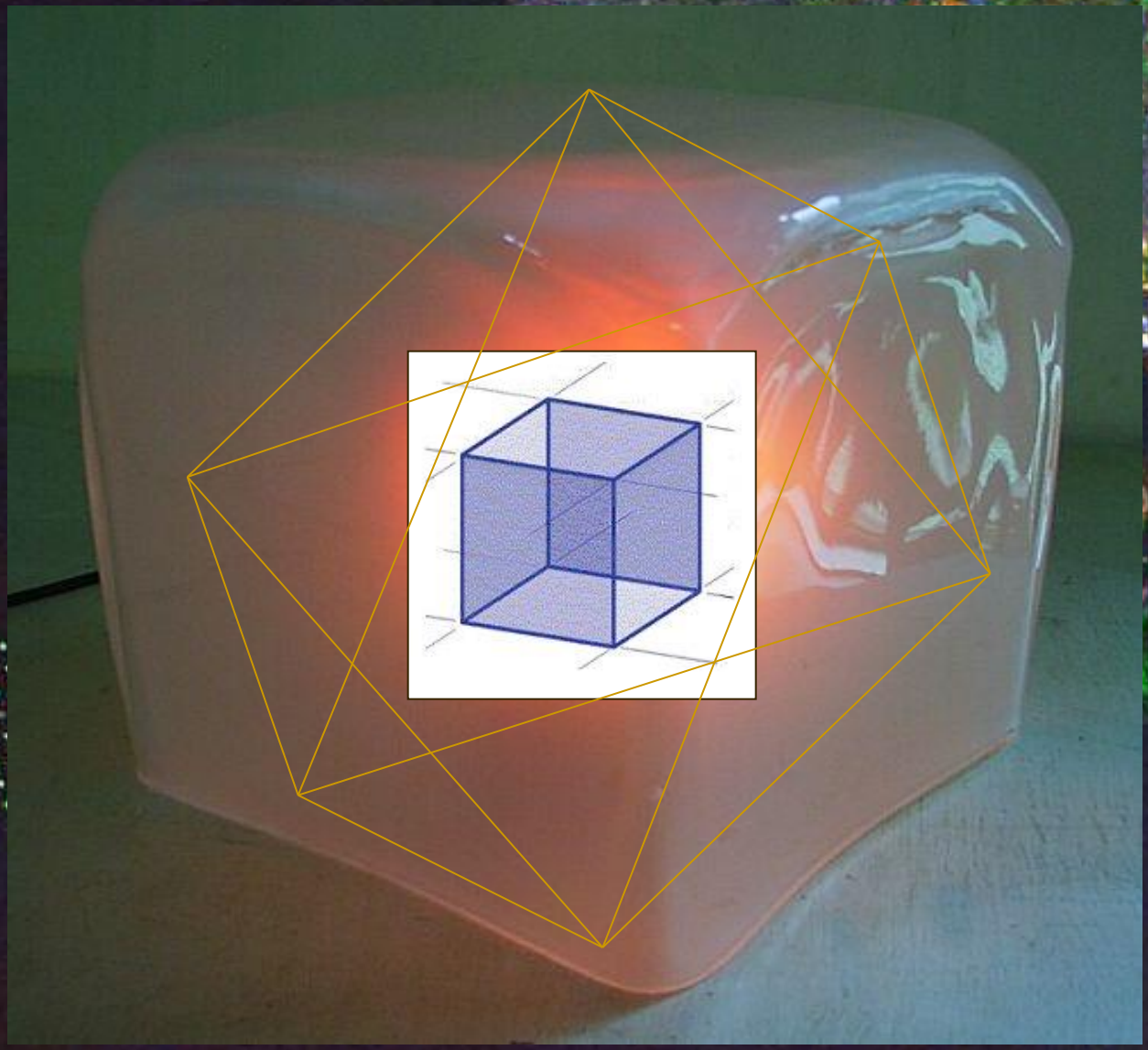

MUĞLA ÜNİVERSİTESİ

Technische Hochschule Wildau [FH]
Technical University of Applied Sciences
WILDAU

InnoTesting 2016

International Conference of Simulation and Testing

Wildau/Germany - February 25th/26th, 2016

Forecasting the Feasibility of Wind Energy Projects

Using the Program WindCalc 1.5

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Overview

Prologue - 25 Years plus 5
Future of Energy – four+2 Elements
Wind Energy vs. Height
Wind Energy vs. Statistics
Wind Energy vs. Physics
Electricity from the Wind

