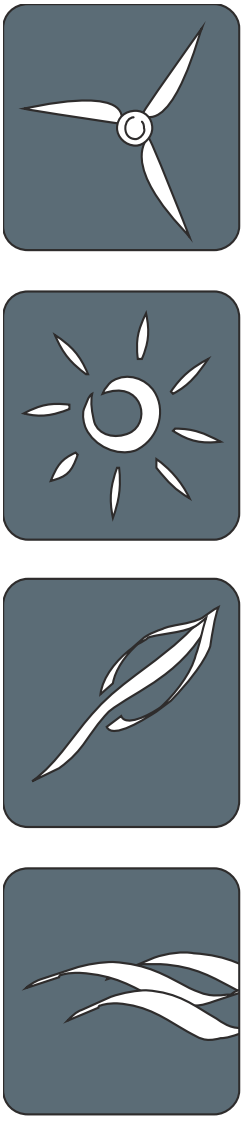
Technical Guidelines

for Wind Turbines



Part 6

Determination of Wind Potential

and Energy Yield

Revision 9

Dated 2015-04-23

Published by:

FGW e.V.

Fördergesellschaft Windenergie und andere Erneuerbare Energien

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The following parts of the FGW Technical Guidelines are available:

Part 1: Determination of Noise Emission Values

Part 2: Determination of Power Curves and Standardised Energy Yield

Part 3: Determination of the electrical characteristics of power generating units and systems in MV, HV and EHV grids

Part 4: Demands on Modelling and Validating Simulation Models of the Electrical Characteristics of Power Generating Units and Systems

Part 5: Determination and Application of Reference Yield

Part 6: Determination of Wind Potential and Energy Yield

Part 7: Operation and maintenance of power plants for renewable energy

Category A: Miscellaneous section

Category B3: Specialist application notes for monitoring and testing foundations and supporting structures for wind turbines

Category D2: State Event Cause Code for Power Generating Units (Zustands-Ereignis-Ursachen-Schlüssel; ZEUS)

Category D3: Global Service Protocol (GSP)

Category D3 – Attachment A: XML schema documentation

Part 8: Certification of the Electrical Characteristics of Power Generating Units and Systems in Medium-, High- and Highest-voltage Grids

Part 9: Determination of High Frequency Emissions from Renewable Power Generating Units

Foreword

This Guideline describes methods to determine the wind potential and energy yield at wind turbine sites. In addition, performing what is known as the 60% reference yield verification is described in Appendix A of this Guideline. This verification was required within the scope of the Act on the Priority of Renewable Energy Sources (German Renewable Energy Act – EEG) in the years 2004 to 2011, in order to obtain a compensation for the electricity fed in by wind turbines in line with EEG.

The FGW Expert Committee on Wind Potential (FAWP) has decided to update the Technical Guideline Part 6 (TG6), because it will remain the basis for expert opinions for determining wind potential and energy yield. The testing method given in Appendix A for the reference yield verification remains a part of the Guideline in order to ensure feasibility and consistency, if needed. FAWP developed the current TG6 Rev.9 and passed it on 2015-04-23.

For example, substantial changes include statements on the representativeness of wind measurements and reference wind turbines, the application of LIDAR and SODAR remote sensing devices, requirements for modelling using the various available numerical models, calculation of reduced yield due to deviations from the optimal operating state of the wind turbines, and more detailed requirements for the uncertainty assessment. These were not previously included in TG6 Rev. 8. The common methods currently in use are described in the new version.

A report on the determination of wind potential and energy yield has to be compiled; the principal results shall be determined using the methods described in this Guideline.

The contents of the Technical Guidelines are the responsibility of the respective technical committees and their working groups. The Guideline was compiled by a variety of stakeholders, the details agreed upon and passed in a general consensus. This guideline is an English translation of a prior german version. In any case of distinction between both revisions of TR6 the german version is valid. In case of the use of non-gender neutral language, it is not the aim of the technical committee to discriminate against any gender. The following bodies were involved in the compilation of these Guidelines by the working groups: independent measuring institutes, manufacturers of power generating units and their components, institutes and universities, engineering consultancies, certification bodies, accredited individuals/institutions which compile surveys, as well as the Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW e.V.).

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Abbreviations used

BWE	The German Wind Energy Association (Bundesverband Windenergie e.V.)
CFD	Computational Fluid Dynamics
DIN	German Institute for Standardization (Deutsches Institut für Normung e.V.)
DKD	Deutscher Kalibrierdienst (German accreditation services)
EEG	Erneuerbare-Energien-Gesetz (German Renewable Energy Act)
FGW	Fördergesellschaft Windenergie und andere Erneuerbare Energien e.V.
IEA	International Energy Agency
IEC	International Electrotechnical Commission
MEASNET	Measuring Network of Wind Energy Institutes
Rev.	Revision
TG	Technical Guideline(s)
a.g.l.	above ground level
VDI	Association of German Engineers(Verein Deutscher Ingenieure)

