Wind farm project planning, Erection and operation

Wind farm project planning

Estimation of the wind regime

- In course of the site selection the estimation and assessment of the wind regime is of prime importance.

$$P_{\text{wind}} = \dot{E} = \frac{1}{2}\dot{m}\, v^2 = \frac{1}{2}\rho\ A\, v^3$$

- if the mean wind speed is 10% less than estimated the energy yield may be reduced by 30% and more.

Assessment of the determined wind speed values

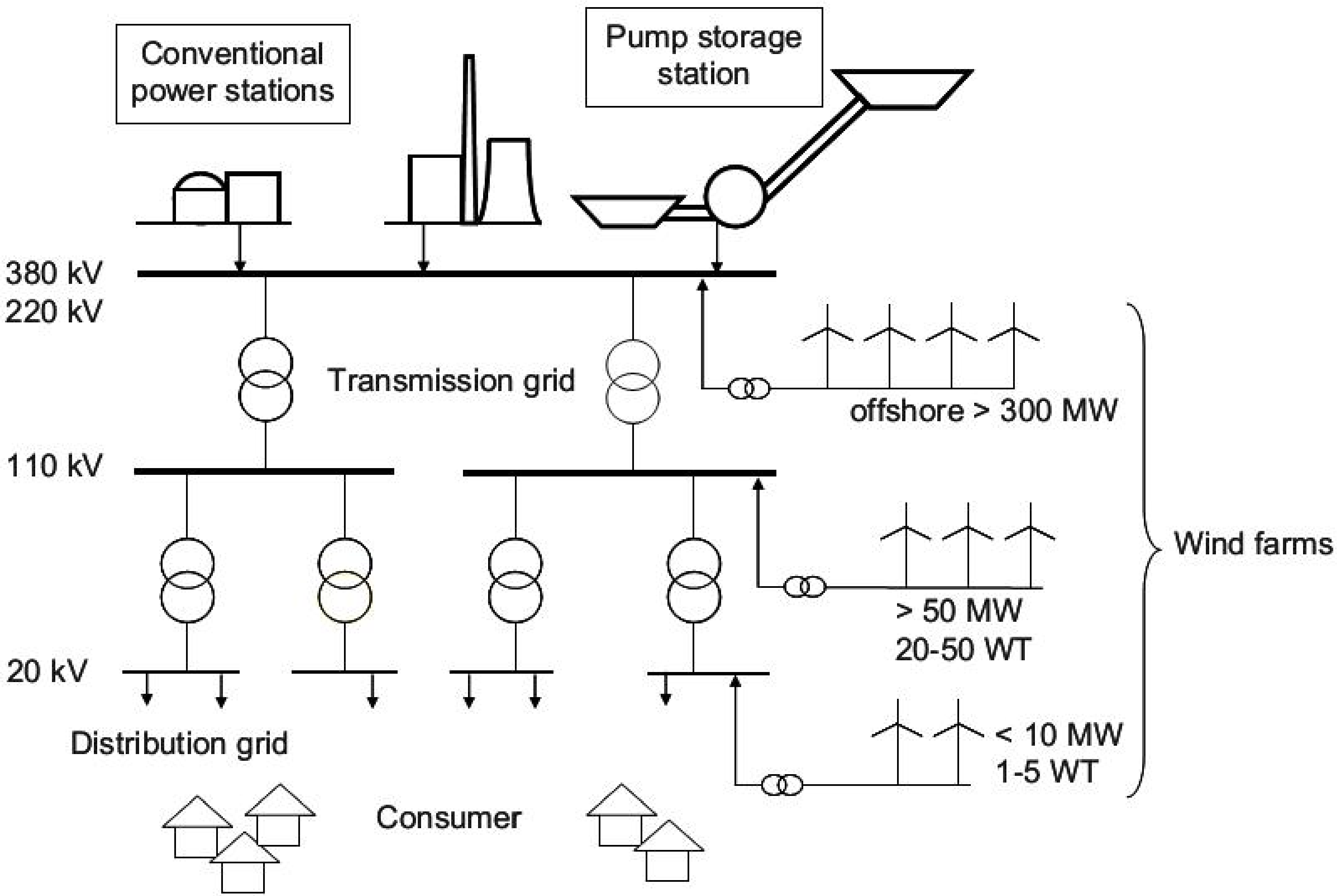
- assessment of general meteorological data
- verification of the orography at the site
- the terrain structure
- the surface roughness
- the type and size of the terrain boundaries
- single obstacles like rows of trees or other wind turbines
- to consult an experienced planning expert

First estimation of the installed capacity and expected energy yield

- Apart from the available area of the site, the available grid connection is a decisive factor in determining the number and rated power of turbines to be installed

- it is reasonable to send an enquiry to the local grid operator at an early stage in order to check the possible grid connection capacity, the distance to the next potential feed-in point and the voltage level of the grid connection.

- It may be reasonable or necessary to build a separate sub-station for larger capacities (> 20 MW).



