INTRODUCTION TO
SMALL WIND TURBINES

OTTI Seminar: Basics of Small Wind Turbines | Tarragona, Spain | 28 April 2010

Paul Kühn | Fraunhofer Institute for Wind Energy & Energy System Technology

Fraunhofer IWES

Fraunhofer Institute for Wind Energy and Energy System Technology
Bremerhaven & Kassel

Research spectrum:

- Wind energy from material development to grid optimization
- Energy system technology for all renewables

Foundation: January 2009 **Employees:** approx. € 15 million

Personal: approx. 240 (full-time: 170)

Directors: Dr. Hans-Gerd Busmann, Prof. Dr. Jürgen Schmid

Formerly:

- Fraunhofer-Center für Windenergie und Meerestechnik CWMT in Bremerhaven
- Institut für Solare Energieversorgungstechnik ISET in Kassel

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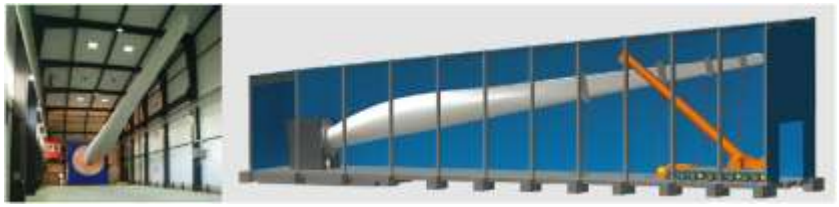
Business fields I



- Wind energy technology and operating management
- Elasticity and dynamics of turbines and components
- Competence center rotor blade
- Development of rotors, drive trains and foundations

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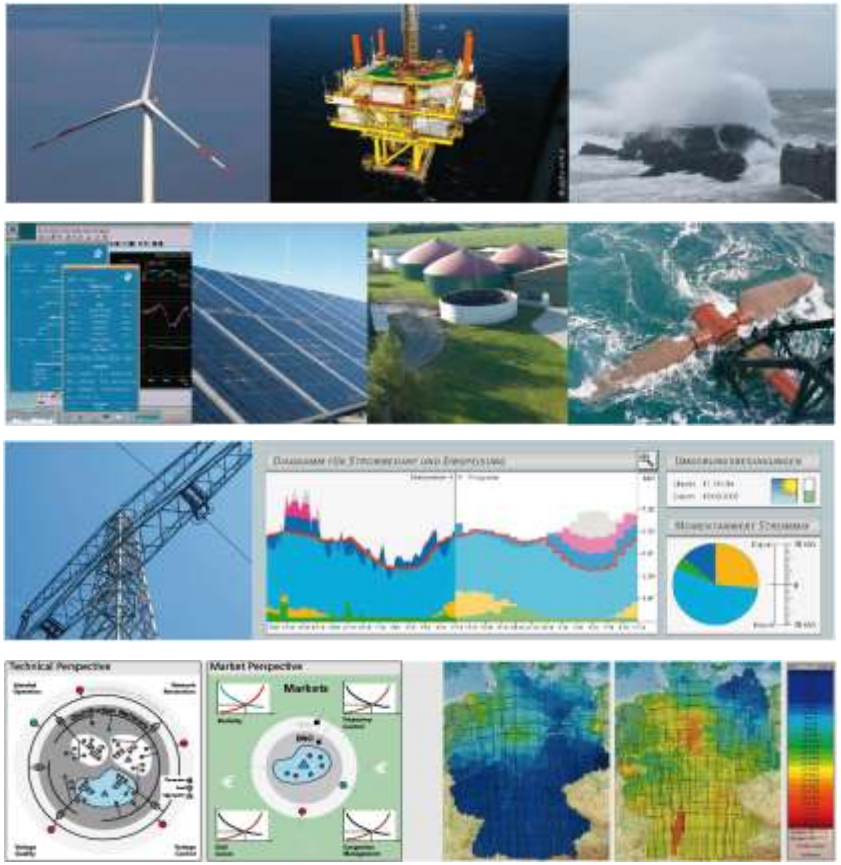
Business fields II



- Environmental analysis for wind and ocean energy
- Control and integration of decentralized converters
- Energy management and grid operation
- Energy supply structures and systems analysis

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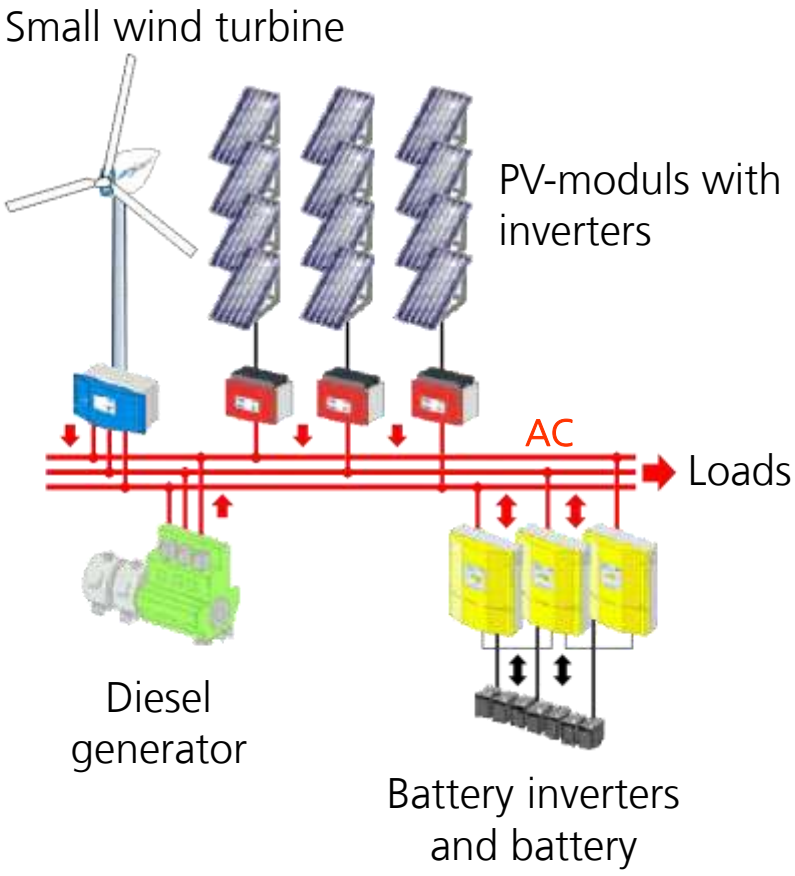
Small wind turbines and hybrid systems at IWES

IWES test site



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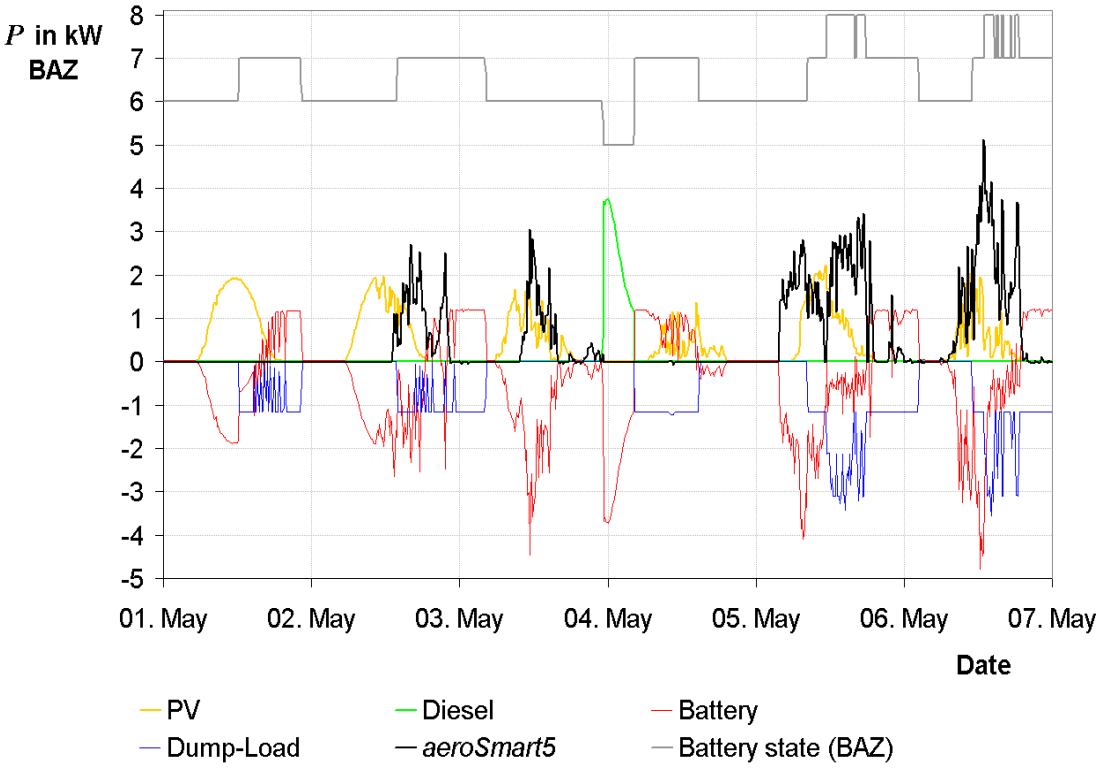
Small wind turbines and hybrid systems at IWES