Prologue – 25 Years plus 5

from: „*Kaffeefahrt nach Tschernobyl*“

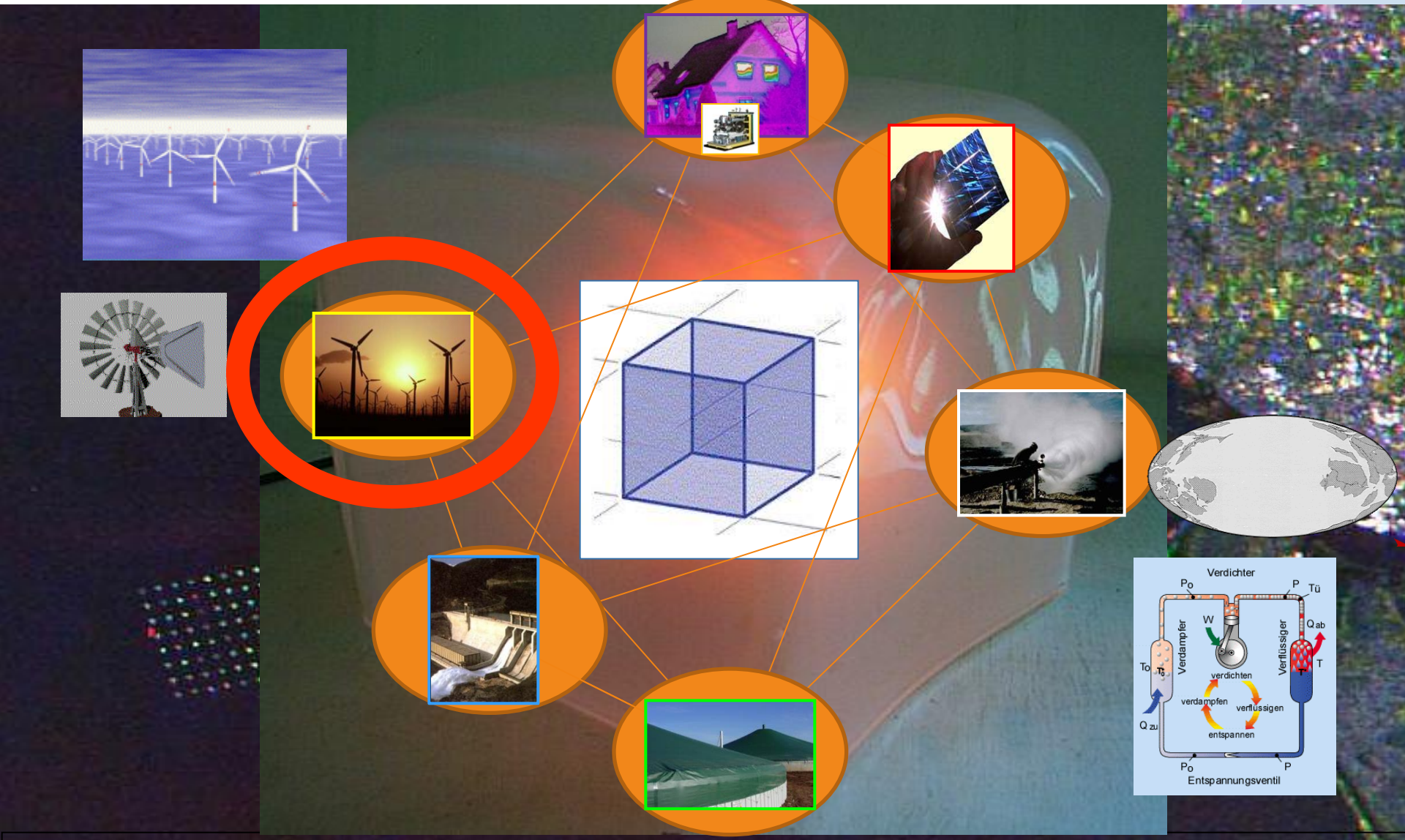
1986

Pictures: BWE, ZDF

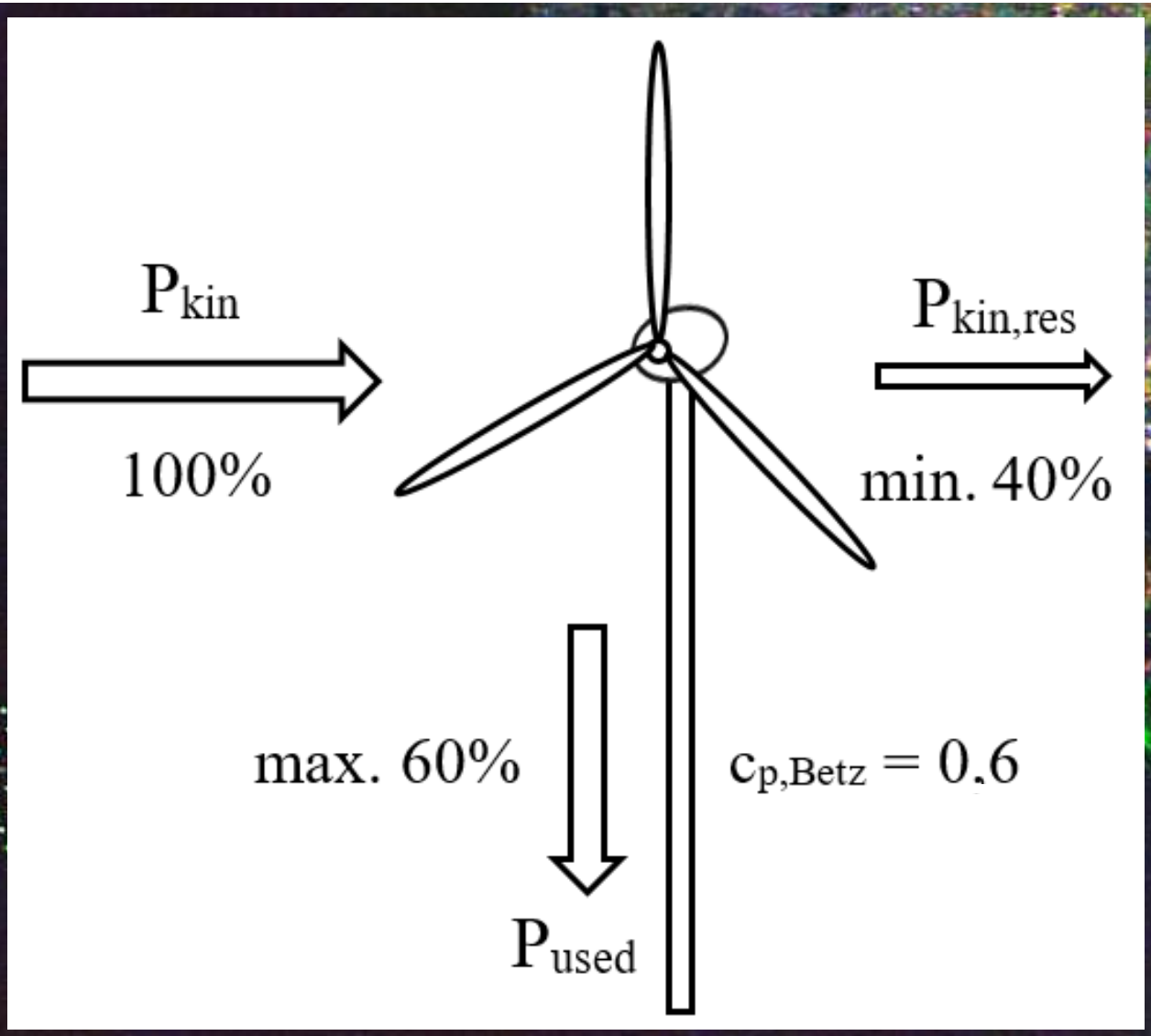
