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GERMANY 2011**



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# SPECIAL REPORT

## Wind energy utilization onshore - wind conditions and suitable locations

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### Introduction

Renewable energies will in the future be one of the mainstays of energy provision. In this regard, of ever increasing importance is the matter of where the energy production facilities can be built.

Following the start up of offshore wind energy utilization in Germany and accompanying research programs, this study devotes itself explicitly to onshore wind energy utilization and the identification of suitable locations in Germany for wind turbines. The study was commissioned by the Bundesverband WindEnergie e.V. (BWE) and carried out by Fraunhofer IWES.

The objective of the study was to check the feasibility of the scenario of the BWE (usage of 2% of the land surface) using Geographical Information Systems (GISs). In contrast to previous studies, this study was based on GIS data. The excluded areas and useable areas were identified on the basis of the ground cover and different land usage (e.g. urban areas and infrastructure areas). In order to take account of distance regulations, the excluded areas were where necessary surrounded by suitable buffer zones.

### Data basis and methodology

#### Overview of the methodology

The method essentially involved five steps (see Figure 1). Firstly, areas based on available GIS data were defined which were excluded for geographical reasons (step 1). From the remaining area, the useable area was determined taking into account the assumptions for different land usage, distance regulations, etc. (step 2). For each location the wind conditions were determined (step 3). Wind turbines were sited in the useable areas (step 4) in accordance with the given scenarios. The potential wind energy that could be feed-in was calculated (step 5).

#### Data basis

The ground cover data [Corine] (resolution 100 × 100 m) and infrastructure data (e. g. roads, railway lines, power lines) and data for special areas (nature conservation areas) originated from the Bundesamt für Kartographie und Geodäsie (Federal

Agency for Cartography and Geodesy) [BKG 2003]. In order to calculate the wind energy that could be feed-in, wind data of the German Meteorological Agency [DWD] were used and extrapolated to the relative hub height.

### Determination of useable areas

Wind turbines are nowadays usually sited in open fields, away from conservation areas and forests. However, their siting in forests and to a limited extent also in certain conservation areas is conceivable. Studies were hence carried out for the following three scenarios:

1. **Areas without restrictions**, for example agricultural areas
2. **Areas in forests**
3. **Areas in conservation zones**, for example nature reserves, FFH (Flora-Fauna-Habitat)

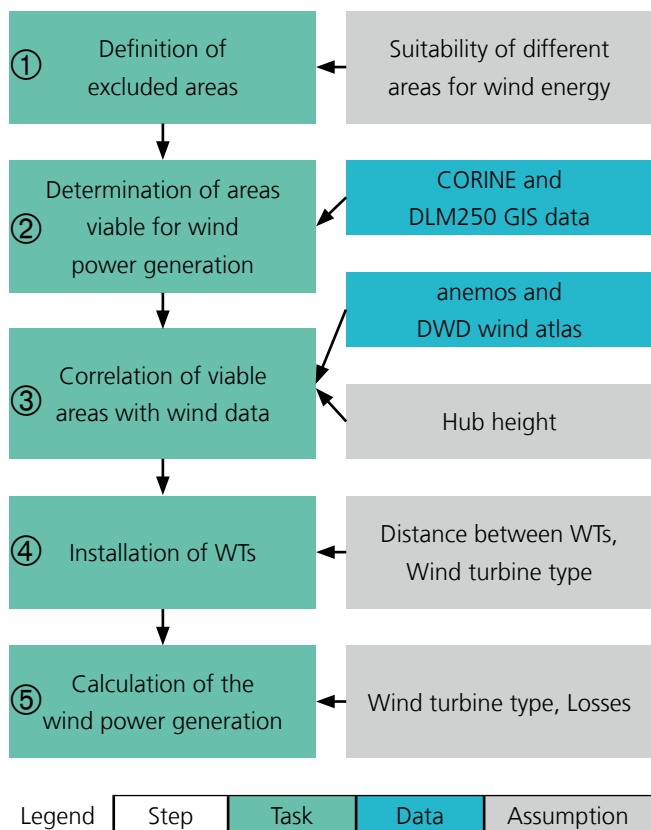
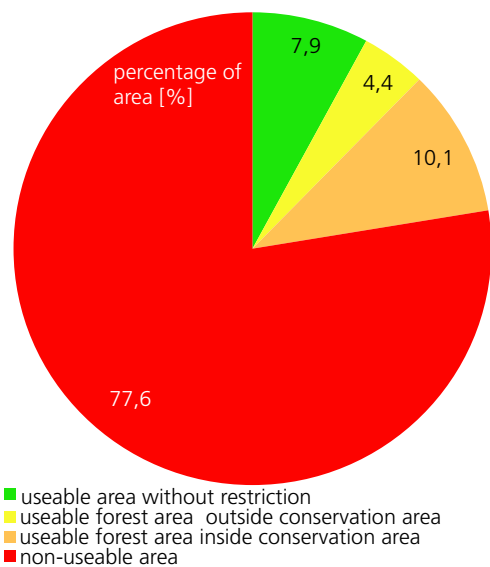