Voltage levels of the grid in Germany

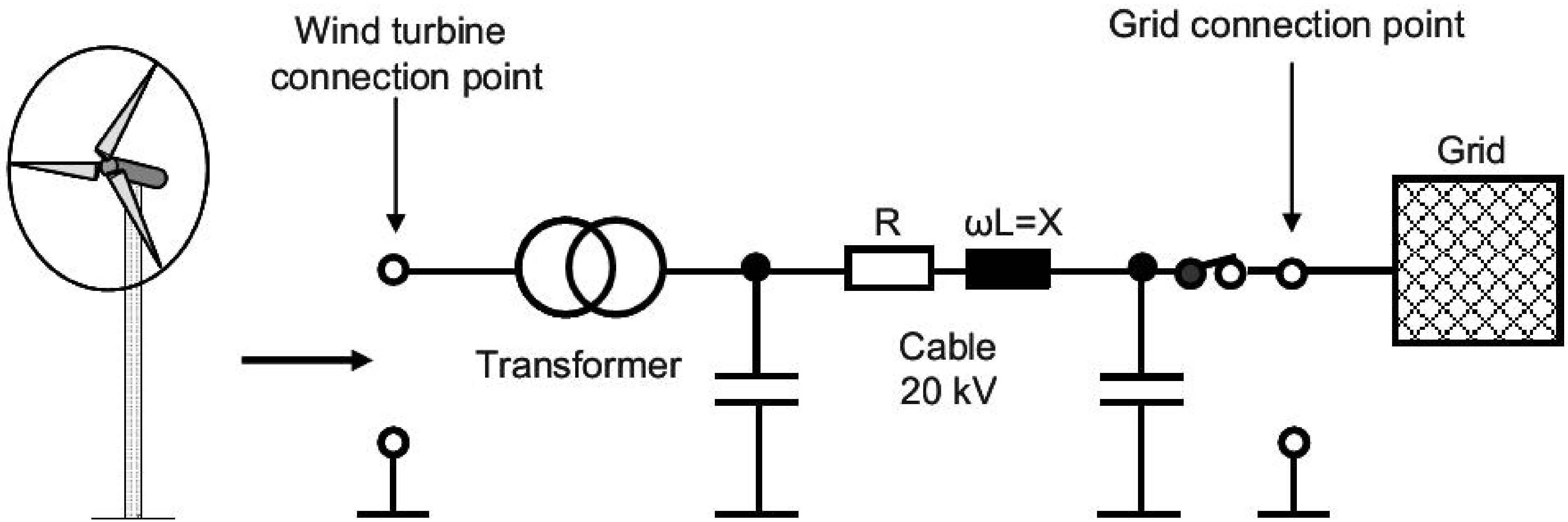


Fig. 14-11 Equivalent circuit diagram of the connection of a wind turbine to the medium-voltage power grid

- In wind farm planning the yield is predicted for each wind direction sector using its individual wind frequency distribution function and the power curve of the chosen wind turbines.

- This is necessary in order to find the optimum placing of the wind turbines in the mico-siting of the wind farm which gives the maximum wind farm energy yield and also reduces the inevitable interactions of the wind turbines.

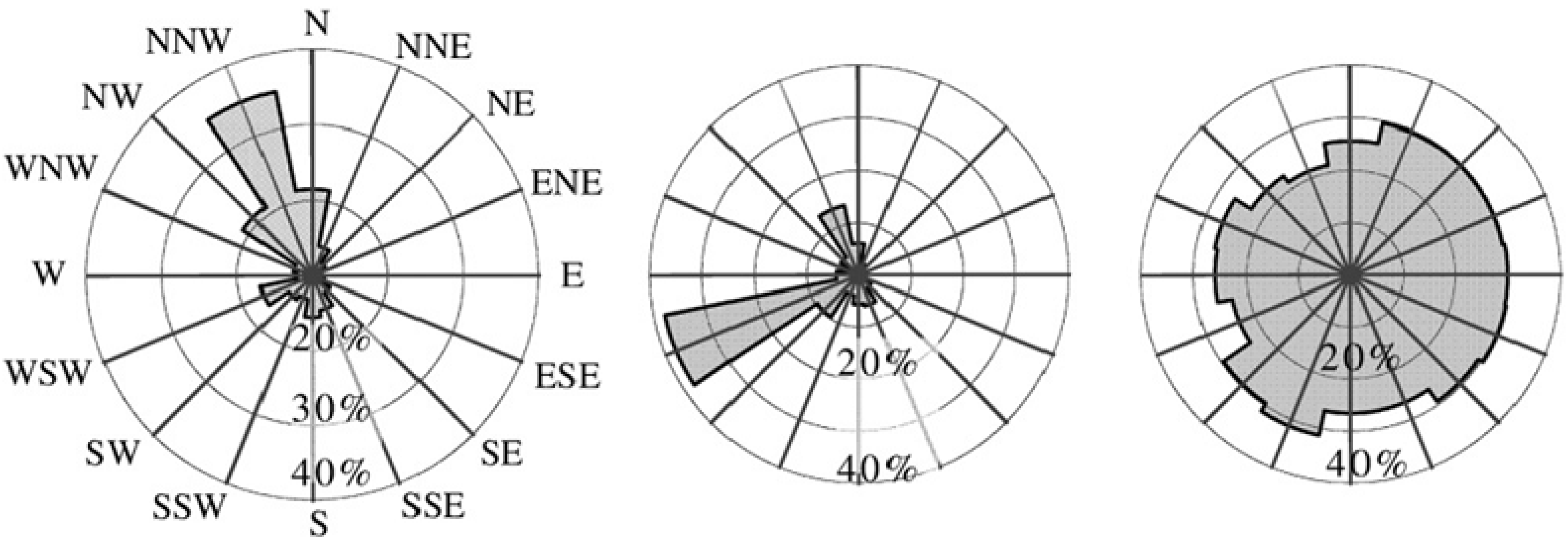


Fig. 3. Wind rose (*left*); energy rose (*center*); turbulence rose (*right*). Hub height 18 m_{agl}.

