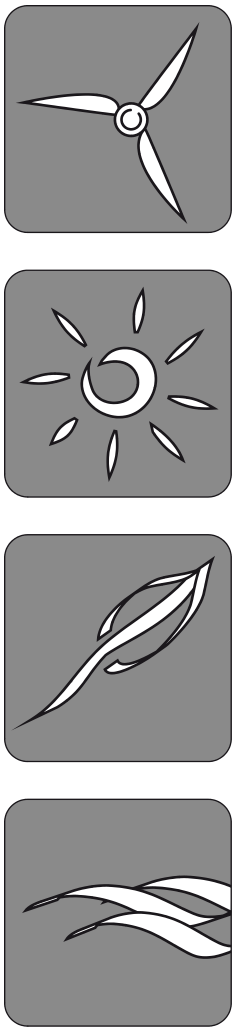
Technical Guidelines
for Wind Turbines

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 Determination of 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.

These Guidelines refer to the third edition (2022) of IEC 61400-12-1 [1] as well as the versions of the first edition (2022) of the 61400-50 series [2], [3].

A report on the determination of wind potential and energy yields must be compiled in accordance with Chapter 8. It is based on the present Guidelines. All essential steps, decisions and interim results must be handled in accordance with the general principles of quality assurance.

All previous revisions of TG 6 are withdrawn with the current revision. There is a transitional period that ends on 01.07.2024. From 01.07.2024, energy yield calculations must be prepared in accordance with revision 12 of the TG 6.

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 and the details agreed upon. The following bodies were involved in the compilation of these Guidelines by the sub-committees: independent measuring companies, manufacturers of power generating units and their components, institutes and universities, engineering consultancies, certification bodies, accredited individuals/companies 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.

Contents

Abbreviations

AEP	Annual Energy Production
AGL	Above ground level
BWE	Bundesverband WindEnergie e.V. (German Wind Energy Association)
CFD	Computational Fluid Dynamics
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardisation)
DKD	Deutscher Kalibrierdienst (German Calibration Service)
DWD	Deutscher Wetterdienst (German Meteorological Service)
EEG	Erneuerbare-Energien-Gesetz (German Renewable Energy Sources Act)
EnWG	Energiewirtschaftsgesetz (German Energy Economy Law)
FGW	FGW e.V.-Fördergesellschaft Windenergie und andere Dezentrale Energien
IEA	International Energy Agency
IEC	International Electrotechnical Commission
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	Verein Deutscher Ingenieure (Association of German Engineers)
WT	Wind turbine/s

Symbols and units

Symbol	Meaning	Unit
A	Wind turbine swept area	m^2
c_p	Power coefficient	
D	Rotor diameter	m
E	Energy yield	kWh
E_{frei}	Energy yield determined for the wind turbine on-site (free in-flow)	kWh
E_{St0}	Site yield determined for the wind turbine on-site compliant with C.2.1 No. 3	kWh
f	Frequency	Hz
h_N	Hub height of the wind turbine	m
P	Power of a wind turbine	kW
R	Reference yield	kWh
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_{frei} (ratio of absolute standard uncertainty to energy yield)	%
v	Wind speed	m/s

Terms and definitions

For application of these Guidelines the following terms shall be defined based on IEC 60050 Part 415, “International Electrotechnical Vocabulary (IEV)” [4]:

Application mode: Wind conditions from the site of a wind data base may be transferred to another site in the form of statistics (Weibull distribution or frequency table) or by means of time steps so that a wind time series at the point assessed is available as a result.

Availability (WT, 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.

Availability (WT, 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 operating at individual times during the reference period for technical or other reasons. The energy-based method does not refer to the time the wind turbine was available but to energy loss. This is in contrast to time-based availability.

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: Height of the centre of the wind turbine rotor above the terrain surface. For a vertical axis wind turbine, the hub height is the height of the equator plane.

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 which results from the gross energy yield determined and the wind farm wake effects and further losses.

Power curve: The relationship between wind speed and power output determined for each wind turbine type independent of the hub height [5], [6], [7] Annex 2 to Section 36h point 5.

Rated power: 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 [1] Maximum continuous electric output power which a wind turbine is designed to achieve under normal operating conditions.

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 [5], [6], [7].

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

Reference yield: “[...] the quantity of electricity determined for each type of a wind energy installation including the respective hub height which this type would arithmetically produce if erected at the reference site on the basis of a measured P-V curve in five years operation.” [5], [6], [7]

Sensitivity factor: Change of the average energy yield in case of a minor change of average wind speed.

Simulation mode: Flow models may be operated under steady-state conditions with constant boundary conditions or alternatively under transient conditions with time-dependent boundary conditions.

Type of wind turbine: “[...] shall be determined by the designation of the type, the swept rotor area, the nominal capacity and the hub height in line with the manufacturer's data.” [5], [6], [7]

Validation: Successful qualitative and quantitative examination of a procedure or model for the given situation based on observation data.

Wake current: Flow conditions in the lee of the wind turbine.

Wind farm area: Area of the planned wind turbine/s.

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.