Figure 1: Schematic representation of the procedure



Figure 2: Map showing viable areas for wind turbines in Germany



Other areas such as national parks, urban areas, and surface waters, including relevant buffer zones, were not considered as useable areas.

### Calculation of the energy yield

The electricity that could be generated at suitable locations was modeled with a 3 MW wind turbine having a hub height of 100 m and a ratio of rotor surface to generator nominal power of 2.6 m<sup>2</sup> / kW (100 m rotor diameter). If this resulted in an equivalent number of hours operating at full load of less than 1600, the modeling was undertaken with a wind turbine for poor wind conditions (hub height of 150 m and a rotor to generator ratio of 3.5 m<sup>2</sup> / kW; 115 m rotor diameter). If the resulting equivalent number of hours operating at full load was still less than 1600, then this location was excluded from use.

The distance between the wind turbines was set at 4 rotor diameters. Despite this minimum distance, there are aerodynamic losses in wind farms and losses due to technical non-availability. For these, a fixed deduction was taken into account.

## Results

### Useable areas

The useable areas were split into four categories as per the aforementioned definitions (see Figure 2): Areas without restrictions (green), useable forest areas outside conservation areas (yellow), useable forest areas inside conservation areas (orange), and non-useable areas (red).

Figure 3: Viable areas as a percentage of the total area

More than three-quarters of the land area in Germany cannot be used (see Figure 3). The remaining 22% can potentially be used. About a third of this (8% of the total area) can be used without restrictions (namely it is not in forests and not in nature conservation areas). The useable forest area which lies outside nature conservation areas represents 4% of the total surface of Germany and is hence of interest for wind energy yield.

As expected, the majority of the useable area is in the large German states. The area without restrictions is much reduced in the southern states of Baden-Württemberg, Bavaria, the Rhineland-Palatinate, and Hesse due to the large forested areas (inside and outside conservation areas). Thus the use of forested areas for wind energy utilization is especially relevant here. The areas in the city states are so small compared to the large states that they are hardly visible in Figure 4.

Regarding the states with most useable area (see Figure 5), Saxony-Anhalt (30%) is just ahead of Lower Saxony (27%).

**Evaluation of the calculated useable areas**

It is assumed that not all the areas designated as theoretically useable will actually be able to be used. Many other aspects play a role (e. g. issues of ownership, army radar).

The aim was, however, to assess the plausibility of the assumptions of the commissioning party. The numbers below hence assume 2% usage of the land for wind energy utilization.