IWES test site



IWES test site, 10-min-data

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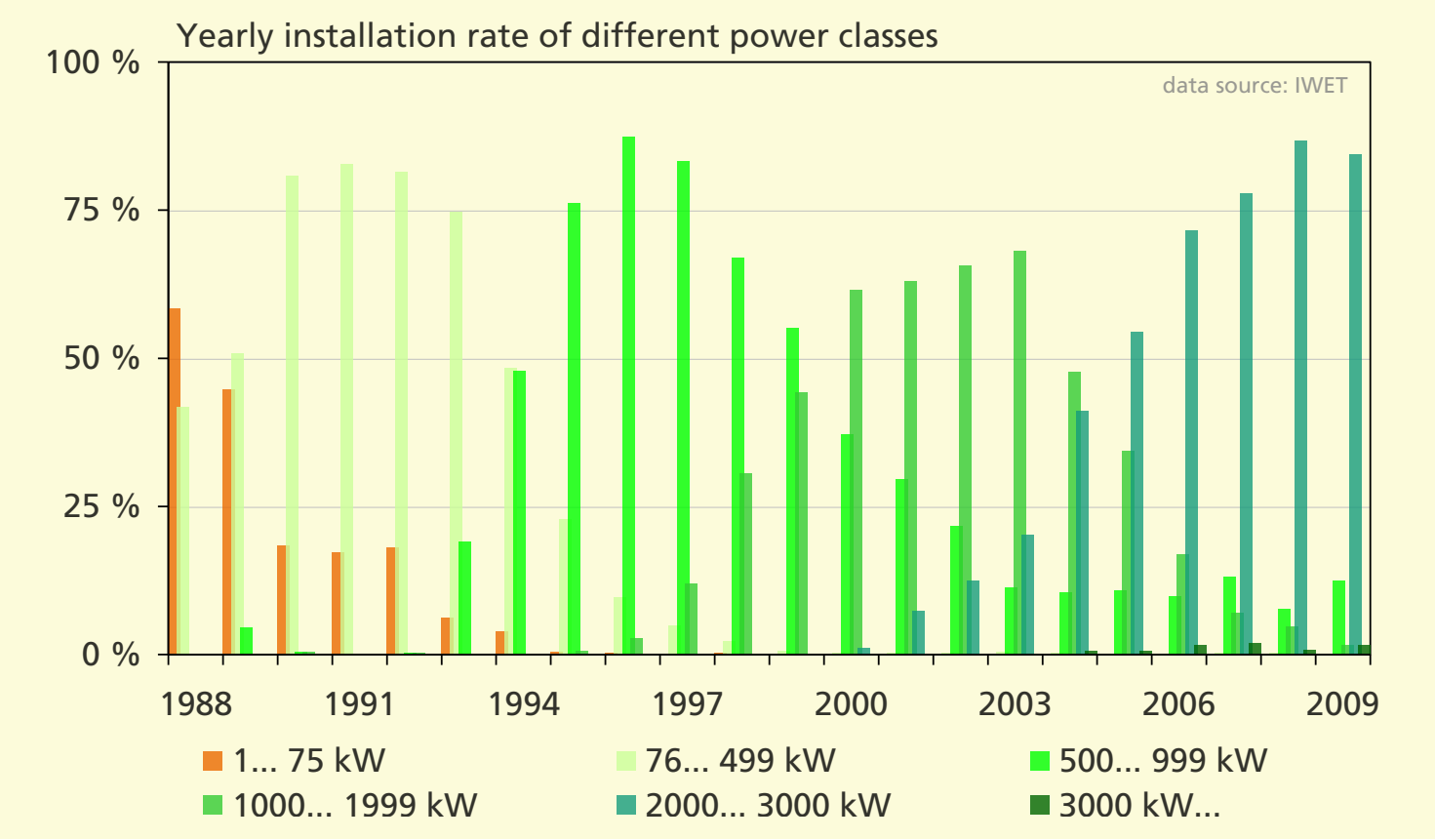
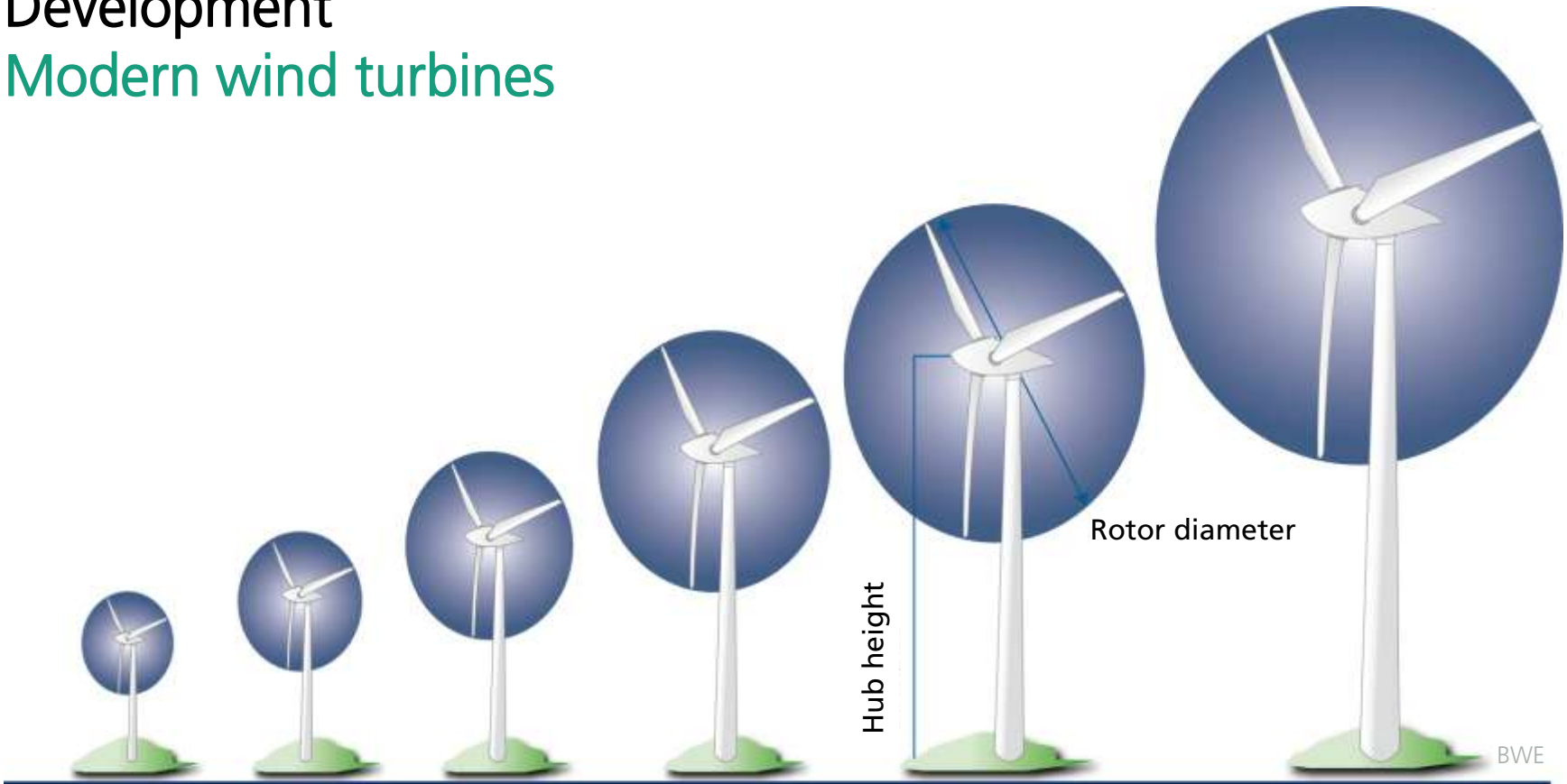
Agenda

1. Size of modern wind turbines
2. Small wind turbine classification and current market status (design, application, costs)
3. Planning and yield estimation
4. Conclusion

Development
Wind turbine size - rated power



Development
Modern wind turbines



	1980	1985	1990	1995	2000	2005	2008
Rated power	30 kW	80 kW	250 kW	600 kW	1.500 kW	3.000 kW	6.000 kW
Rotor diameter	15 m	20 m	30 m	46 m	70 m	90 m	126 m
Hub height	30 m	40 m	50 m	78 m	100 m	105 m	135 m
AEP*	35.000 kWh	95.000 kWh	400.000 kWh	1.250.000 kWh	3.500.000 kWh	6.900.000 kWh	ca. 20.000.000 kWh

*Annual Electricity Production

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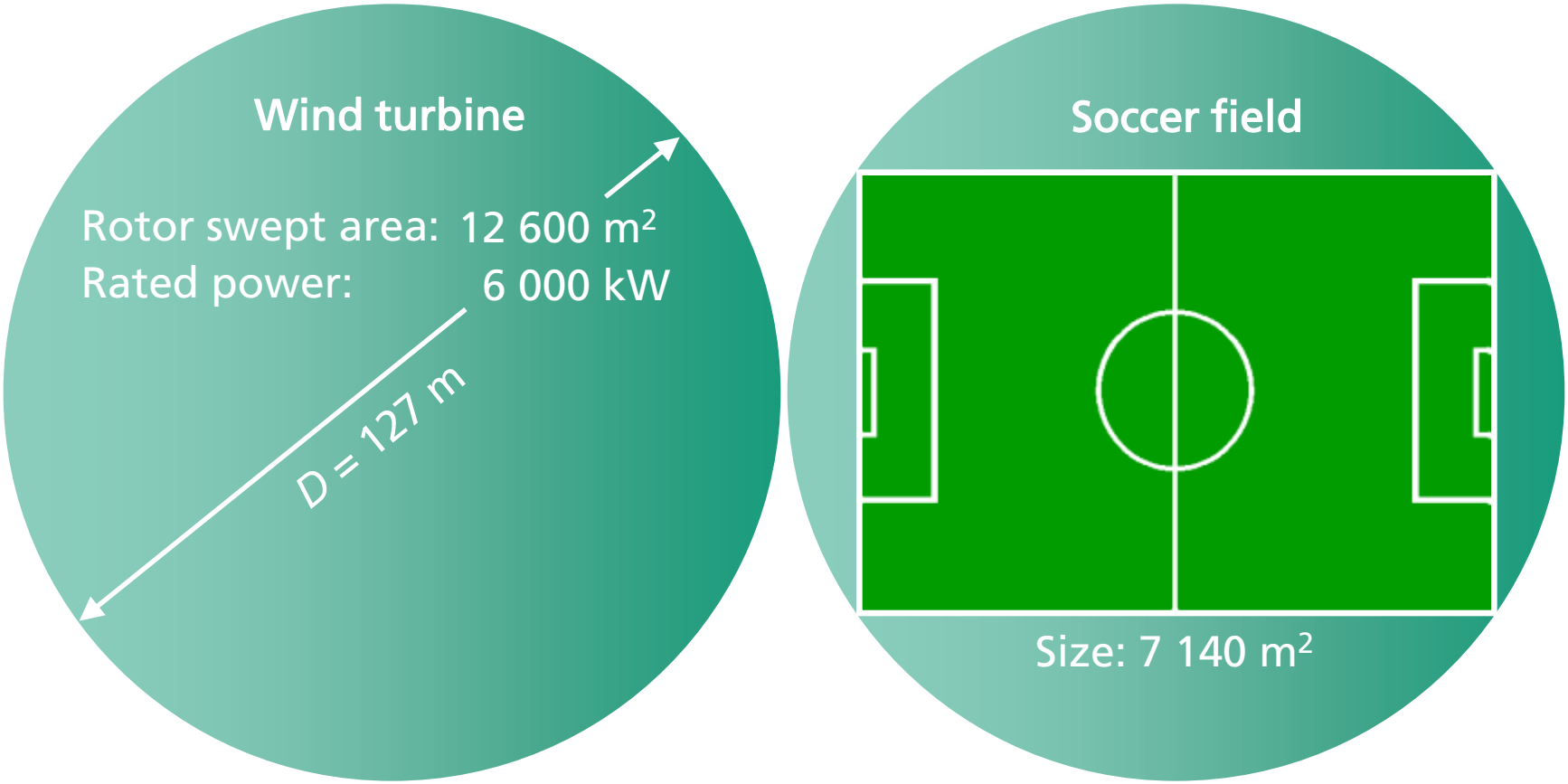
Size of modern wind turbines