Prologue – Everything is OK

Everything is OK, *is it?*

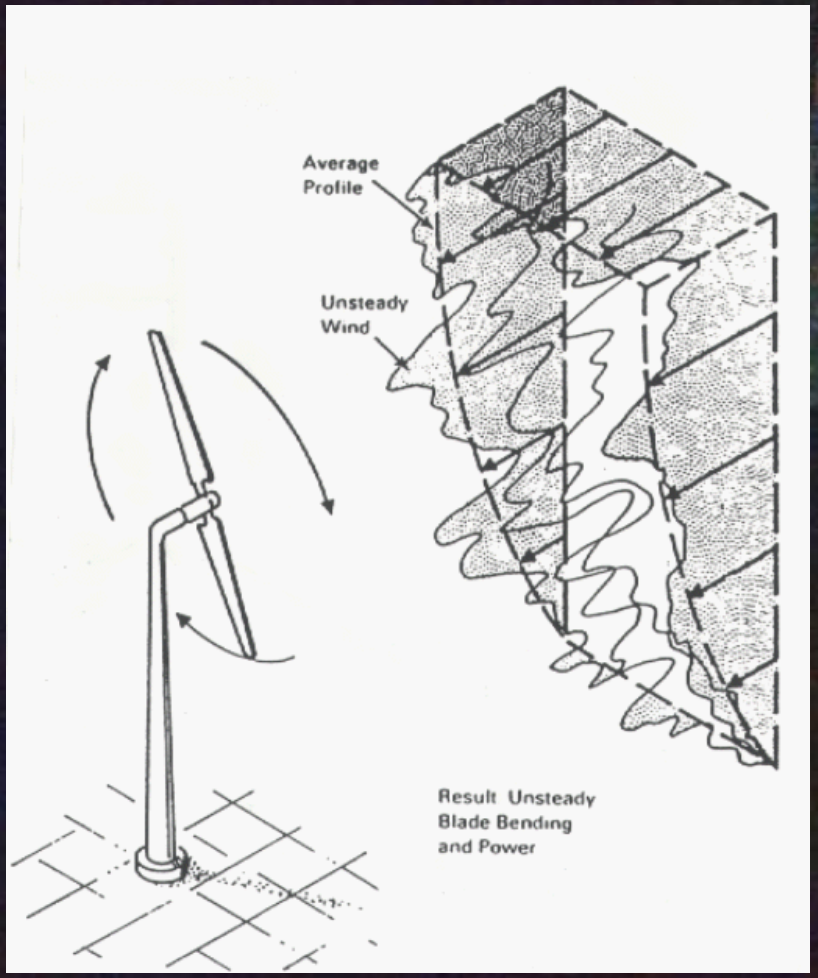
Future of Energy – The four+2 Elements



Wind Energy vs. Height