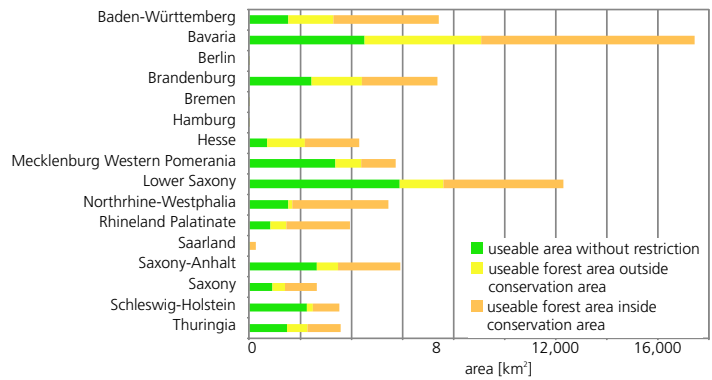


Figure 4: Viable areas in km² in the different German states

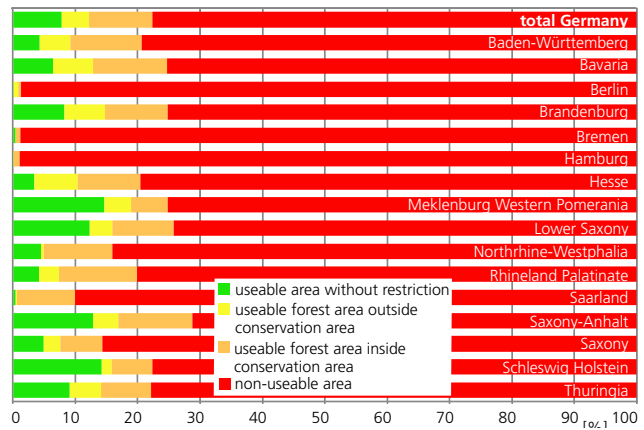


Figure 5: Viable areas as a percentage of the areas of the states

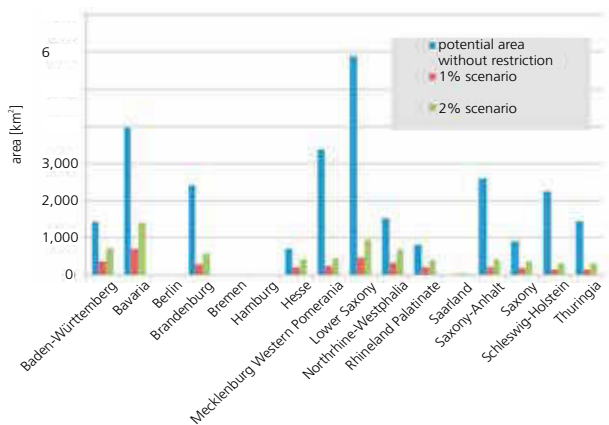


Figure 6: Viable areas (in km<sup>2</sup>) in the different German states for different scenarios

### Wind turbines and generated wind energy

The results presented here give a general picture of the maximum wind power generation capability and should not be deemed to represent a goal. Under the given assumptions, the areas without restrictions (8%, 28,116 km<sup>2</sup>) are suitable for 240,562 wind turbines having a total nominal power of about 722 GW (or 1500 GW for usage of all potential areas (22.4%)). The total wind power generating capacity installed in Germany at present is 156 GW [BDEW 2011].

The 2% scenario gives power generation capacity of 198 GW. The electricity generation can be estimated to be ca. 400 TWh per year. This corresponds to ca. 65% of the total electricity consumption of Germany (603 TWh) in 2010 [BMW 2011].

### Summary

The Fraunhofer IWES has determined the potential area for wind energy utilization in Germany using GIS data.

The key results are as follows:

- Overall, the 2% goal can be deemed to be realistic
- Based on the GIS data, about 8% of the land area is available for wind energy utilization outside forested areas and conservation areas
- If forested areas and conservation areas are included, the useable area increases to 12.3% and 22.4% respectively
- Usage of 2% of the area of each state corresponds to a total nominal wind power generating capacity of 198 GW
- Viable areas are available throughout Germany and are not limited to the northern states, which are currently most used for wind energy utilization
- The wind energy output ranges from 1600 hours at full load (locations with low energy yield were excluded) to 4996, with an average of 2071 hours at full load
- This gives a potential wind energy output of 390 TWh
- This corresponds to 65% of the total electricity consumption of Germany (603 TWh) in 2010



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