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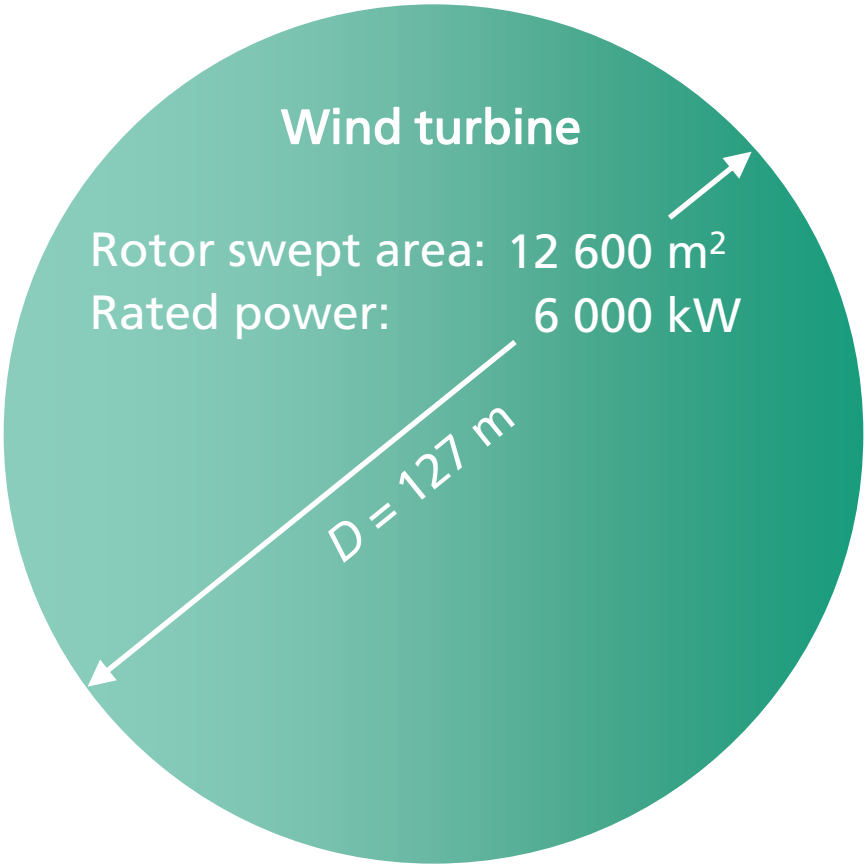
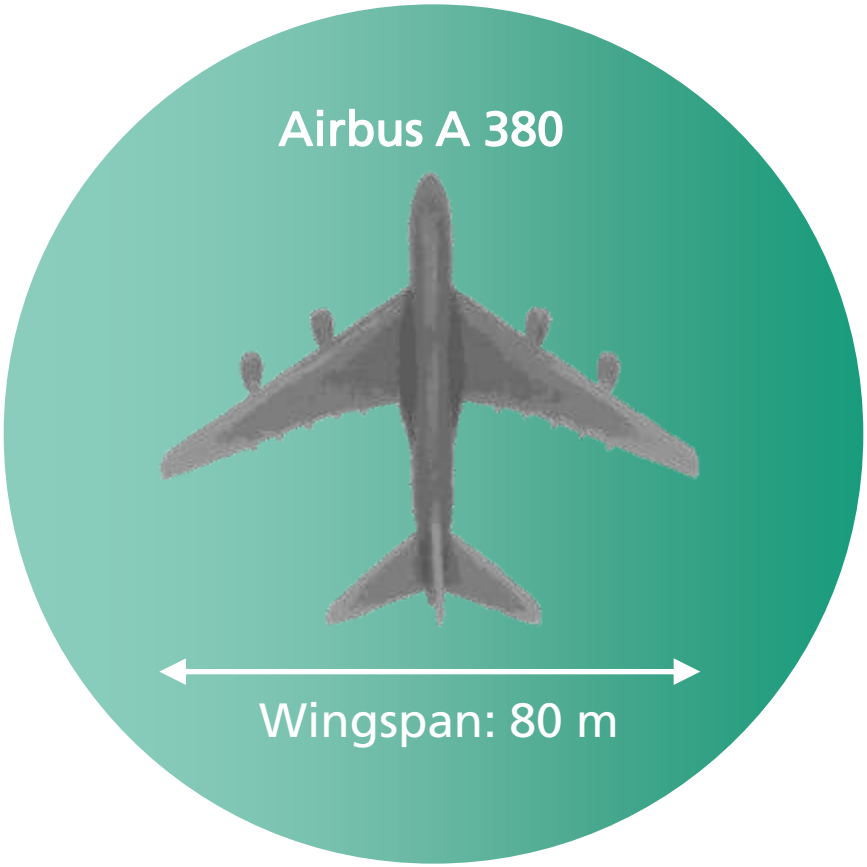
Size of modern wind turbines





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Size of modern wind turbines

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Characteristics of modern wind turbines*

Number of blades	three	100 %
Rotor axis	horizontal	100 %
Rotor position	upwind, active yaw	100 %
(Power) speed limitation	active pitch	100 %
Blade material	fibre-reinforced composites	100 %
Variable speed	(doubly-fed) induction generator	51 %
	synchronous generator	49 %
Tower	tubular (concrete, steel)	> 90 %

* Characteristics of wind turbines installed in Germany between 2006 and 2008 (Source: Windenergie Report Deutschland 2008; ISET)

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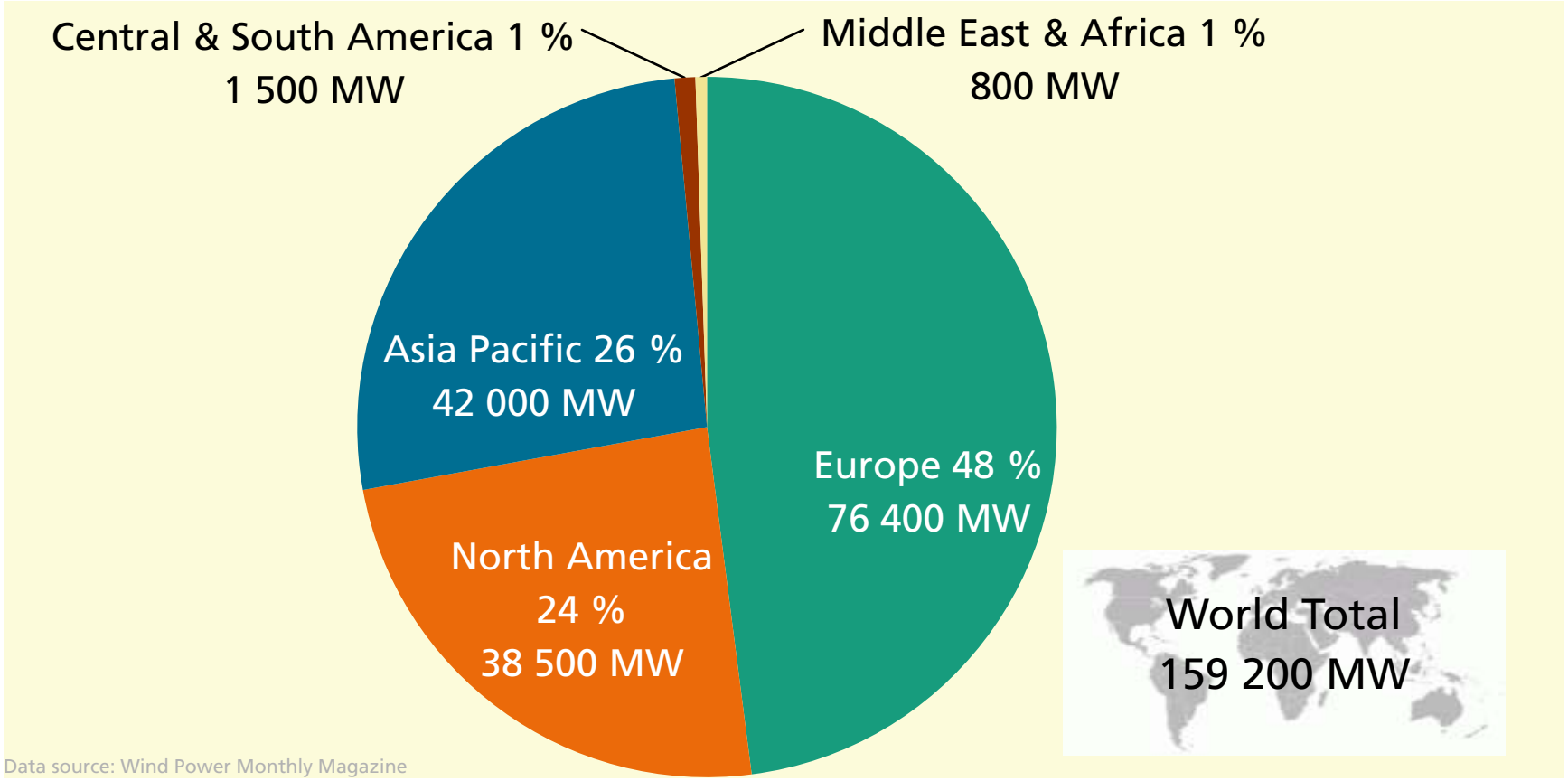
Installed wind power capacity, April 2010



Data source: Wind Power Monthly Magazine

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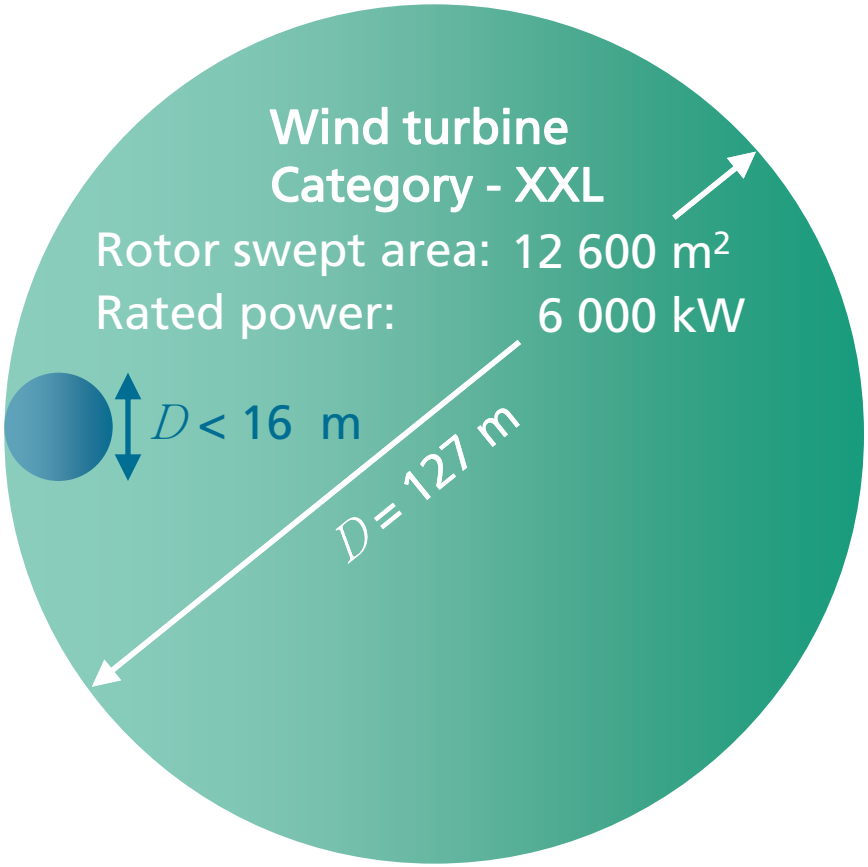
Wind turbines
Size categories

Small wind turbine
Category - S

Rotor swept area: up to 200 m²
Rated power: up to 75 kW



Small wind turbine classification

Size, rated power, design, application…

Model	Superwind 350	Fortis Montana	Quietrevolution qr5	Hannevind 30 kW
Rotor diameter	1,2 m	5 m	3,1 m x 5 m	13 m
Rotor swept area	1,1 m^2	19,6 m^2	15,5 m^2	133 m^2
Rated power	0,35 kW	5 kW	6 kW	30 kW
Rotor axis	horizontal	horizontal	vertical	horizontal
Type of generator	permanent magnet	permanent magnet	permanent magnet	induction
Tower head weight	11,5 kg	230 kg	450 kg	950 kg
Typical application	remote, mobile, battery charger	on- or off-grid,	building mounted, on-grid	commercial, on-grid

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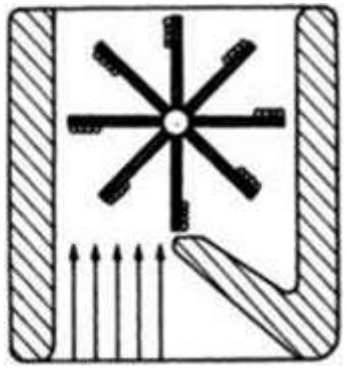
Design - rotor concepts
Drag and lift