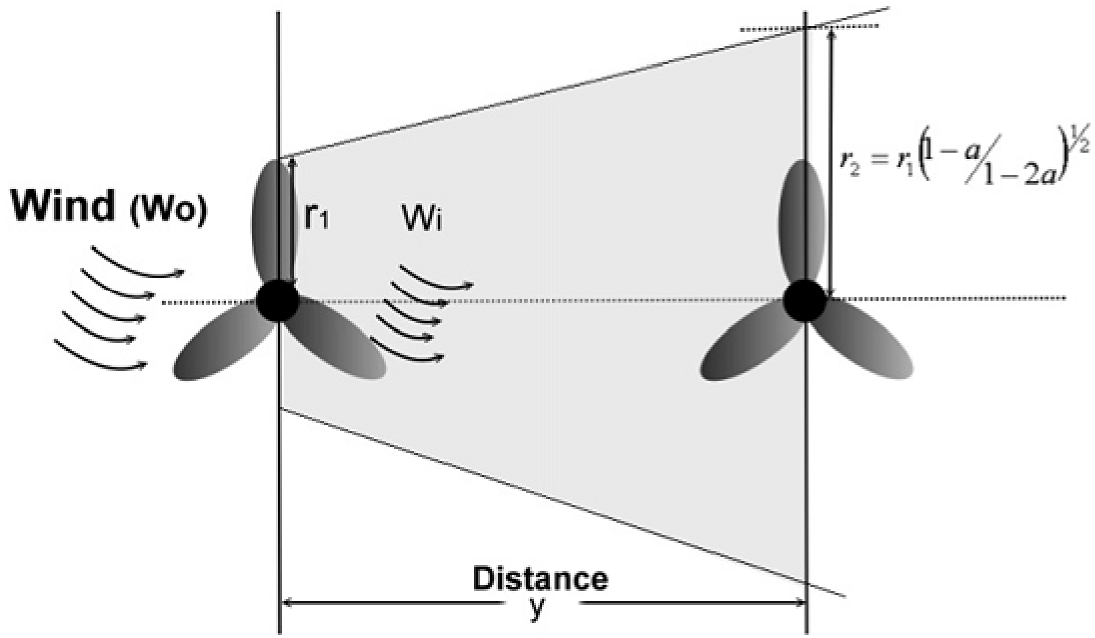
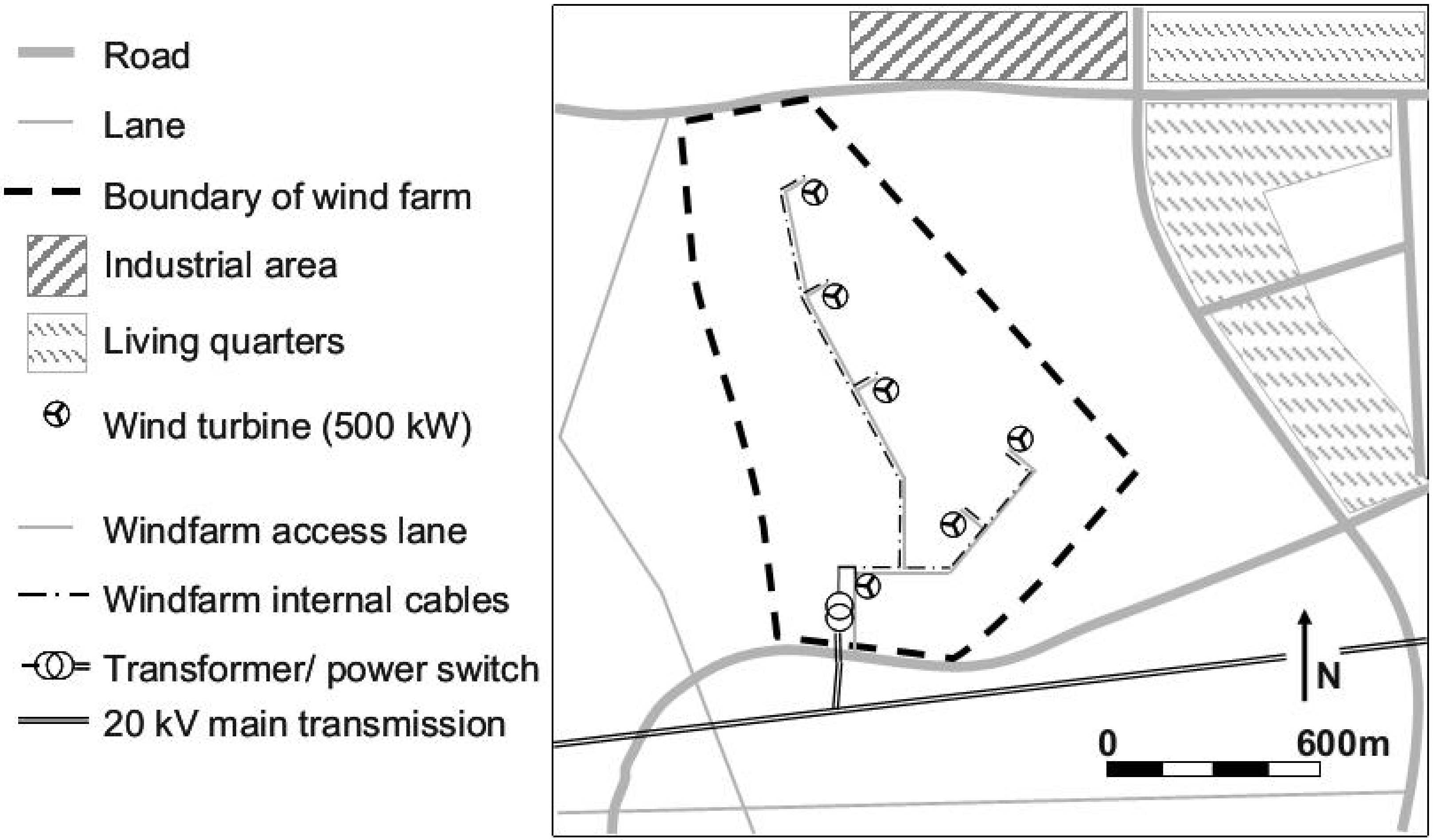