Symbols and units

Symbol	Meaning	Unit
A	Rotor swept area of a wind turbine	m^2
c_P	Power coefficient	
D	Rotor diameter	m
E	Energy yield	kWh
E_{free}	Energy yield determined for the wind turbine on the site (free inflow)	kWh
h_H	Hub height of the wind turbine	m
P	Power of a wind turbine	kW
R	Reference yield	kWh
ρ	Standard air density	kg/m^3
U_{Efree}	Relative uncertainty of the determined energy yield E_{free} (ratio of absolute standard uncertainty to energy yield)	%
v	Wind speed	m/s
VER	Ratio (“Verhältnis”) of energy yield at the wind turbine site (E_{free}) to reference yield (R)	%

Terms and definitions

The following terms based on DIN IEC 60050 Part 415, "International Electrotechnical Vocabulary – German edition" apply when using this Guideline:

Yield: In the context of this Guideline equal to energy yield.

Energy yield: Energy generation of a wind turbine or several wind turbines.

Gross energy yield (also free energy yield): Mean energy generation of one or several wind turbines expected within a one year period, based on the wind potential at hub height with a specific power curve and without any reductions.

Free inflow: Air inflow to a wind turbine at a site, without consideration of wake effects by neighbouring wind turbines.

Power curve: The relationship between wind speed and power output for each wind turbine type independent of the hub height [1].

Hub height[1]: Height of the centre of the wind turbine rotor above the ground.

Rated power[2]: A quantity of power assigned, generally by the manufacturing company to a component, an installation or a piece of equipment for a defined operating condition (DIN EN 61400-12-1: 2005).

Net energy yield: Mean energy generation of one or several wind turbines expected within a one year period at a single site or at a site within a wind farm, based on the wind potential at hub height with a specific power curve, and including any reductions due to wake effects in the wind farm and further losses.

Wind farm energy yield: Gross energy yield minus wake losses in the wind farm.

Reanalysis data: The chronological sequence of atmospheric conditions (among others wind speed, temperature, air pressure, humidity) as the result of the analysis of observation data using a uniform atmospheric flow model. Fixing the flow model results in good temporal consistency, which is highly advantageous to the purpose of long-term comparisons.

Reference yield: The arithmetically determined amount of electricity of a specific wind turbine type at a specific hub height and based on a measured power curve during five operating years at a reference site in the sense of the EEG [1].

Reference site: Site with a theoretical, defined wind potential. The site definition can be found in EEG [1] Appendix 2.

Type of wind turbine (wind turbine type): Determined by the type, the rotor diameter, the rated power and the hub height in accordance with the manufacturer's data [1].

Reference wind turbine: Wind turbine in operation, results of which are used as reference data for an energy yield determination, to verify the calculation methods.

Availability (time-based): Ratio of total hours of wind turbine operation during a period of time minus the number of hours of non-operation due to maintenance or interference, and the total number of hours during a period of time, expressed in per cent.

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1 For a wind turbine with a vertical axis the hub height is the height of the equatorial plane.

2 Highest continuous electrical power output for which a wind turbine is designed under normal operating conditions.

Availability (energy-based): Ratio of true generated energy yield in a reference period to the energy yield that could have been generated by the wind turbine in this period, if the wind turbine had not been at standstill at individual times during the reference period for technical or other reasons. The energy availability, in contrast to the temporal availability, is with reference to the energy losses and not to time. If the energy availability is less than the temporal availability, the turbine was at a standstill during periods of strong winds.

Losses: In the context of this guideline yield losses of a wind turbine, caused by wake effects in wind farms, for example, or for technical reasons and/or which result from sub-optimal operating conditions.

Wind potential: Wind conditions at a site, given by wind field parameters (wind speed, wind power density, frequency distribution of wind speed and of wind direction) for a specific height above ground level.

1 General information

1.1 Scope

This guideline describes the methods to determine the wind potential and energy yield at wind turbine sites. The wind potential and energy yield at a wind turbine site must be determined using state-of-the-art technology. Additional quality criteria are defined below.

Wind potential and energy yield are determined at a site by an independent institution, which produces the survey. This is performed on the basis of the data of the client (wind and/or yield data, wind turbine sites and types, topographical data).

The task of this institution is to check the data with respect to plausibility and to evaluate its quality, as well as to provide further input data when possible. However, the quality and value of the survey depend substantially on the quality, accuracy and validity of the client's input data. It also depends on how current the data is. The client therefore has to comprehensively and truthfully inform the institution producing the survey in accordance with his possibilities and confidentiality obligations and to make the respective data available.

1.2 Normative references

The specifications of the following standards are an integral part of this guideline. At the time of publication of this Guideline the following versions were effective:

IEC 61400-12-1: 2005 German standard: DIN EN 61400-12-1	Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines Windenergieanlagen - Teil 12-1: Messung des Leistungsverhaltens einer Windenergieanlage
DIN ISO 2533:1997	Standard atmosphere
DIN IEC 60050	International Electrotechnical Vocabulary, Part 415
ISO/IEC Guide 98-3:2008	Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement