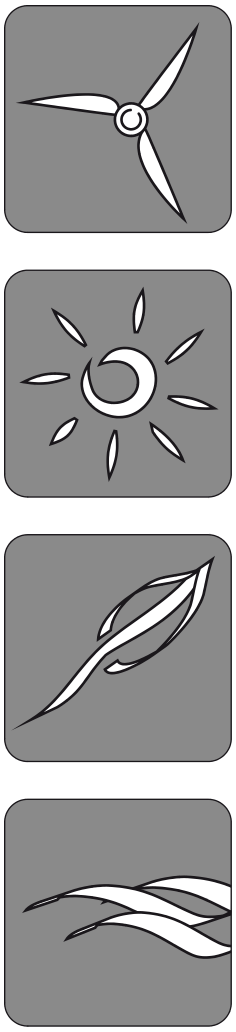
Technical Guidelines
for Wind Turbines

PART 6 (TG 6)
Determination of Wind Potential and Energy Yields



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In the interest of easier legibility, a gender-neutral differentiation is not used here. Any gender-specific terminology always refers to any gender.

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 Yields

Part 3 Determination of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as for their Components in Medium-, High- and Extra High-Voltage Grids

Part 4 Demands on Modelling and Validating Simulation Models of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as their Components

Part 5 Determination and Application of Reference Yield

Part 6 Determination of Wind Potential and Energy Yields

Part 7 Operation and Maintenance of Power Plants for Renewable Energy

Category A: Miscellaneous section

Category A1: Plant responsibility

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, Systems and Storage Systems as well as their Components on the Grid

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

Part 10 Determining the Site Quality after Commissioning

Foreword

These Guidelines describe the methods to determine the wind potential and energy yields at wind turbine sites and are regularly updated. The FGW Expert Committee on Wind Potential (FAWP) developed these TG6 Rev. 11 and adopted them on 21 September 2020. Amendments concern the chapters on wind measurement requirements and uncertainty analysis.

These Guidelines refer to the first edition (2005) and second edition (2017) of IEC61400-12-1, even if the second edition cancels and replaces the first edition published in 2005.

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

All previous revisions of TG 6 are withdrawn with the current revision. As of 1 January 2021, determination of wind potential and energy yields may only be performed using Revision 11.

The contents of the Technical Guidelines are the responsibility of the respective Expert Committees and their sub-committees. These Guidelines were compiled by a variety of interest groups, the details agreed upon and passed in a general consensus. The following bodies were involved in the compilation of these Guidelines by the sub-committees: 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 FGW e.V. - Fördergesellschaft Windenergie und andere Dezentrale Energien (FGW e.V.).

These Guidelines are an English translation of a prior german version. In any case of distinction between both revisions of TG 6 the german version is valid.

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Abbreviations used

BWE	German Wind Energy Association (Bundesverband WindEnergie e.V.)
CFD	Computational Fluid Dynamics
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardisation)
DKD	Deutscher Kalibrierdienst (German Calibration Service)
DWD	Deutscher Wetterdienst is Germany's national meteorological service
EEG	German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
FGW	FGW e.V.-Fördergesellschaft Windenergie und andere Dezentrale Energien
IEA	International Energy Agency
IEC	International Electrotechnical Commission
LIDAR	Light detection and ranging
MCP	Measure-Correlate-Predict
MEASNET	Measuring Network of Wind Energy Institutes
MSL	Mean Sea Level
NTF	Nacelle Transfer Function
Rev.	Revision
RSD	Remote Sensing Device
TG	Technical Guidelines
VDI	Association of German Engineers (Verein Deutscher Ingenieure)
WT	Wind turbine/s

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Symbols and units

Symbol	Meaning	Unit
A	Wind turbine swept area	m²
c_p	Power coefficient	
D	Rotor diameter	m
E	Energy yield	kWh
E_{frei}	Energy yield determined for the wind turbine on site (free inflow)	kWh
E_{St0}	Site yield determined for the wind turbine on site compliant with C.2.1 No.3	kWh
h_N	Hub height of the wind turbine	m
P	Power of a wind turbine	kW
R	Reference yield	kWh
ρ	Standard air density	kg/m³
SG	Site quality (ratio of site yield to reference yield), given as a percentage rounded to one decimal place	%
U_{Efrei}	Relative uncertainty of the determined energy yield E_{free} (ratio of absolute standard uncertainty to energy yield)	%
v	Wind speed	m/s

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Terms and definitions[1]

Availability (energy-based): Ratio of true energy yield produced in a reference period to the energy yield that could have been produced 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-based as opposed to time-based availability does not refer to the time the wind turbine was available but to energy loss. If the energy-based availability is less than the time-based availability, the wind turbine was at a standstill during periods of stronger winds.

Availability (time-based): Ratio of total number of hours of wind turbine operation during a certain period, excluding the number of hours that the wind turbine could not be operated due to maintenance or fault situations, to the total number of hours in the period, expressed as a percentage.

Energy yield: Measure of the capability of one or several wind turbines to produce energy.

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

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

Hub height[2]: Height of the centre of the wind turbine rotor above the terrain surface.

Losses: In the context of these Guidelines this term refers to yield losses of a wind turbine, which may be caused by wake effects in wind farms or technical reasons and/or which may result from unfavourable operating conditions.

Net energy yield: Estimate of mean total energy production of one or several wind turbines during 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.

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

Rated power[3]: 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 61400-12-1:2017-03 Edition 2).

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 great temporal consistency, which is highly advantageous to the purpose of long-term comparisons.

Reference site: Site with a theoretical, defined wind potential. Please refer to Annex 2 of the EEG for a definition of the term “reference site” [1].

Reference wind turbine: Existing wind turbine the operating results of which are used as reference data in order to determine the energy yield, to verify the calculation method.

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[1] The terms and definitions of the prior German version of this guideline are based on DIN IEC 60050-415, "International Electrotechnical Vocabulary - German edition".

[2] For a vertical axis wind turbine, the hub height is the height of the equator plane.

[3] Maximum continuous electric output power which a wind turbine is designed to achieve under normal operating conditions.

Reference yield: The quantity of electricity determined for each type of a wind turbine including the respective hub height which this type would arithmetically produce if erected at the reference site within the meaning of the EEG on the basis of a measured power curve in five years operation [1].

Type of wind turbine: Determined by the designation of the type, the swept rotor area, the rated power and the hub height in line with the manufacturer's data [1].

Wake current: Flow conditions in the lee of the WT

Wind farm area: Area of the planned wind turbine

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

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.

Yield: In the context of these Guidelines corresponds to energy yield.

Should/May/Must rules: When preparing TG 6 Revision 10 in particular the Chapters 7.2 Energy loss factors and 4 Requirements for methods for long-term correction have been revised. For TG 6 Revision 11, Chapter 3.1 to 3.4 as well as Chapter 8 Uncertainty analysis have been revised. For these Chapters the following rules have to be applied to start with:

- Must rules: Such rules do not grant the expert any discretion and must be observed. Non-compliance with such rules shall represent a deviation from TG 6. The same applies to rules worded "...shall".
- Should rules: Such rules should be adhered to by the expert in principle. In atypical or special cases however, the expert is granted a certain amount of discretion. Plausible reasons have to be given in any case of non-compliance. If such reasons are given, non-compliance shall not represent a deviation.
- May rules: Such rules may be considered as recommendations and grant the expert full discretion. Non-compliance with such rules may not represent a deviation from TG 6.

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