Wind Energy vs. Height



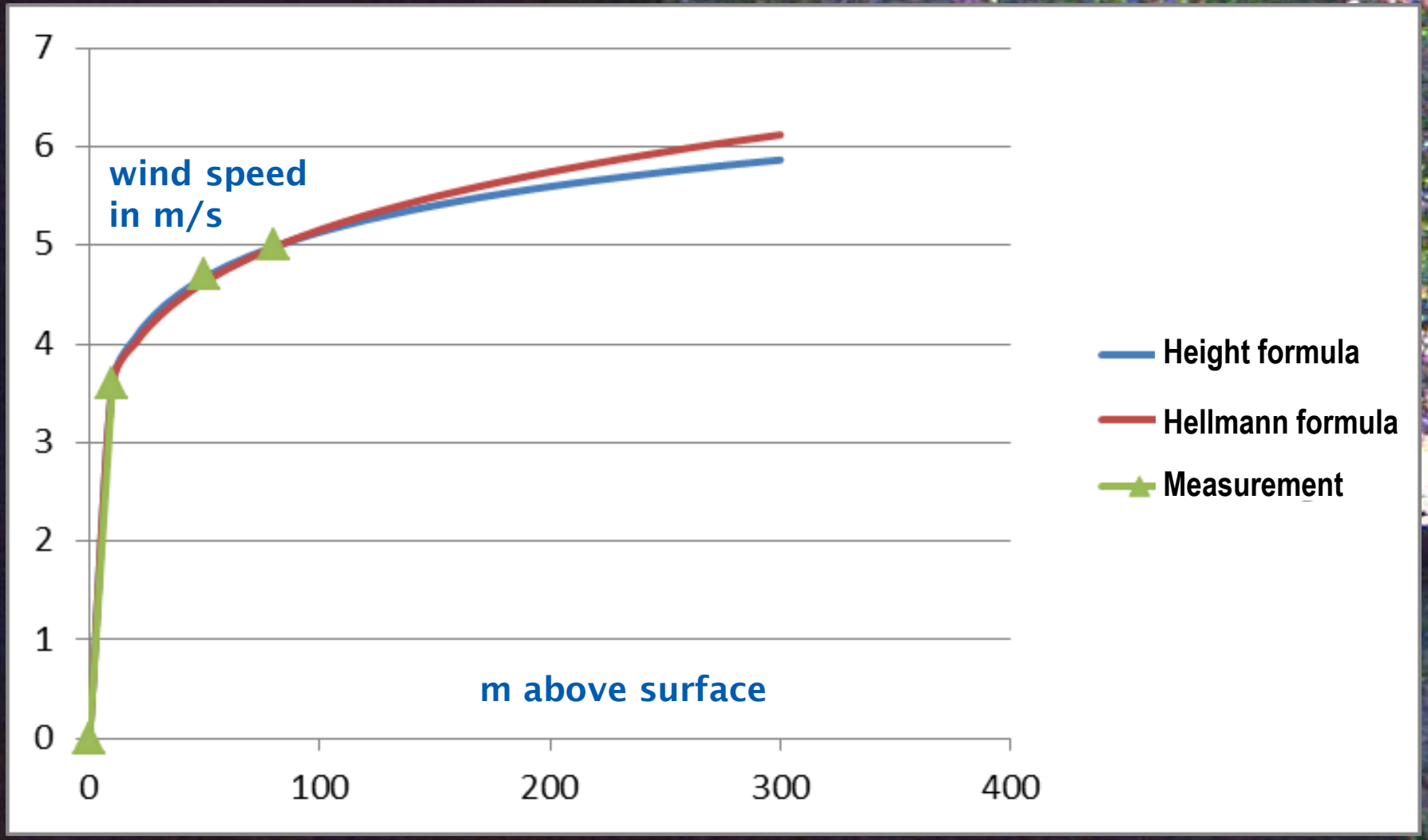
$$v_2 = v_1 \frac{\ln\left(\frac{h_2 - d}{z_0}\right)}{\ln\left(\frac{h_1 - d}{z_0}\right)}$$

$$v_2 = v_1 \left(\frac{h_2}{h_1}\right)^{\alpha}$$

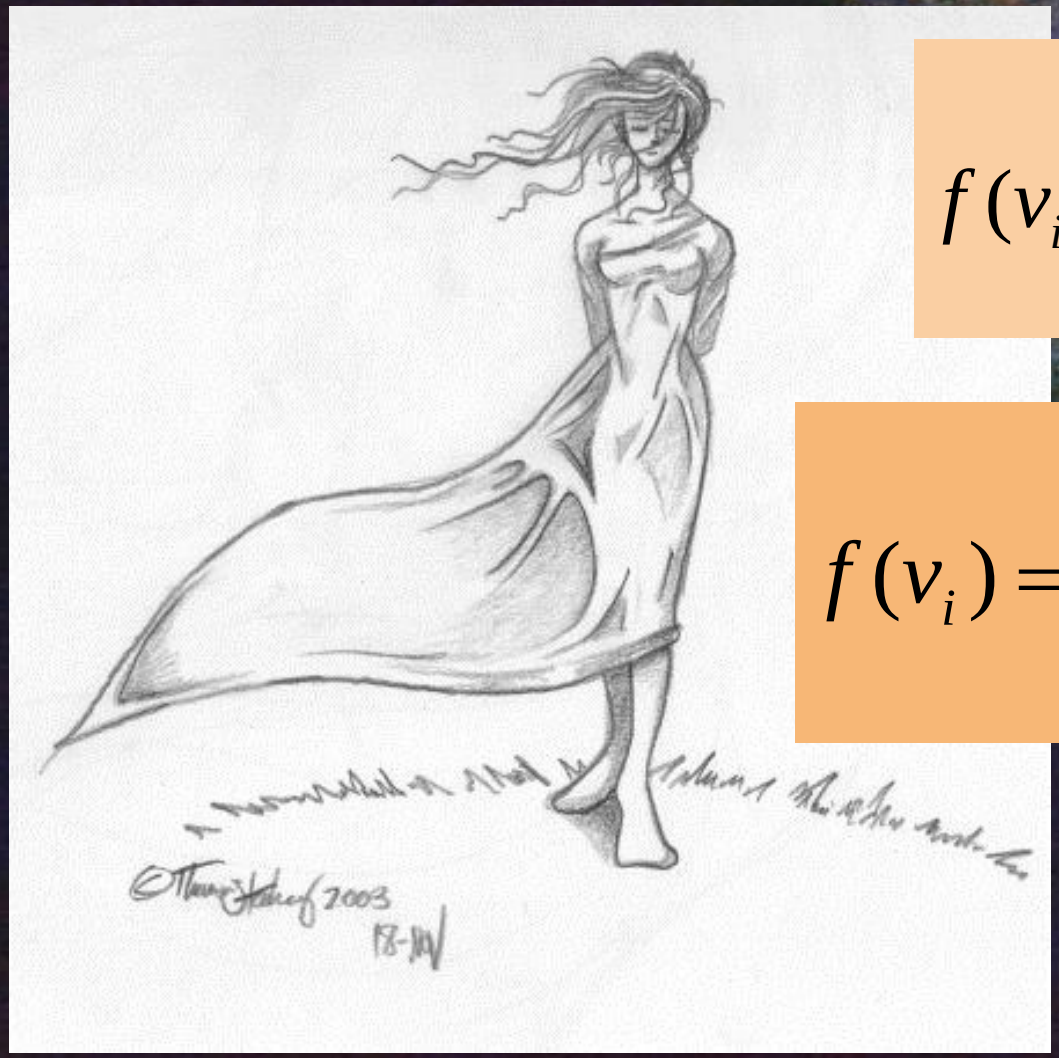
Wind Energy vs. Height

Class of Roughness	Roughness z_0 (m)	Energy Index (%)	Typ of Landscape
0	0.0002	100	Ocean
0.5	0.0024	73	Flat land, greenland, coastal land
1	0.03	52	Open agricultral land
1.5	0.055	45	Wide agricultural land
2	0.1	39	Medium agricultural land
2.5	0.2	31	Narrow agricultural land
3	0.4	24	Settlements, forest etc.
3.5	0.6	18	Cities with high buildings
4	1.6	13	Big cities

Wind Energy vs. Height



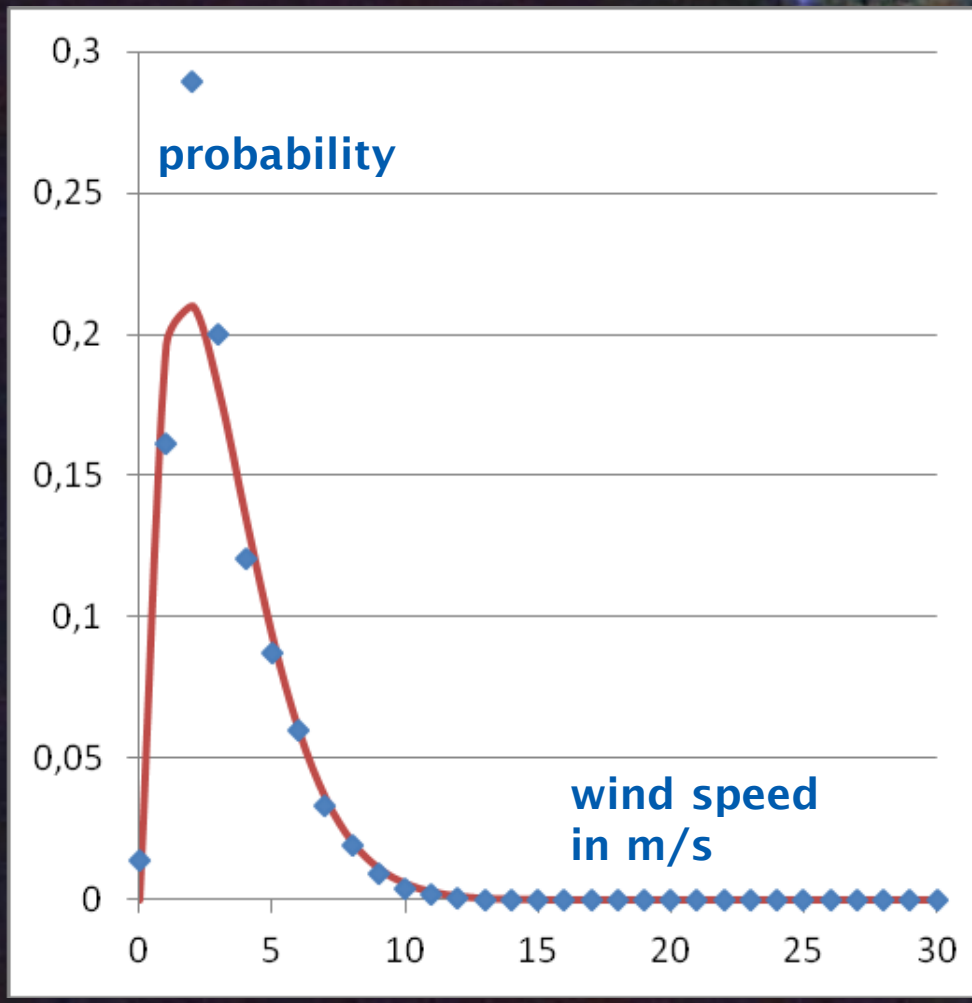
Wind Energy vs. Statistics

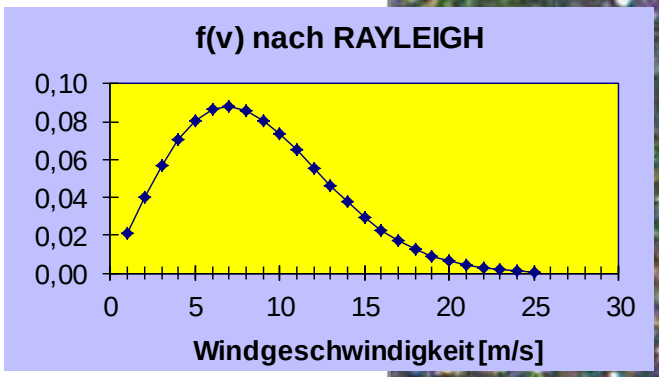


$$f(v_i) = \frac{\pi}{2} \frac{v_i}{v_m^2} e^{-\frac{\pi}{4}\left(\frac{v_i}{v_m}\right)^2}$$

$$f(v_i) = \frac{C}{A}\left(\frac{v_i}{A}\right)^{C-1} e^{-\left(\frac{v_i}{A}\right)^C}$$