Fig. 3. Wind wake model.

Wind farm micro-siting

- The optimum arrangement of the wind turbines in the site area is obtained in the course of the micro-siting.



- The main criterion is the maximisation of the overall energy yield of the entire wind farm

- However, the wind farm layout is as well in-fluenced by the required infrastructure:

  - Ø the internal cabling
  - Ø the access lanes for transport
  - Ø Erection
  - Ø operation and maintenance costs (O&M)
  - Ø service vehicles

Further restrictions influencing the siting

- minimum distances to living quarters and working areas
- environmental protection
- allowed maximum total height

- It would be advisable to gather information on these issues in advance rather than having to change the planning later during the approval process due to imposed restraints.

Local conditions

- Foundation
- Accessibility and transportation to the site
- Investigation of the grid access
- Grid connection

Legal aspects of the approval process

- Building Code
- Aviation Act
- Traffic Regulation
- Nature Conservation Act
- Environmental Impact Assessment Act

Noise impact

- The noise impact LP at a relevant point of immission at a distance d from the noise source is estimated by:

$$L_P = L_{WT} - 10 \log_{10} (2 \cdot \pi \cdot d^2) - \alpha \cdot d + K$$

where:

L_{WT}:	Sound power level at the source (nacelle or hub of wind turbine) in dB(A)
d:	distance between source and (measuring) point of imission in m
α:	coefficient for absorption in dB(A)/m
K:	penalty supplement for tonality and/or impulse in dB(A)