Drag


Hau


Gasch/Twele


Thies Clima

Lift


Superwind


Windside


Dörner (Dornier)


Enercon

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Design
Tower types

free-standing lattice

free-standing tube

tilt-up, guyed lattice

tilt-up, guyed tube

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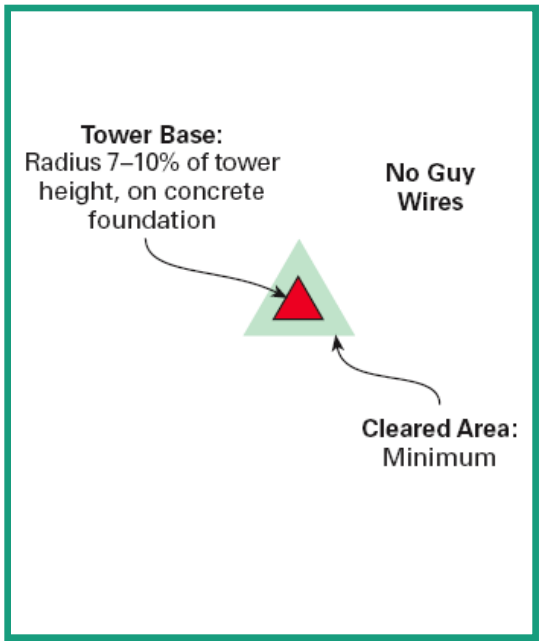
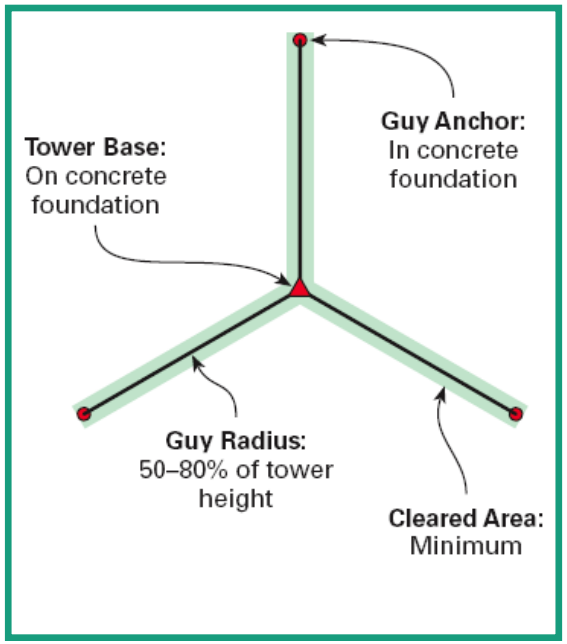
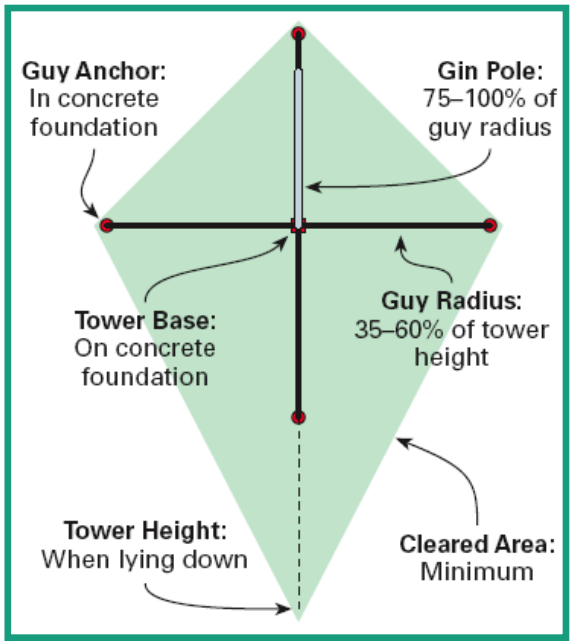
Design
Tower footprints



fixed, free-standing tower footprint



fixed, guyed tower footprint



source: Home Power Magazine, Issue 105

tilt-up, tower footprint

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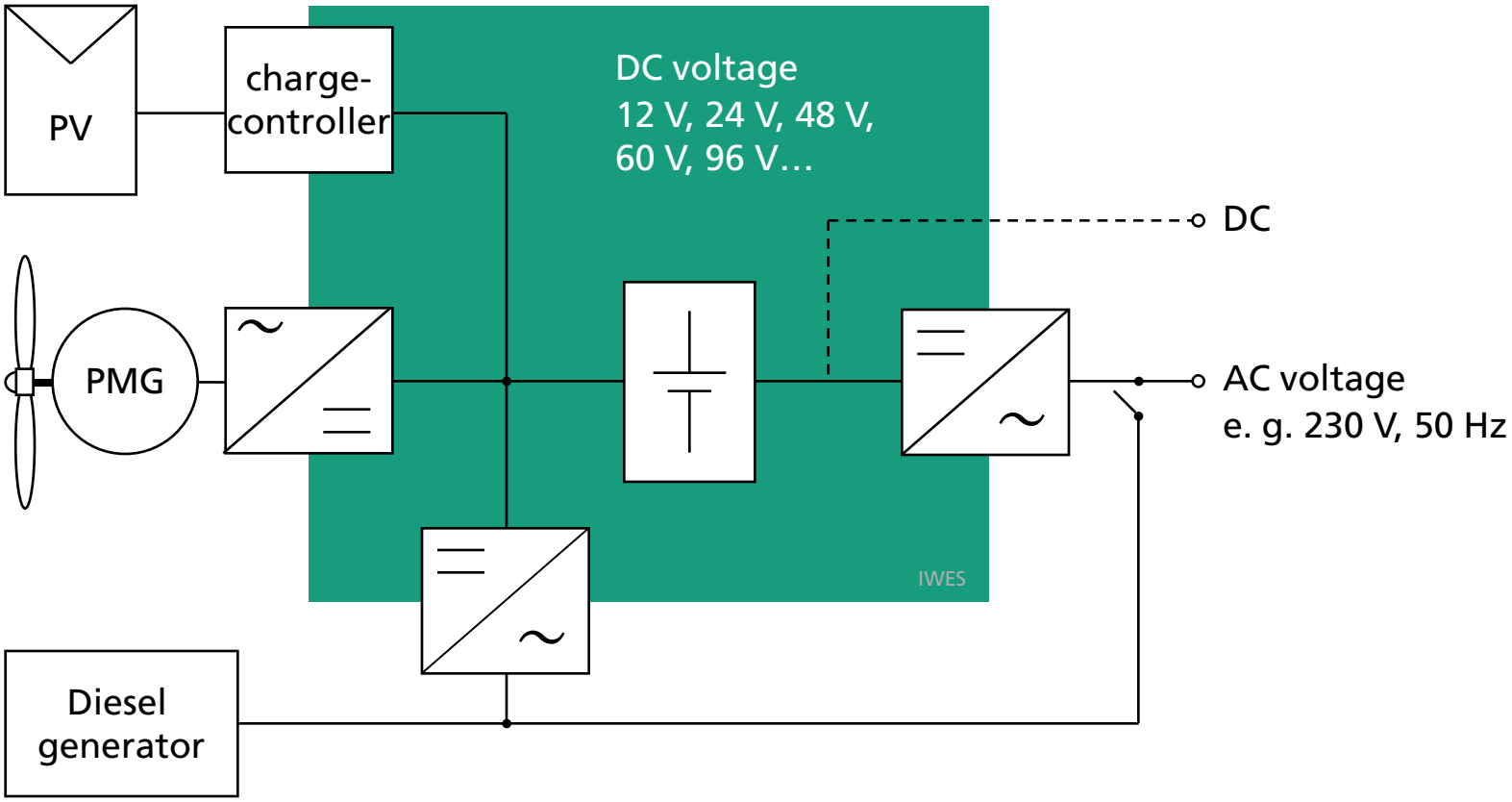
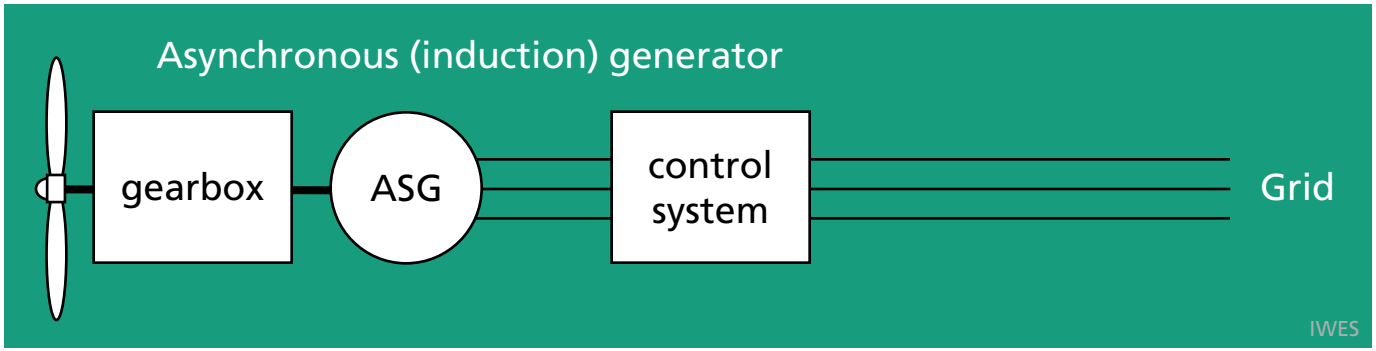
Small wind turbine systems
DC coupled system

