidity of 70 % were taken into account. Additionally the DTM was involved in the calculation but not the screening and reflecting characteristics of buildings and ground evaluations.

Single detached buildings were represented by one receiver. Areas assigned to living were represented through receivers located at the boarder of this area. The already existing noise level was not taken into account.

5. Acoustical source

According to the study specifications wind-turbines with the following data were used as source:

- Hub height 135 m
- Rotor diameter 100 m
- Emission in sound optimized mode: 104 dB(A)
- Emission in energy optimized mode: 106 dB(A)
- SPL used for calculation = 106.5 dB (spectral information not required as calculation was based on A-weighted sound level according to ISO 9613-2, part 7.3.2) (see 5. Acoustical calculation)
- Power output 3 MW/2 MW

After deducting all areas of exclusion (nature conservation, water bodies, villages, low wind conditions etc.) from the territory, the areas which are potentially usable for the production of wind energy remain. Based on this data status the acoustical optimization can be initiated.

Figure 5 - Detailed view of potential and restricted areas

6. Acoustical calculation

In order to account for the always remaining uncertainty in the process of propagation calculation, an uncertainty of 2.5 dB was attributed to the emission of the wind turbines. For the sound optimized mode of the wind turbine during night an emission level of 106.5 dB (A) had therefore been used.

With respect to the production yield a minimum distances between each wind turbine had to be acknowledged. These distances are 5 rotor diameter in main wind direction and 3 rotor diameters across main wind direction. The main wind direction was defined by 240° relative north.

As a first step of the optimization process point sources at a height of 135 m – which reflects the height of the hub- the given distance and the sound emission were distributed within all the remaining areas automatically. This first step resulted in 168,488 locations for possible wind turbine.

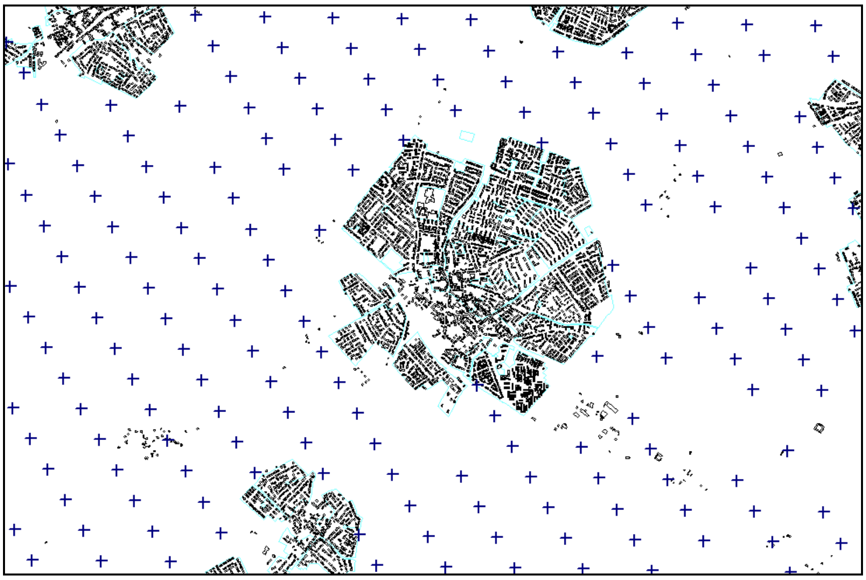
Figure 6 - Grid of wind turbine sources (500m x 300m) - aligned to main wind direction

Henceforth the optimization calculation starts according to a procedure suggested by Piorr [2] and modified for the implementation via software [3]. During the process the overall sound level caused by all wind turbines together within the affected area and the partial sound level caused by each individual turbine is calculated at all 4.2 million single receivers.

As a second step the receiver with the highest excess above the present limiting value is chosen and the wind turbine with the highest contribution to this excess is identified by analyzing the partial level contribution. The wind turbine identified through this process is deactivated within this model and the calculation process of the overall sound level and the partial level starts again.

This iterative process is repeated till all receivers comply with the defined limiting values.

Figure 7 - after the optimization process remaining wind turbines corresponding to scenario Fig. 6

It needs to be mentioned that this procedure demands remarkable software capabilities as approximately 80 Gigabyte of data needed to be kept within the working storage - by saving and loading the calculation time would have by far exceeded the project duration.