$$K = 1 \ldots 2 \text{ dB(A)}$$

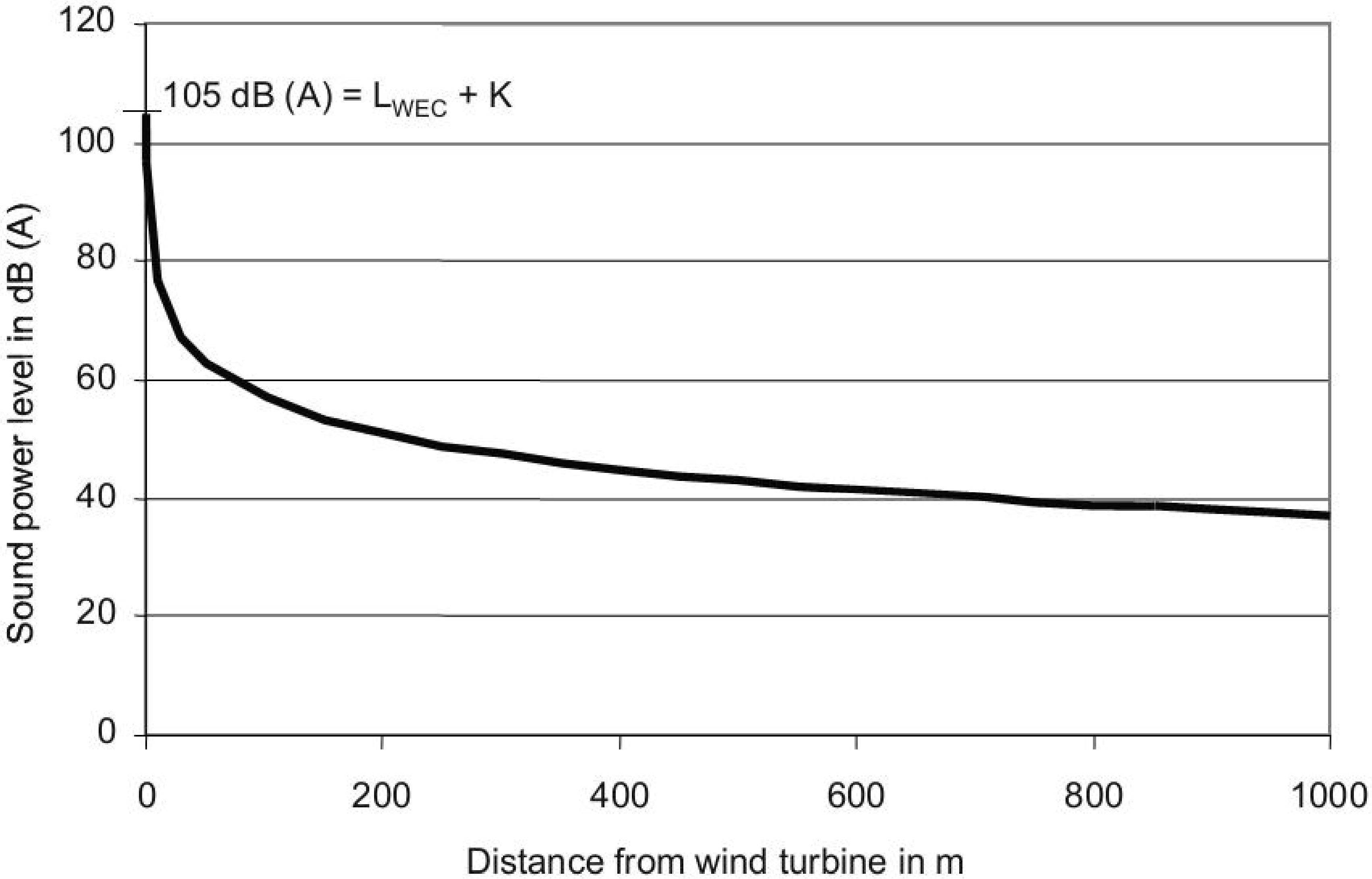


Fig. 15-5 Decay of the sound power level $L_P = L_{WEC} + K$ with the distance from the wind turbine

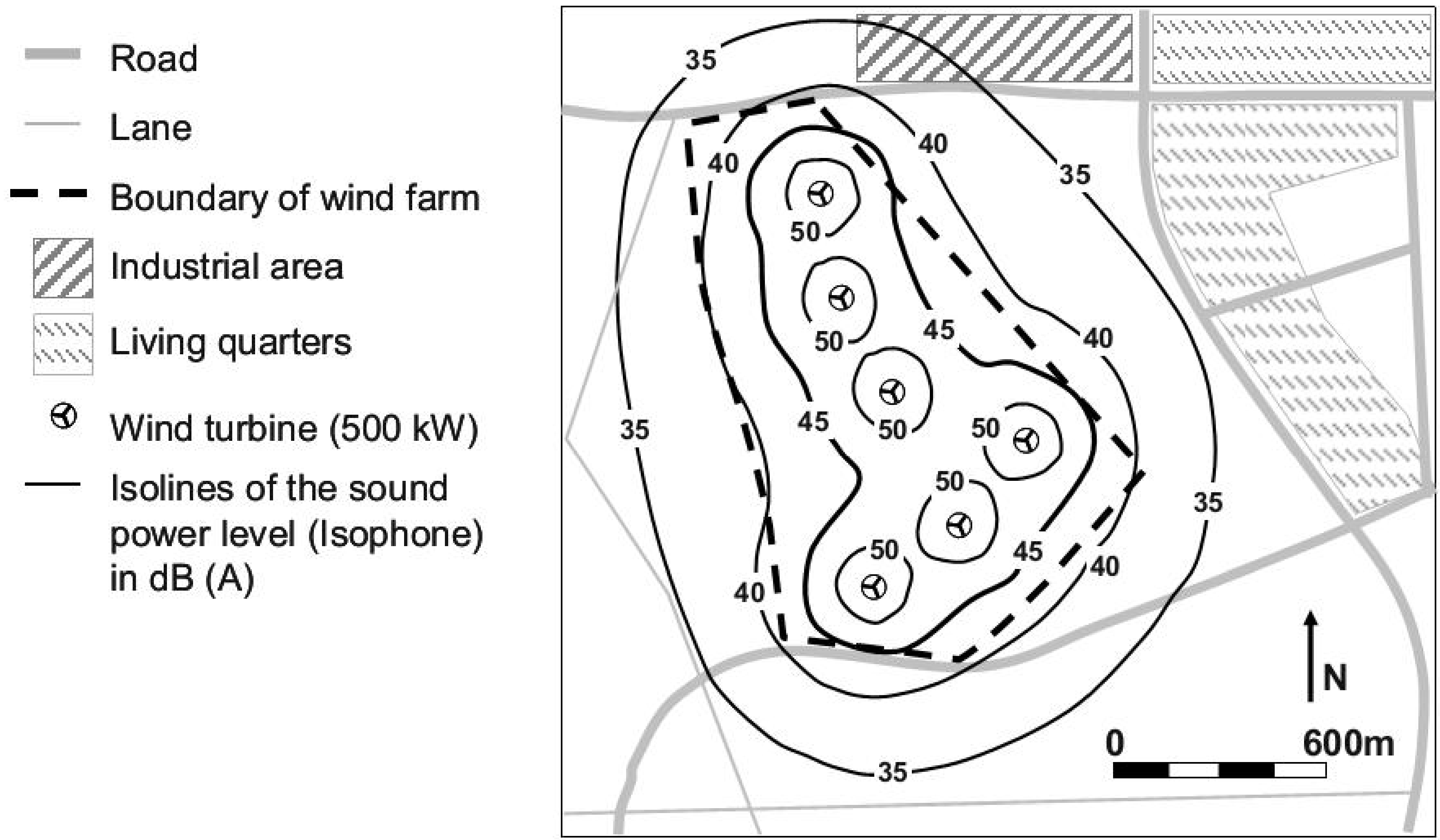


Fig. 15-6 Wind farm site map with isophone lines from the noise impact study

Table 15.1 Admissible sound power level according to the German Manual on Noise Impact Regulations (TA Lärm)

Area type	Day dB(A)	Night dB(A)
Industrial area	70	70
Majority commerce	65	50
Mixed (living/ commerce)	60	45
Majority living	55	40
Exclusive living	50	35
Hospitals, health resorts	45	35

Shadow casting

- Turning rotor casts a disturbing periodical shadow on any problematic spot in the wind turbine’s surroundings.