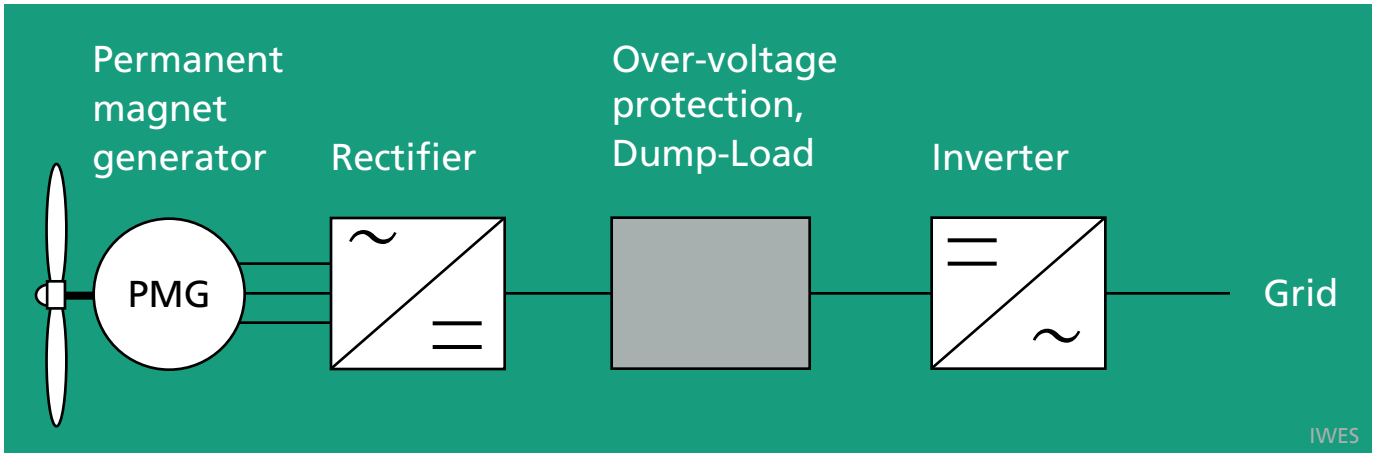


Small wind turbine systems
AC coupled system

Direct
grid coupling

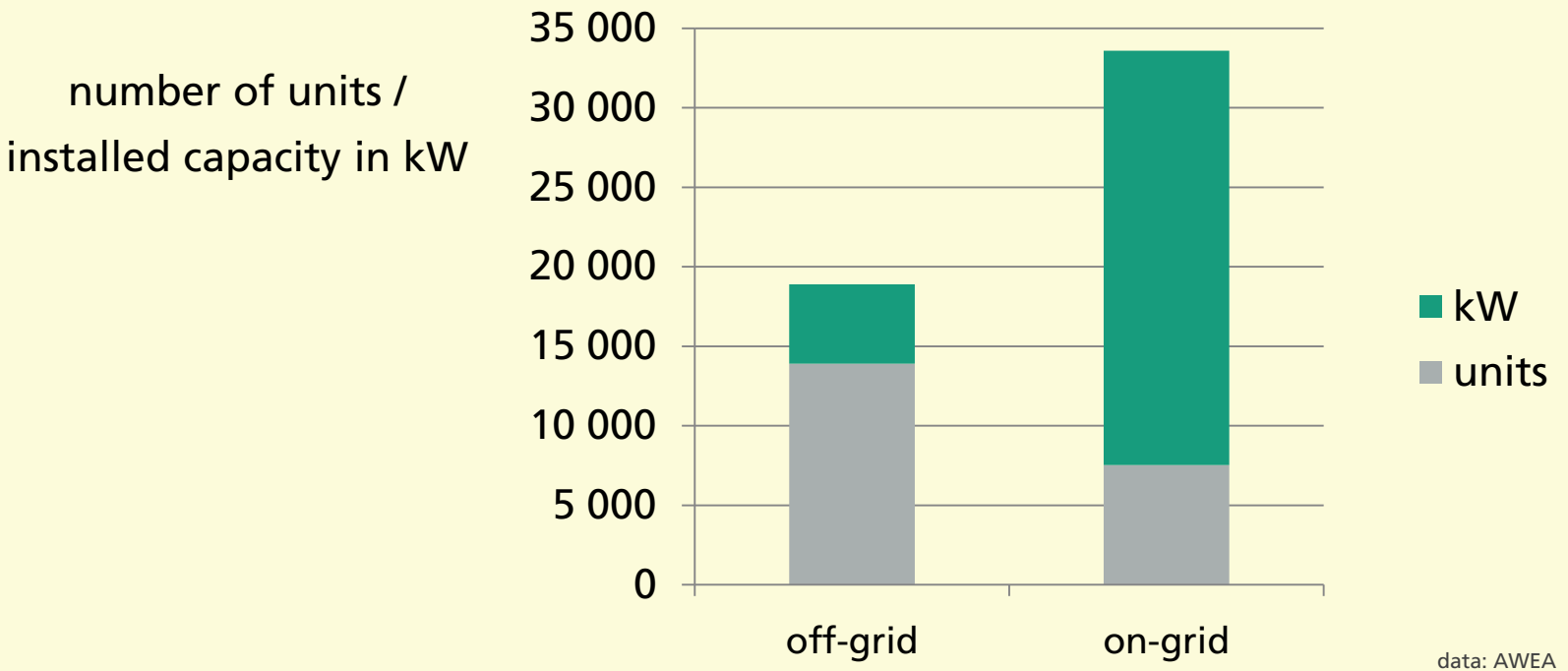


Inverter
Concept



World small wind turbine market growth

Wind power capacity installed & number of units sold in 2008



Market
Examples of available types


Windside


Tassa


HiEnergy


Turby


Ropatec


Eoltec


Southwest Windpower


Proven


Bergey


Fortis


Aircon


WES energy


Renewable Devices


Crome (Kukate)


Turbex

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Applications of small wind turbines
Grid connected systems in the built environment

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Applications of small wind turbines

Remote systems


Bergey


Superwind


Bergey

Marlec


Hannevind


Westwind Wind Turbines


Windside

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Applications of small wind turbines

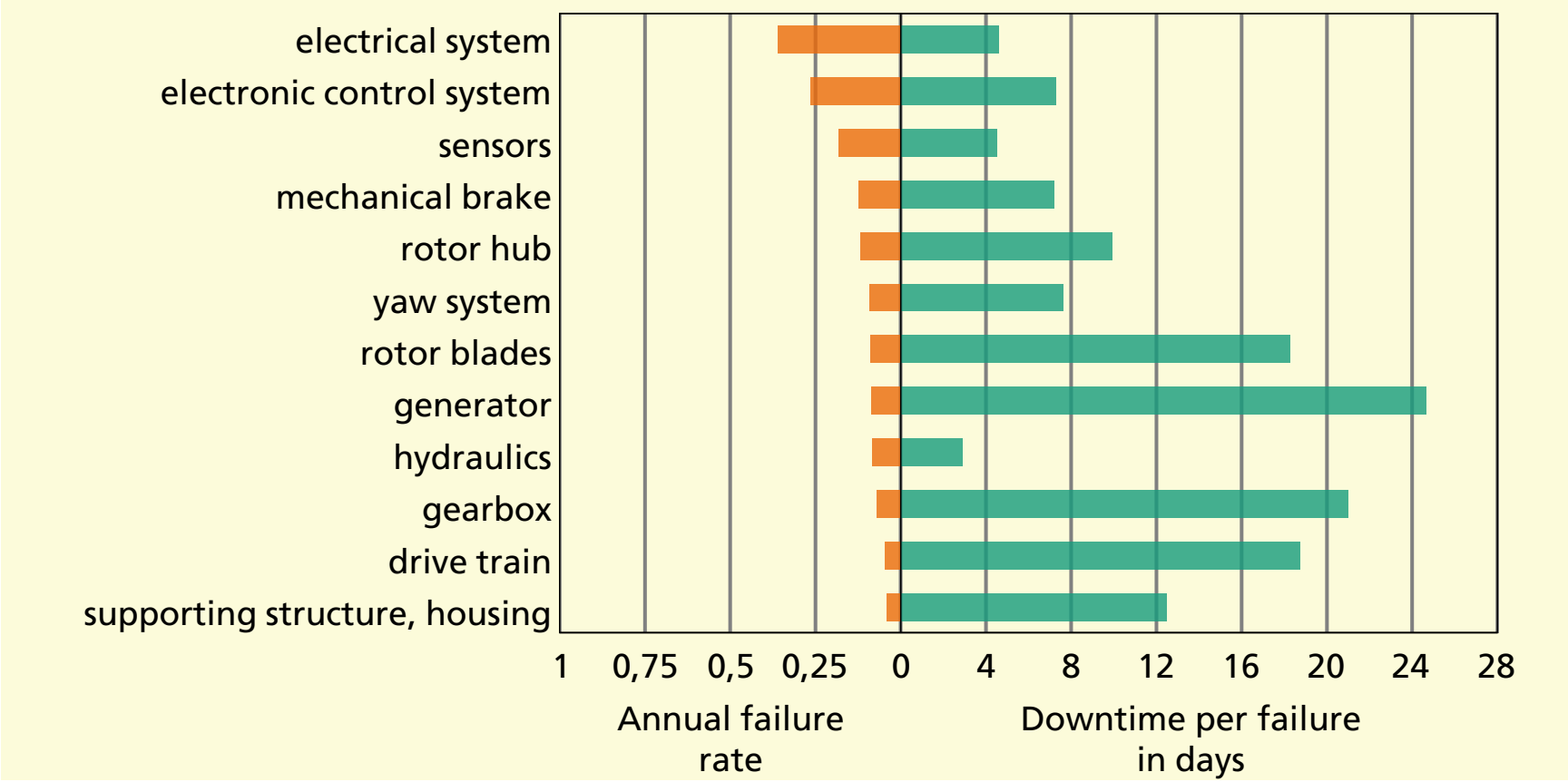
???

Adams County, Colorado (USA), source: Jim Green, NREL

Costs

- High up-front costs: installation costs vary from about 2 500 € to 7 000 € per kilowatt installed rated power
  - great variety of available small wind turbine designs and applications
  - different system sizes
  - different manufacturer backgrounds and different manufacturing economies of scale
- Reoccurring costs are often not considered
  - Maintenance and repair, replacement of components etc.
  - Production losses

Reliability and downtime
Small wind turbines in Germany



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Why are wind turbines so high?
World's highest wind turbine

Fuhrländer FL2500
Laasow, Germany

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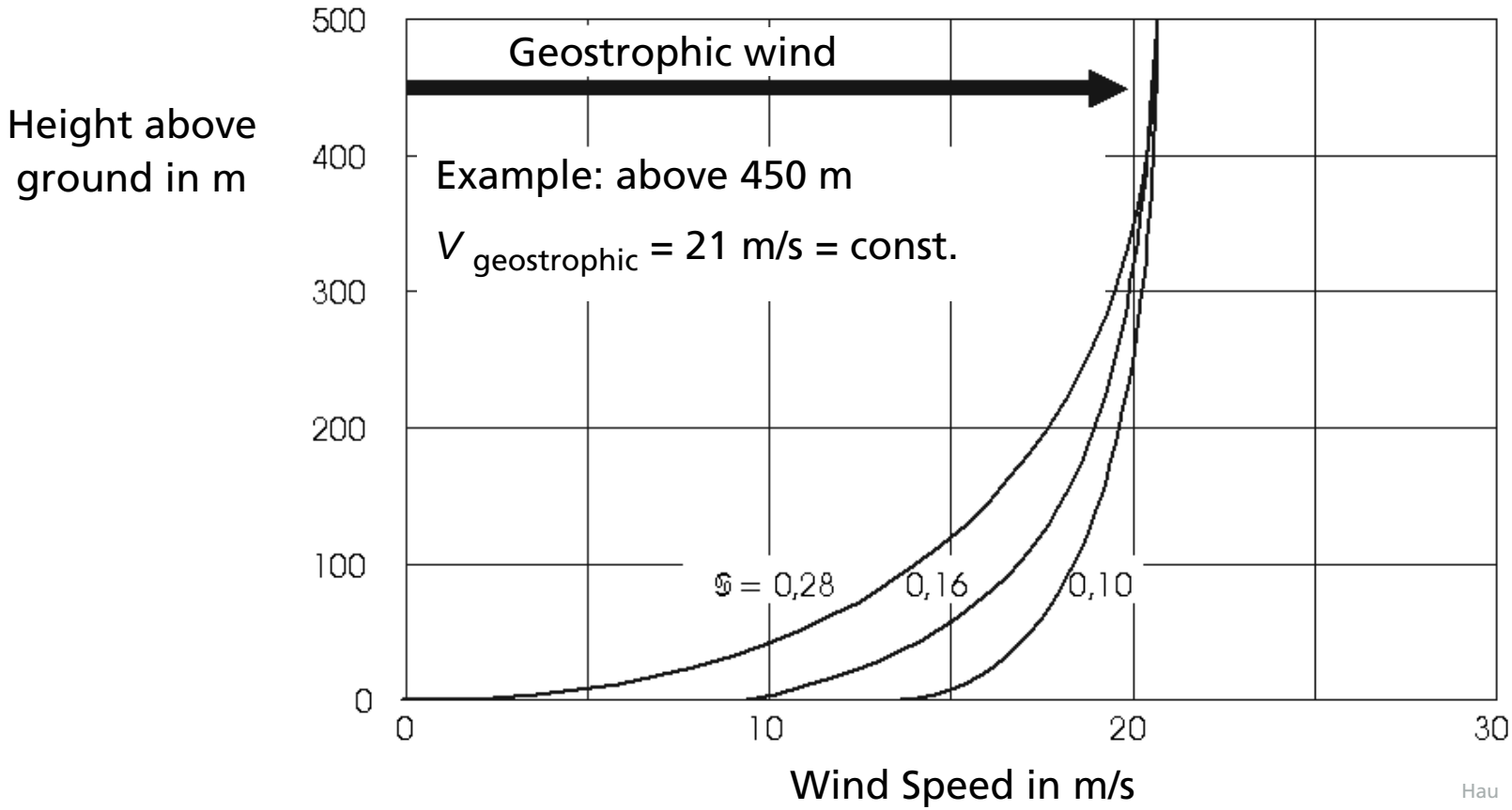
Why are wind turbines so high?
Boundary layer and free atmosphere