Wind Energy vs. Statistics

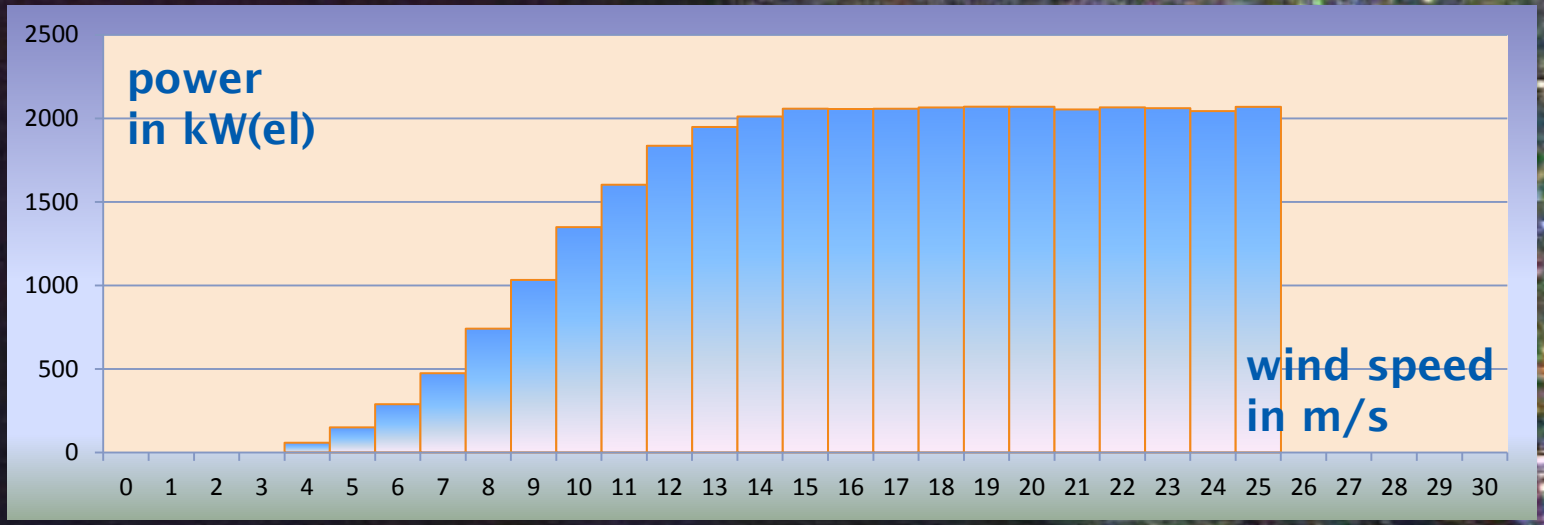




Weibull Statistics

Measurement

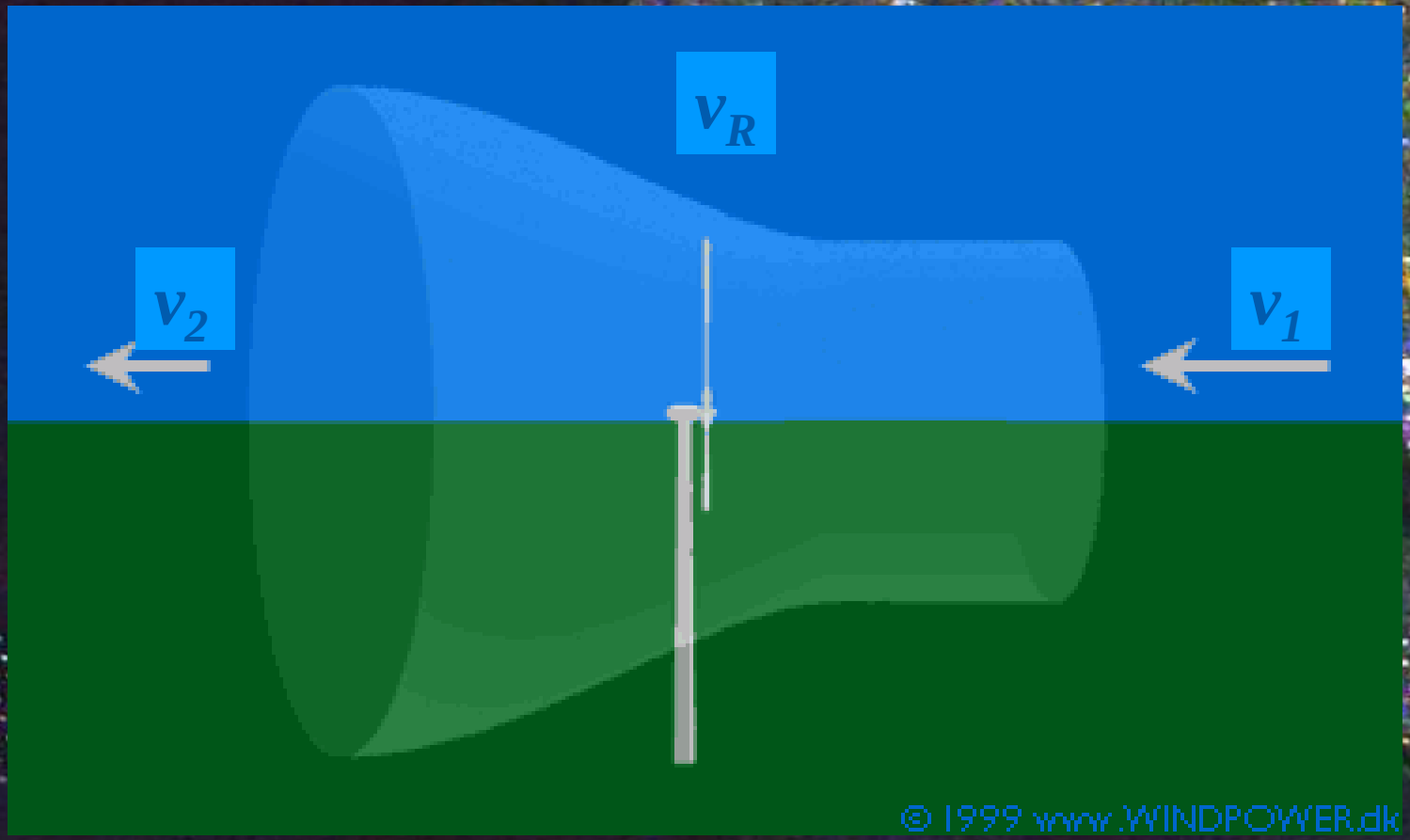
Wind Energy vs. Physics



$$P_{el}(v_i) = 0.5\, c_{p,anl}(v_i)\, A\, \rho\, v_i^{\,3}$$

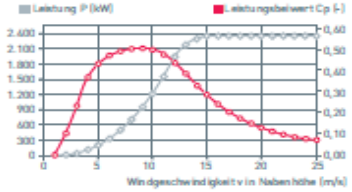
$$W_{el,a} = \sum_{i=1}^{n} \left(P_{el}[v_i]\, t[v_i]\right) = \sum_{i=1}^{n} \left(0.5\, c_{p,anl}[v_i]\, A\, \rho\, v_i^{\,3}\, t[v_i]\right)$$

Wind Energy vs. Physics



Wind Energy vs. Physics

Berechnete Leistungskennlinie



Wind (m/s)	Leistung P (kW)	Leistungs-beiwert Cp (-)
1	0,0	0,00
2	2,0	0,10
3	18,0	0,27
4	56,0	0,36
5	127,0	0,42
6	240,0	0,46
7	400,0	0,48
8	626,0	0,50
9	892,0	0,50
10	1.223,0	0,50
11	1.590,0	0,49
12	1.900,0	0,45
13	2.080,0	0,39
14	2.230,0	0,34
15	2.300,0	0,28
16	2.310,0	0,23
17	2.310,0	0,19
18	2.310,0	0,16
19	2.310,0	0,14
20	2.310,0	0,12
21	2.310,0	0,10
22	2.310,0	0,09
23	2.310,0	0,08
24	2.310,0	0,07
25	2.310,0	0,06