- This can be simulated on the basis of the site-specific sun’s orbit, the hub height and the rotor diameter for the “worst-case scenario”, i.e. without considering atmospheric opacity or clouds

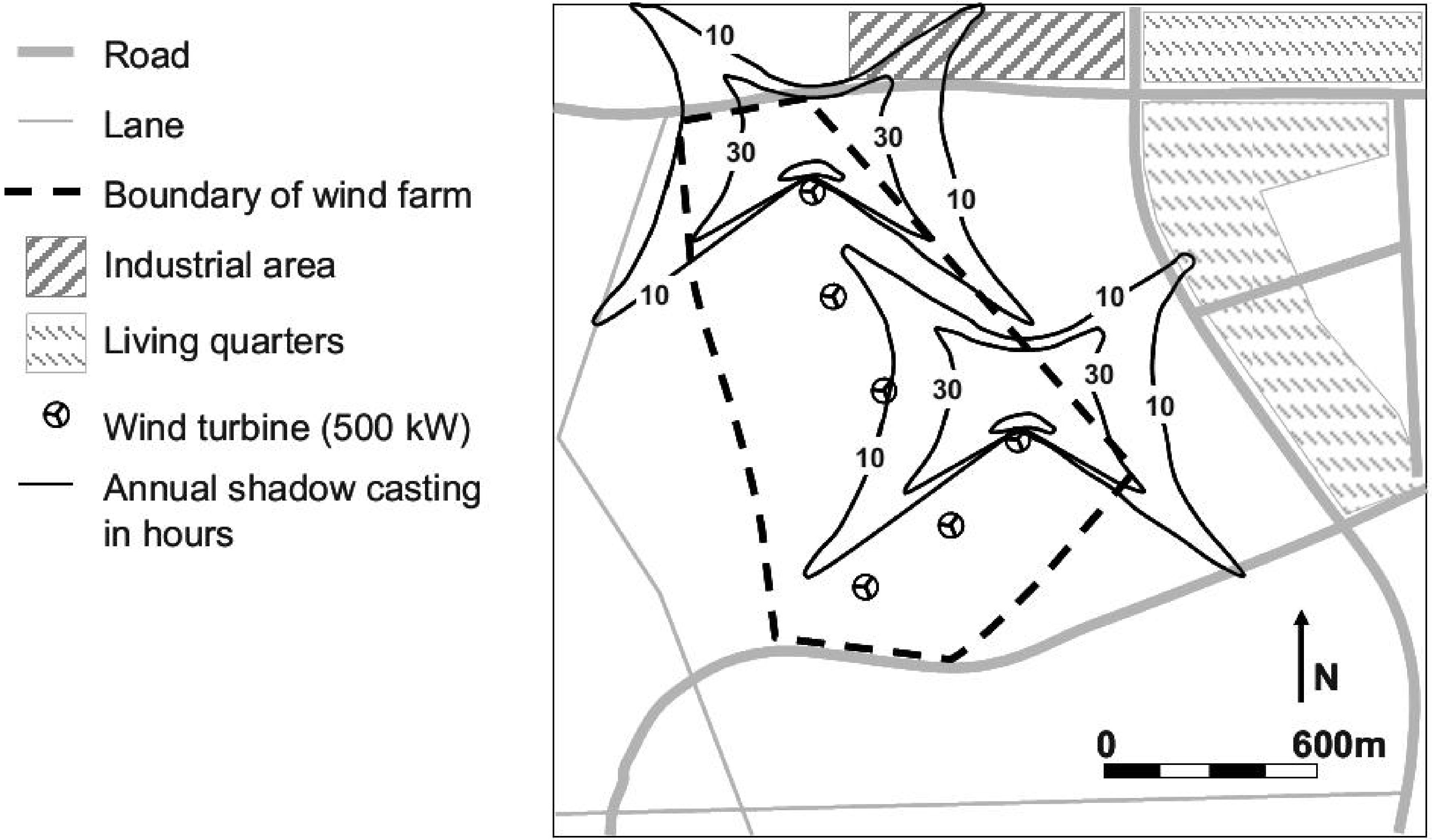


Fig. 15-7 Wind farm site map with isolines of the annual shadow casting in hours for two wind turbines

Land-use planning

Table 15.2 Extract of the distance regulations for wind turbines of the German Federal State Schleswig-Holstein

Type of land use	Minimum distance for Wind turbines with a total height of $h < 100$ m (Decree of 4th July 1995)	Minimum distance for Wind turbines with a total height of $h \geq 100$ m (Decree of 25th November 2003)
Single houses and scattered settlements	300 m	3.5 x *h*
Land settlements	500 m	5 x *h*
Urban settlements, areas with leisure residences and camping sites	1000 m	10 x *h*
Federal freeways, highways and country roads and rail roads	Approx. 50 m to 100 m	In general 1 x *h*
National parks, nature reserves, etc. and other woodland	min. 200 m, for individual cases up to 500 m	4 x *h* minus 200 m
Woodlands	200 m	In general 200 m
Primary waters and waters with a protected regeneration strip	min. 50 m	1 x *h* minus 50 m