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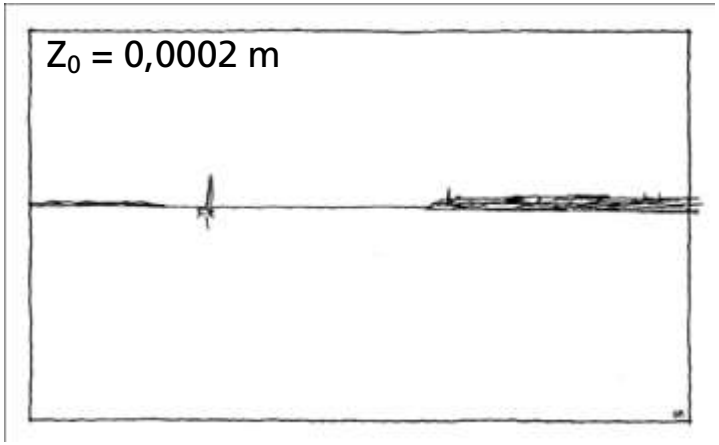
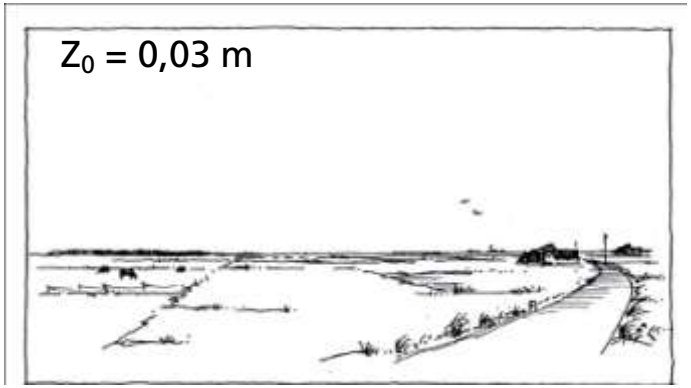
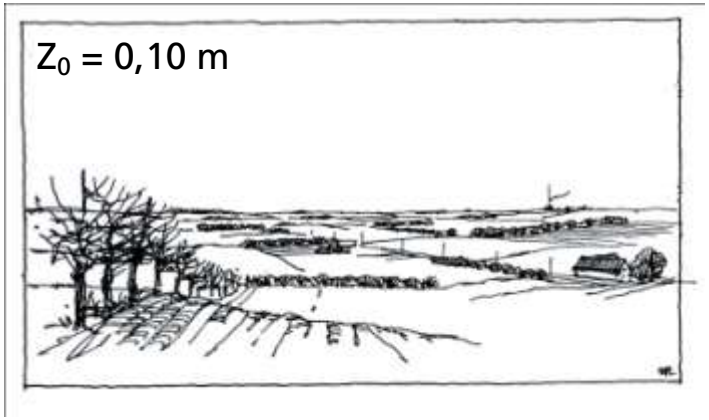
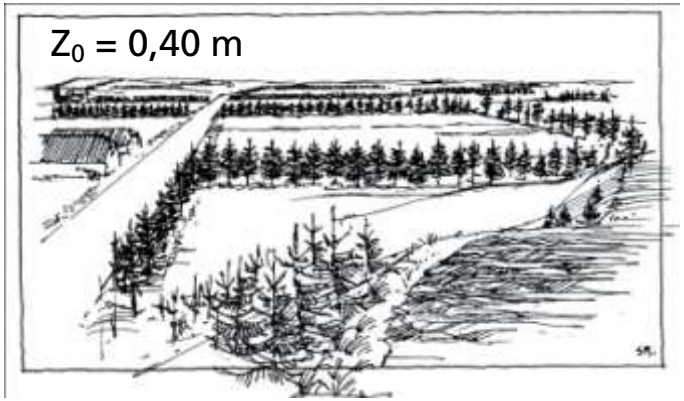
Local wind conditions influenced by terrain type
Descriptions of roughness length z_0 by images





source: European Wind Atlas





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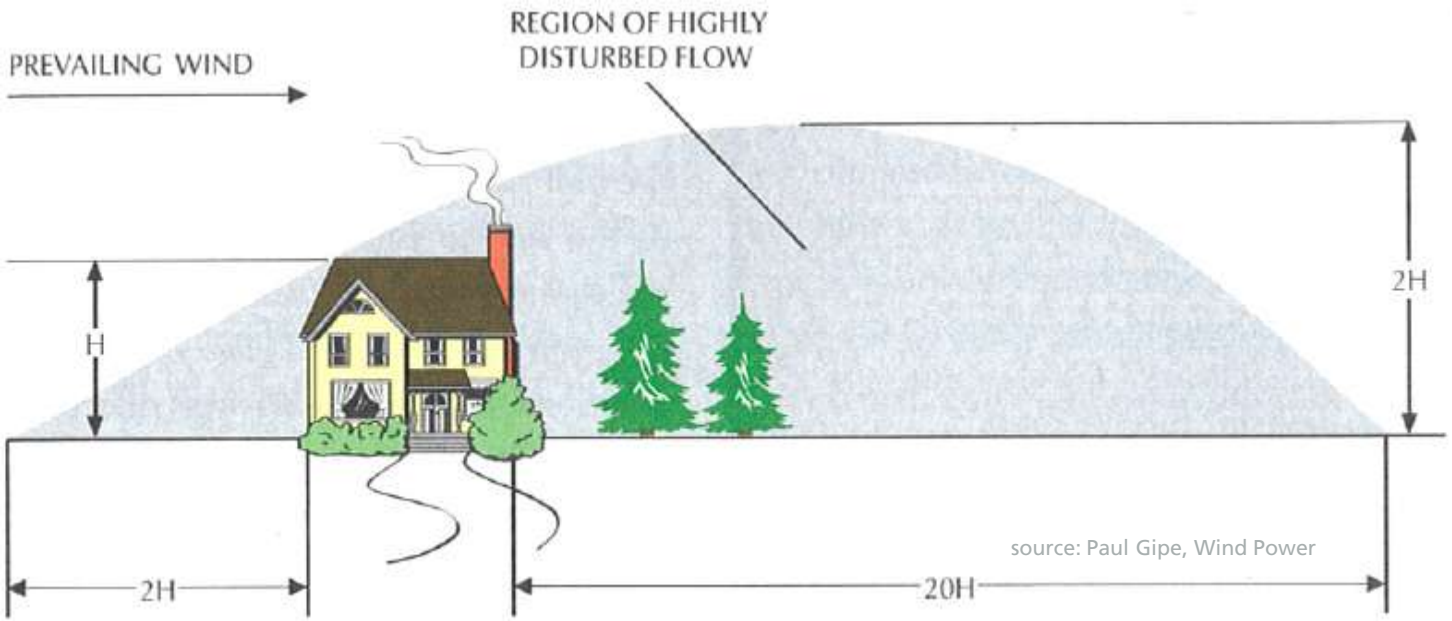
Local wind conditions
Siting of small wind turbines

- Siting of small wind turbines:
  - near the place of electricity consumption
  - no wind data available
  - safety, vibration, noise emissions



source: Paul Gipe, Wind Power

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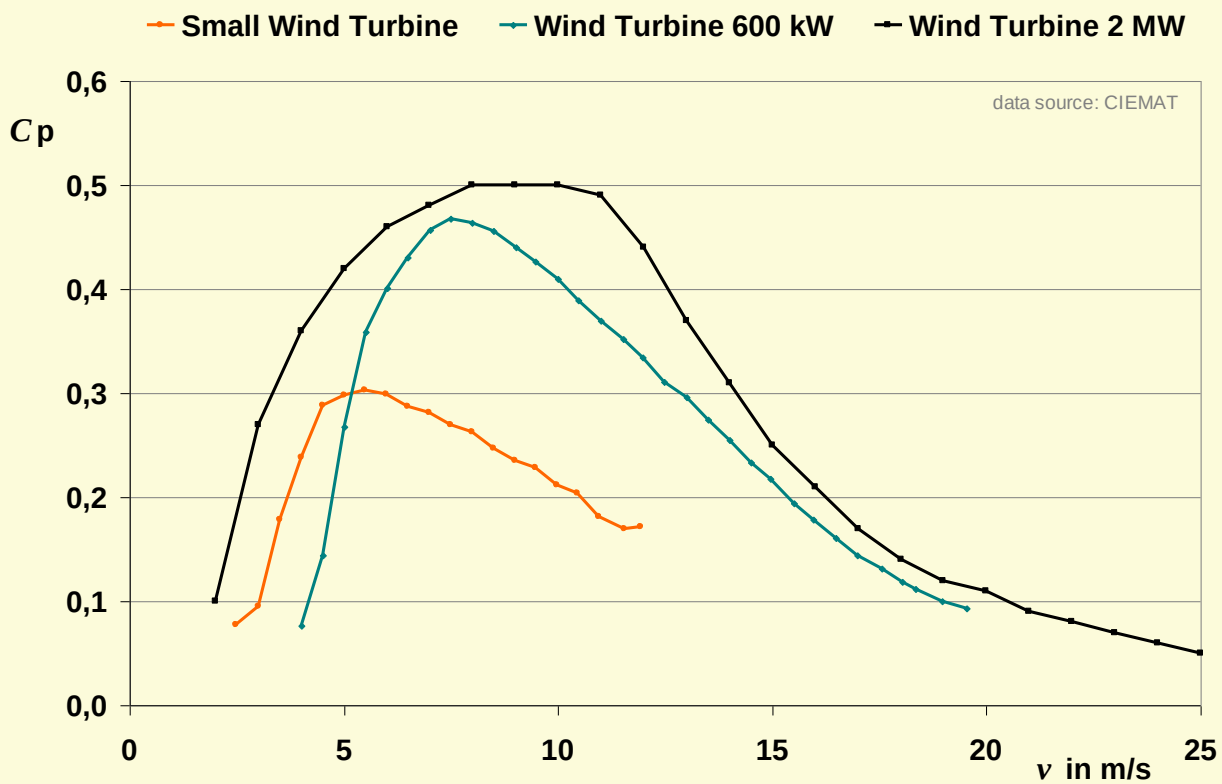
Specifications