During a third step a grid of 10 m x 10 m over the whole territory was calculated under consideration of the remaining wind turbines. Through this calculation, sectors were defined where living areas only restricted by limiting value of 40 dB(A) – green- or 45 dB(A)-yellow- are allowed.

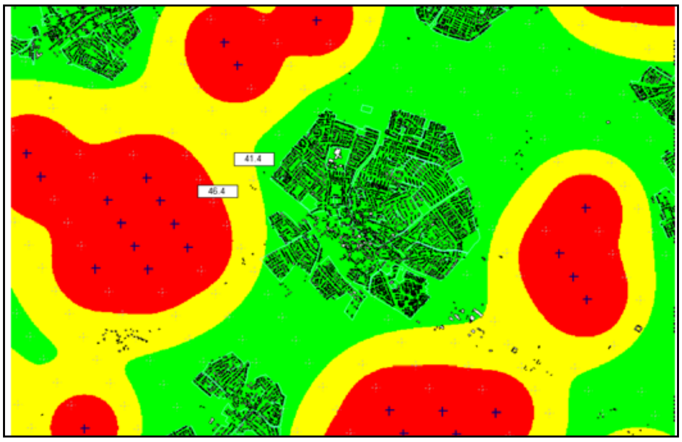

Figure 8 - Noise map depiction of optimized wind turbine distribution (limiting value green 40 dB(A), yellow 45 dB(A))

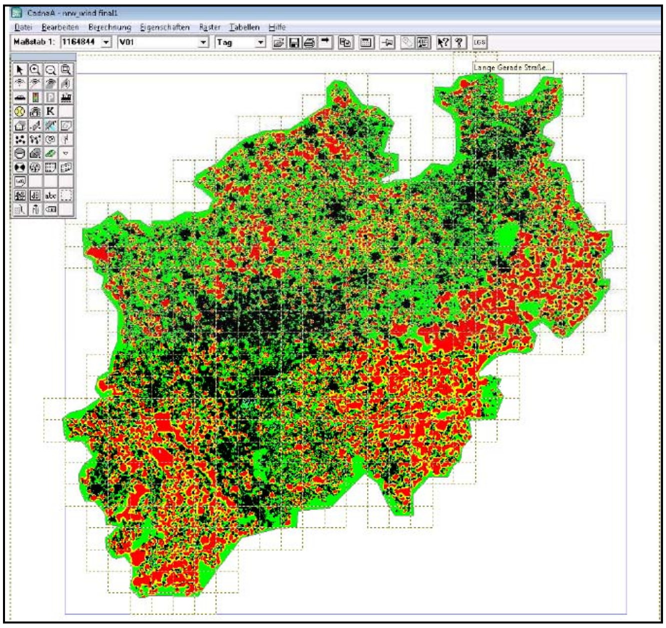

Figure 9 - Project North Rhine-Westphalia after optimization

After the acoustical optimization 21,550 wind turbines remained of the originally 168,488 distributed facilities before the optimization process.

Following the project definition which stipulates an energy optimized operation during the day (3 MW) and an acoustical optimized operation during the night (2 MW) a theoretical gross output of 64,650 MW during the day and 43,100 MW during the night can be concluded.

Furthermore it needs to be mentioned that from a technical perspective a further level of analysis can be included in order to optimize the process to a greater extend. For this every individual wind turbine could have been assigned different performance levels. During the optimization process the wind turbine causing the highest excess at the respective receiver could be reduced to one lower performance level.

As an experiment this calculation had been performed with two performance levels at the same project of North Rhine-Westphalia. On the basis of this calculation 18,991 wind turbines remained which delivered a higher theoretical gross output of 49,524 MW. The reason for the higher energy output is caused by the possibility of wind turbines running in energy optimized mode even during night time as long as no limiting value is exceeded. Altogether this results in 12 % less wind turbines while at the same time the loss of energy yield amounts only to 5 %.

7. Outlook

The described method proofed to be a practical and reliable procedure for supporting communities and governments with realistic information concerning the localization and energy yield of intended wind turbine fields. The dynamic management and active control of wind fields according to temporary changing wind conditions could be a future application for this development.

REFERENCES

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[2] *"Consideration of the immission protection during the expansion of concentration zones for wind turbines"*, D. Piorr

[3] *CadnaA Noise Prediction Software*, DataKustik GmbH