Estimation of economic efficiency

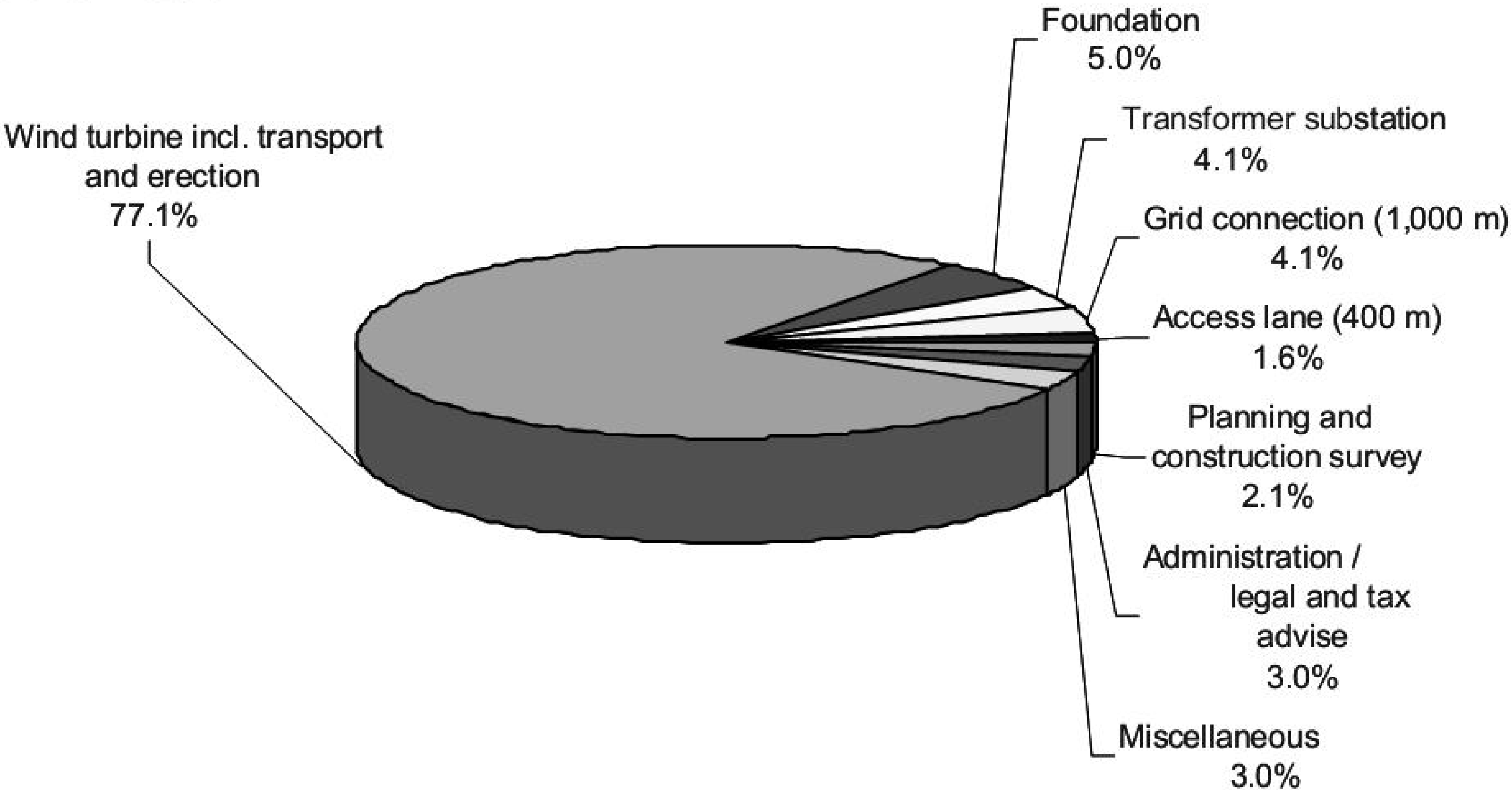


Fig. 15-8 Typical investment cost structure for a project with a single wind turbine in Germany (onshore)

Table 15.3 Cost structure of wind turbine components and assembly , typical values according to [4, 5]

Rated power / Component	600 kW		1,200 kW		Typical span of cost share in %
	€	Share in %	€	Share in %	
Gearbox and coupling	80,400	21.8	115,000	18.1	10 to 25
Rotor blades	63,800	17.3	150,000	23.6	15 to 25
Tower (incl. coating)	58,000	15.7	150,000	23.6	12 to 25
Generator and control	43,800	11.9	65,000	10.2	10 to 20
Nacelle frame and yaw bearing	31,600	8.6	35,000	5.5	5 to 10
Hub and main shaft	29,000	7.9	40,000	6.3	5 to 10
Housing	16,600	4.5	18,000	2.8	2 to 5
Cables and sensors	13,400	3.6	18,000	2.8	2 to 5
Hydraulics	11,600	3.1	15,000	2.4	2 to 5
Yaw system	8,700	2.4	10,000	1.6	1 to 3
Assembly	11.600	3.1	20,000	3.2	2 to 5
Total	**368,500**	**100.0**	**636,000**	**100.0**	
	614 €/W		**530 €/kW**		
Remark: The total wind turbine investment costs include additionally R&D costs, risk, profit, warranty, transport and erection					

- The first measure used to compare different wind farm projects is the power-specific investment costs index

$$SIK_{\mathrm{L}} = \text{Total investment costs / installed capacity} \quad \text{in €/kW.}$$