Power coefficients C_P of wind turbines of different size



Natural limit: Betz factor 0,59

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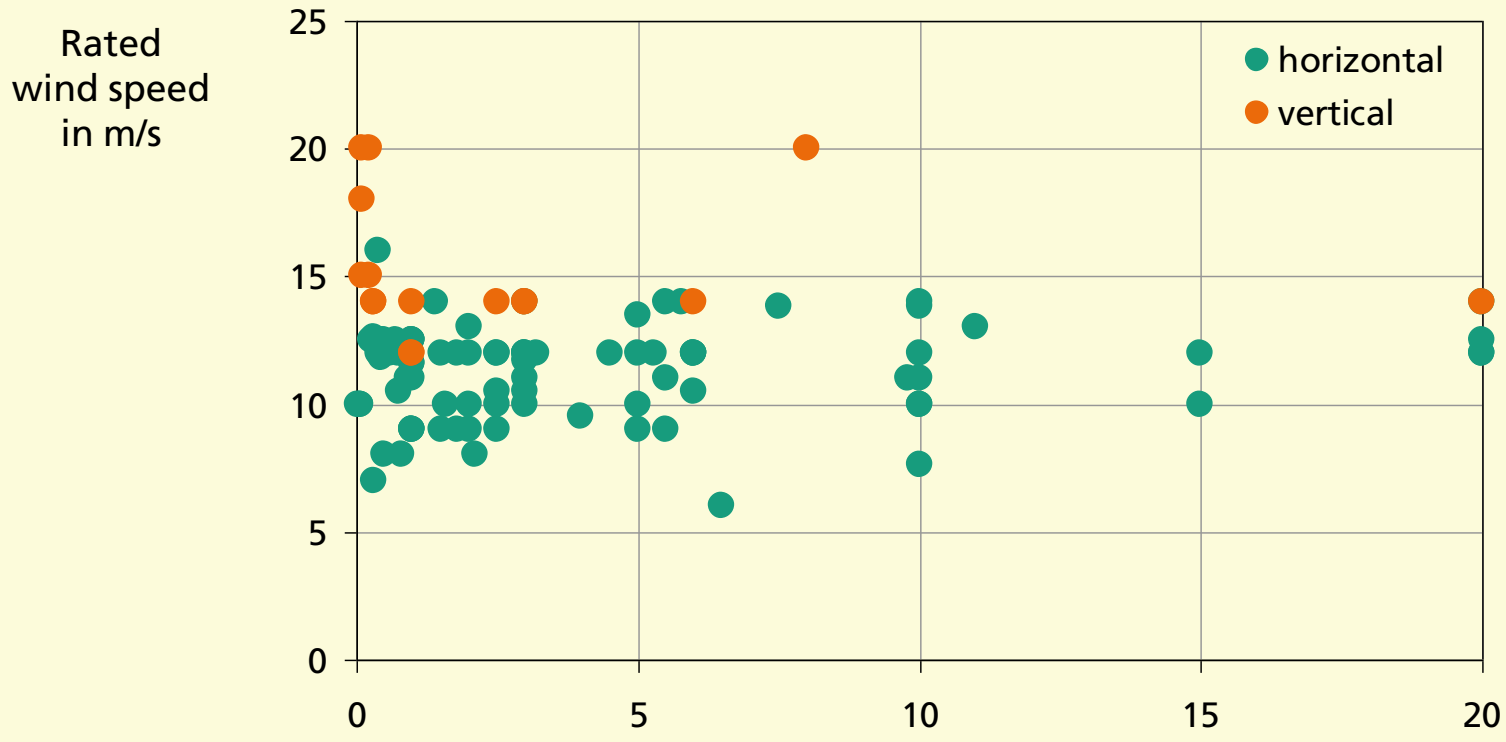
Specifications*: rated power and rated wind speed

No standard rating system for small wind turbines



* data of about 100 small wind turbines
data source: internet, manufacturer's data sheets

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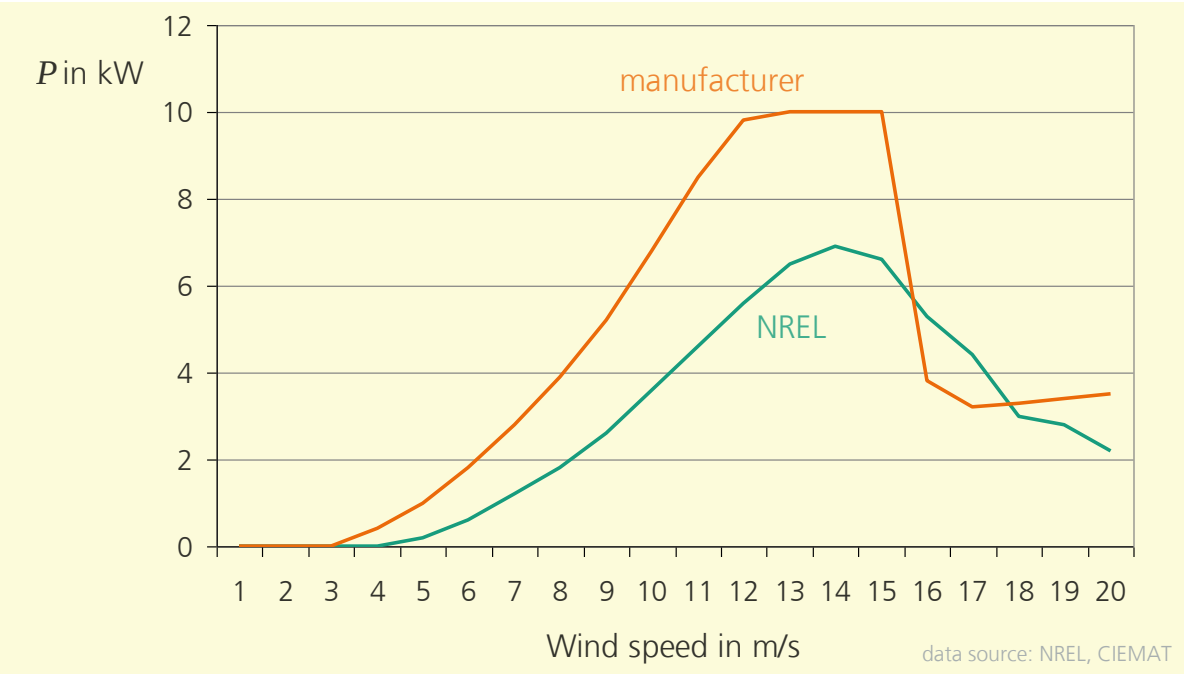
Specifications and product information
Example: power curve

- In many cases, published power curves are not measured according to standard procedures, based on estimations etc.



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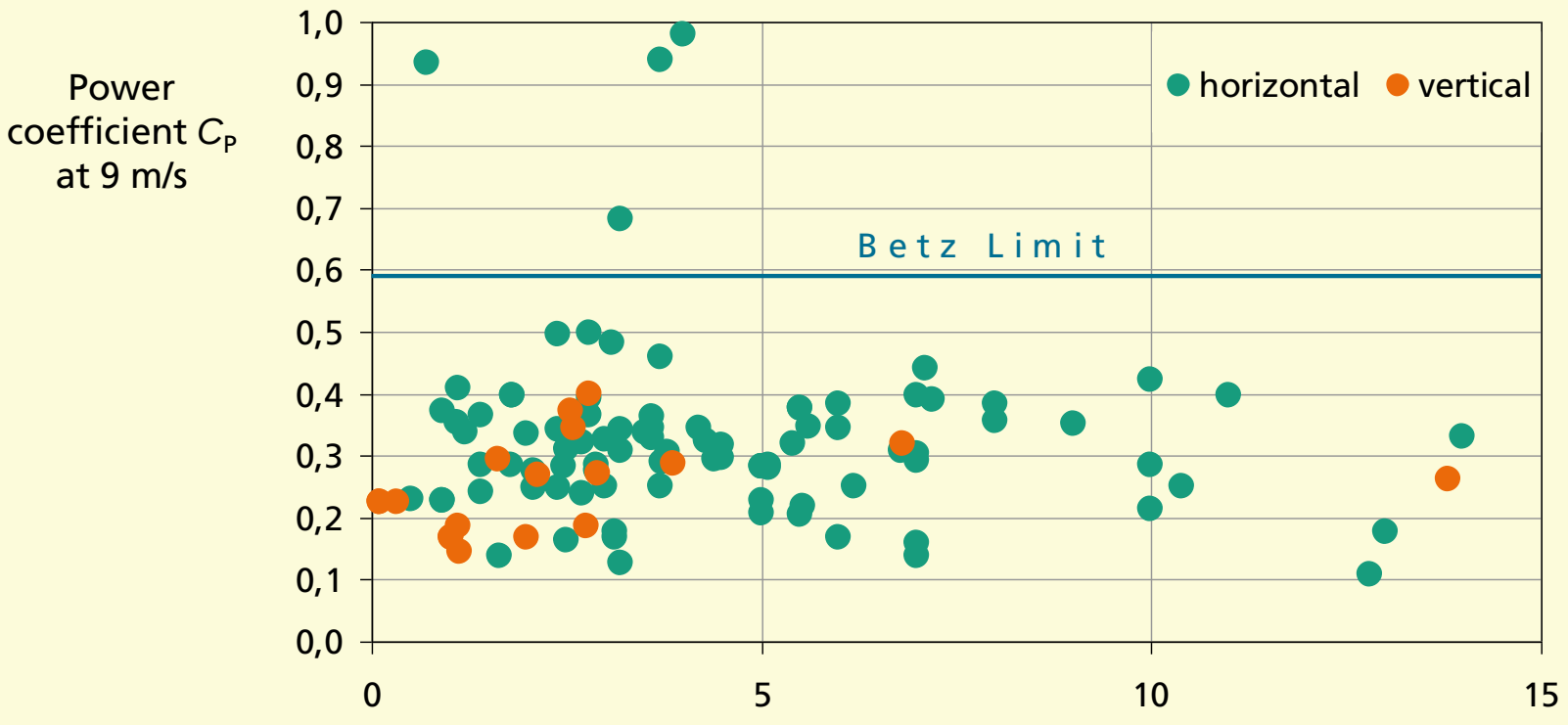
Specifications: power coefficients

No standard rating system for small wind turbines



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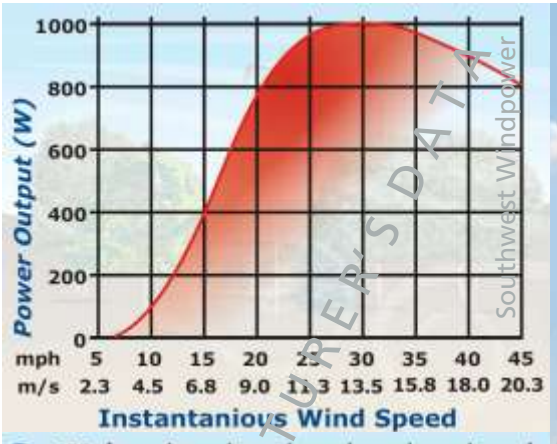
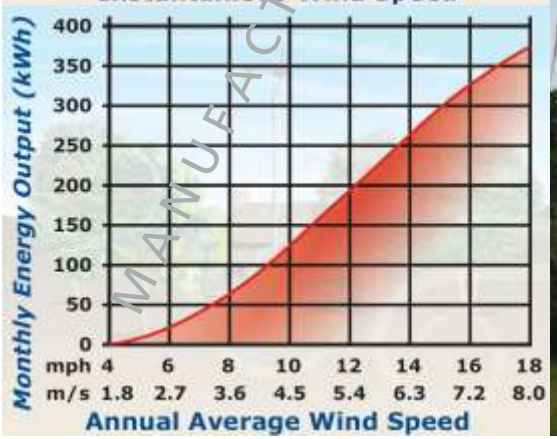
Estimating annual electricity production (AEP)
Electrical chacteristics of small wind turbines






Whisper H80, Southwest Windpower, IWES Test site

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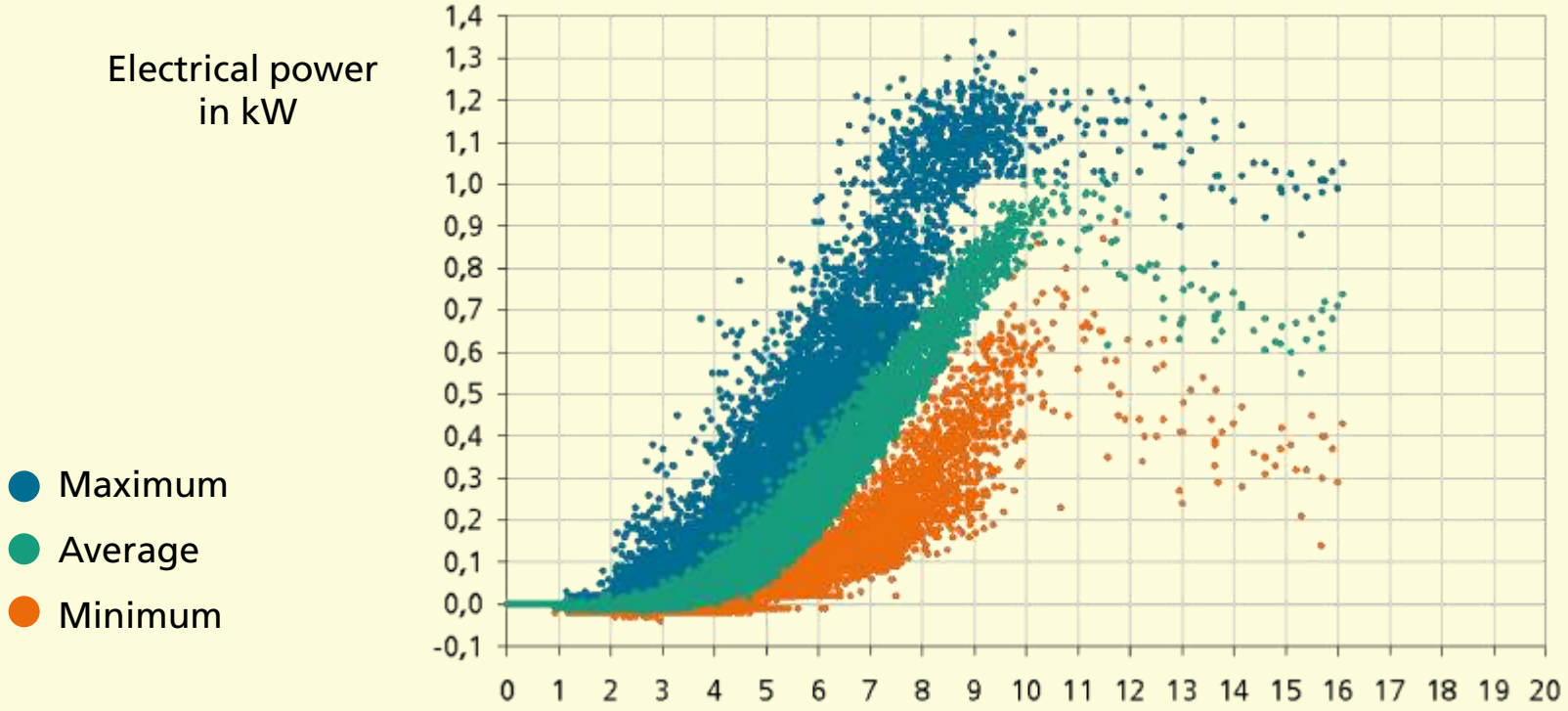
Estimating annual electricity production (AEP)
Power output: real time data and averaging



Data: 10-min-data, sampling rate: 1 Hz,

IWES test site, measurement period: 2009-07-28 to 2009-10-14, Whisper H80, Southwest Windpower

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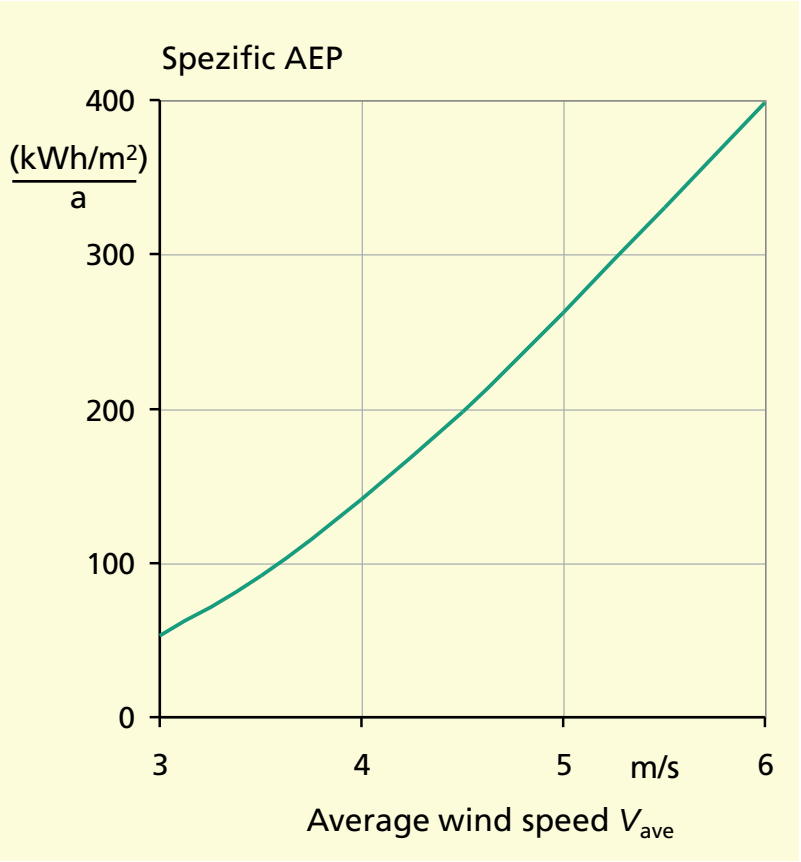
Estimating annual electricity production (AEP)
Rotor diameter / swept area

Rotor diameter	Rotor swept area	Power in the wind x 0,3 at 9 m/s
1 m	0,8 m^2	105 W
3 m	7 m^2	950 W
5 m	20 m^2	2 630 W
7 m	40 m^2	5 150 W
10 m	80 m^2	10 520 W



Example

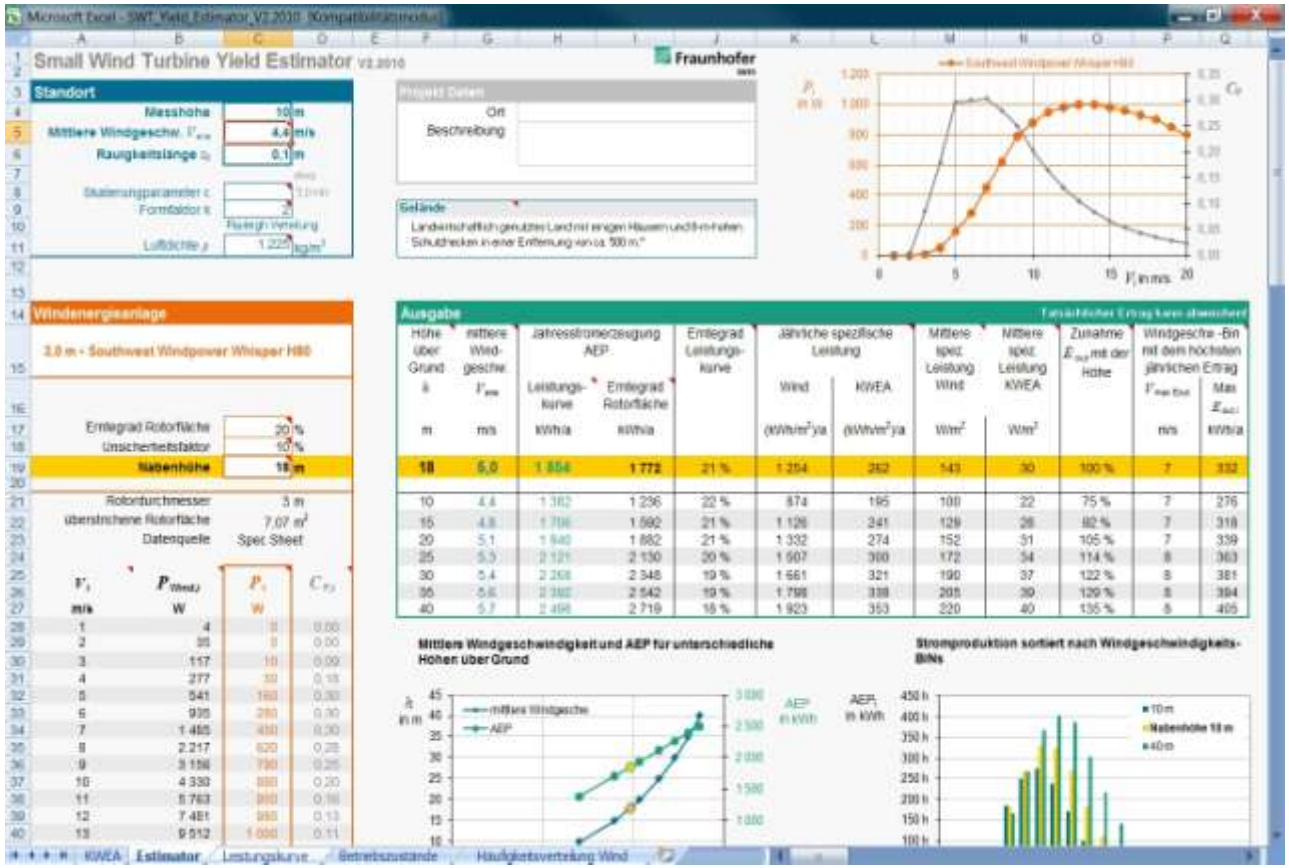
rotor diameter: D = 3 m

avg. wind speed: V_{ave} = 5 m/s

AEP = 260 (kWh/m^2)/a x 7 m^2

= **1 820 kWh/a**

Small Wind Turbine Yield Estimator
MS Excel-Spreadsheet



Free download:
www.windmonitor.de

windmonitor

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Photovoltaics and small wind turbines
A brief comparison

Task	Photovoltaic system 	Small wind turbine 
Resource assessment	solar radiation	average wind speed, main wind direction, turbulence, wind shear
Siting	module orientation and inclination angle, shadowing effects are visible	positioning of tower, effects (wind shadow, turbulence) of obstacles and terrain type are not visible
Sizing	collector area, peak power	swept rotor area, rated power, tower height, tower footprint
Choosing technology	module type, inverter (battery), (fixed or tracking)	great variety of technical concepts (rotor design, type of generator, inverter etc.)
Evaluating operational aspects	no moving parts, repair and maintenance, accessibility (rooftop)	due to moving parts potential safety risks, emission of noise and vibrations, repair and maintenance, accessibility (tower)

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SMALL wind turbines – BIG chances

Any questions?

M. Sc. Paul Kühn

Devision Energy Economy & Grid Operation
Fraunhofer Institute for Wind Energy & Energy System Technology IWES

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Southwest Windpower, Mongolia, Photo: Rod Robinson


Hebron, Photo: Superwind


Patagonia, Argentina

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