- However, this index does not provide any information on the yield potential of the site, i.e. the annual energy yield or production. Therefore, the second measure yield-specific investment costs index:

$$SIK_{\mathrm{E}} = \text{Total investment costs / annual energy yield in €/kWh}_{\mathrm{a}}$$

$SIK_{\mathrm{L}} = 1{,}100$ €/kW

$SIK_{\mathrm{E}} = 0{,}50...0{,}75$ €/kWh$_{\mathrm{a}}$

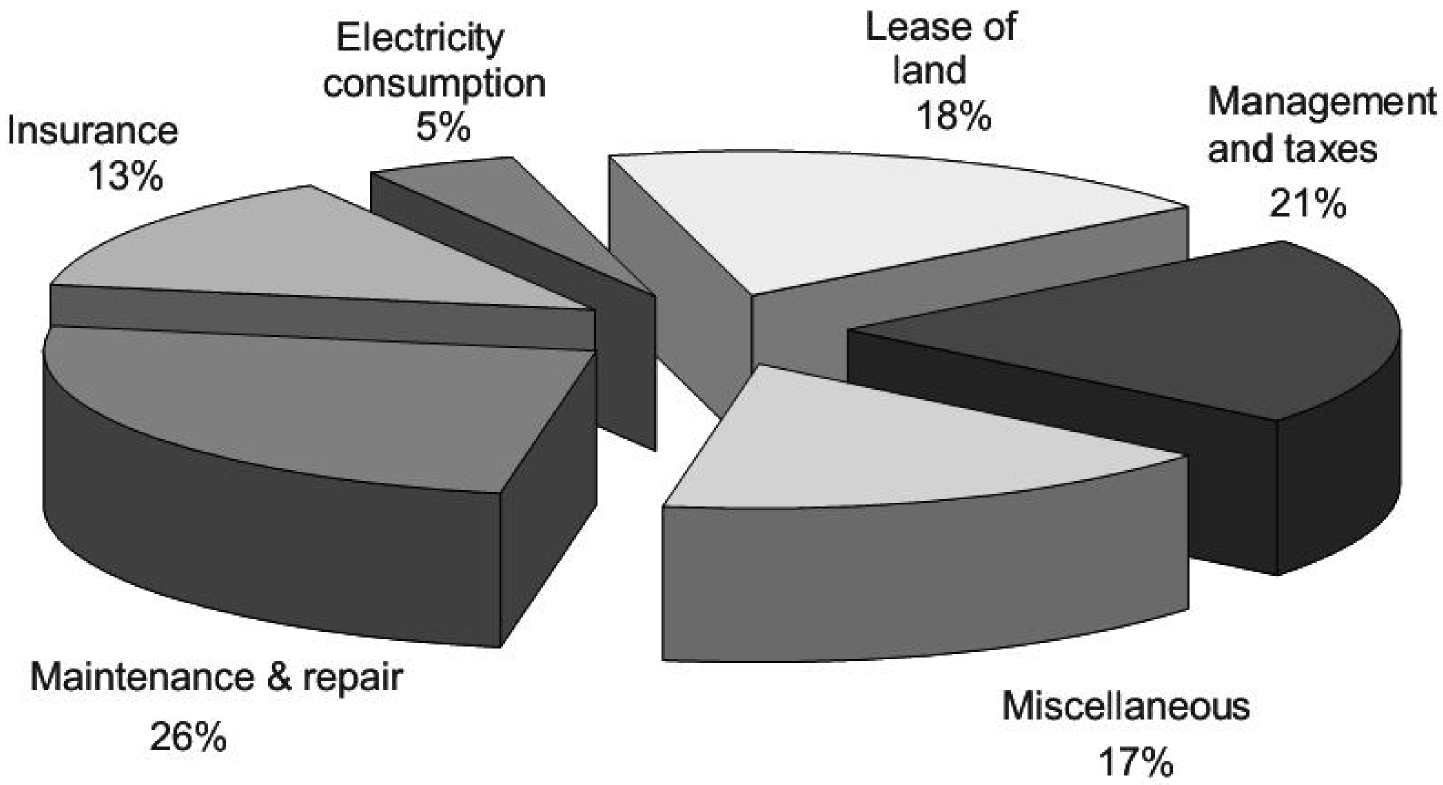


Fig. 15-10 Typical cost structure of the operating cost for a wind farm project in Germany; on-shore and without capital service [2]

the power-specific value of the total annual operating costs amounts to approx. 35€/kW for wind turbines of a rated power below 500 kW, and to approx. 15€/kW for wind turbines of the MW class.

Transport and erection

Table 15.6 Characteristic data of wind turbines and correspondingly required mobile cranes with guyed telescopic crane boom and jib [10]

Rated power of wind turbine in kW	300	600	1.000	1.500	2.000
Nacelle weight in t (without rotor)	15	20	40	50	70
Hub height in m	50	70	80	90	100
Maximum crane capacity load at reach	18 tons / 8 m	25 tons / 25 m	43 tons / 18 m	65 tons / 22 m	73 tons / 20 m
Maximum hook height in m (with jib)	56	76	84	94	104
Self weight of crane and ballast in t	60 50	72 87.5	84 100	96 165	96 160)*
Number of wheel axes	5	6	7	8	8

Fig. 15-13 Hoisting the Rotor by means of main mobile crane and assisting mobile crane [9]

Wind turbine operation

- Operation and inspection
- Maintenance and repair
- Acquisition of operating data and condition monitoring