ρ = 1,225 kg/m³

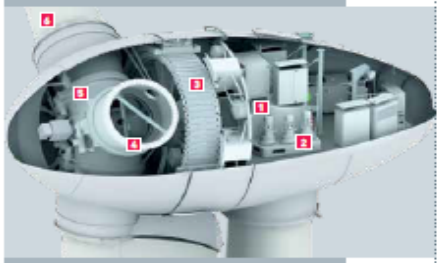
Technische Daten E-70 E4

Nennleistung:	**2.300 kW**
Rotordurchmesser:	**71 m**
Nabenhöhe in Meter:	**57 / 64 / 85 / 98 / 113**
Windzone (DIBt):	**WZ III**
Windklasse (IEC):	**IEC/EN IA und IEC/EN IIA**
Anlagenkonzept:	getriebelos, variable Drehzahl, Einzelblattverstellung
Rotor	
Typ:	Luvläufer mit aktiver Blattverstellung
Drehrichtung:	Uhrzeigersinn
Blattanzahl:	3
Überstrichene Fläche:	3.959 m²
Blattmaterial:	GFK (Epoxidharz); integrierter Blitzschutz
Drehzahl:	variabel, 6 - 21 U/min
Blattverstellung:	ENERCON Einzelblattverstellsystem, je Rotorblatt ein autarkes Stellsystem mit zugeordneter Notversorgung
Antriebsstrang mit Generator	
Hauptlager:	zweireihiges Kegelrollenlager/Zylinderrollenlager
Generator:	direktgetriebener ENERCON Ringgenerator
Netzeinspeisung:	ENERCON Wechselrichter
Bremssysteme:	- 3 autarke Blattverstellsysteme mit Notversorgung - Rotorhaltebremse - Rotorarretierung
Windnachführung:	aktiv über Stellgetriebe, lastabhängige Dämpfung
Abregelwind-geschwindigkeit:	28 - 34 m/s (mit ENERCON Sturmregelung*)
Fernüberwachung:	ENERCON SCADA

*Erläuterungen zur ENERCON Sturmregelung siehe letzte Seite.

E-70

2.300 kW



1 Maschinenträger
2 Azimutantrieb
3 Ringgenerator
4 Blattadapter
5 Rotornabe
6 Rotorblatt

Electricity from the Wind – Example 1

Electricity from the Wind – Repowering Example 1

	Unit	Scenario R	Scenario A	Scenario B	Scenario C
Producer	----	Tacke	Enercon	Enercon	Enercon
Type	----	TW 600	E-82 E2	E-101	E-126 EP4
Rated Power (at NWS)	kW_{el}	600	2,050	3,050	4,200
Nominal Wind Speed	m/s	14	13	13	14
Power Coefficient (at NWS)	----	0.212	0.290	0.283	0.200
Cut-in Wind Speed	m/s	3	3	3	3
Cut-out Wind Speed	m/s	20	25	25	25
Rotor Diameter	m	46	82	101	127
Rotor Area	m^2	1,661	5,281	8,012	12,668
Hub Height	m	52	138	135	135
List of Power Coefficients	----	Catlg. Copy	Int. Catalog	Int. Catalog	Int. Catalog
Air Density (Ref. Air)	kg/m^3	1.225	1.225	1.225	1.225
Air Pressure (Ref. Air)	Pa	$1.013*10^5$	$1.013*10^5$	$1.013*10^5$	$1.013*10^5$
Number of Turbines	----	9	2	1	1
Technical Availability	----	0.96	0.99	0.99	0.99
Wind Farm Factor	----	0.95	0.98	1.00	1.00
Roughness of the Ground	m	0.25	0.25	0.25	0.25
Shift	m	0.0	0.0	0.0	0.0
Hellmann Exponent	----	0.22	0.21	0.21	
Weibull Shape Factor	----	2.0	2.0	2.0	2.0

Electricity from the Wind – Repowering Example 1

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Shift	m	0.0	0.0	0.0	0.0
Hellmann Exponent	----	0.22	0.21	0.21	
Weibull Shape Factor	----	2.0	2.0	2.0	2.0

Electricity from the Wind – Example 2

2002

Electricity from the Wind – Simulation

Übersicht Energieertrag

WEA

Leistung

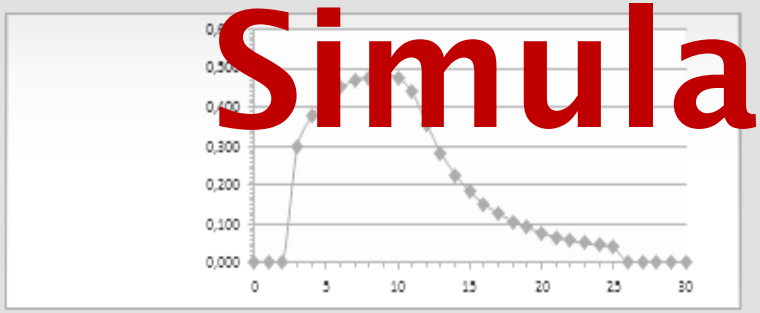
Betrieb

Jahresbilanze

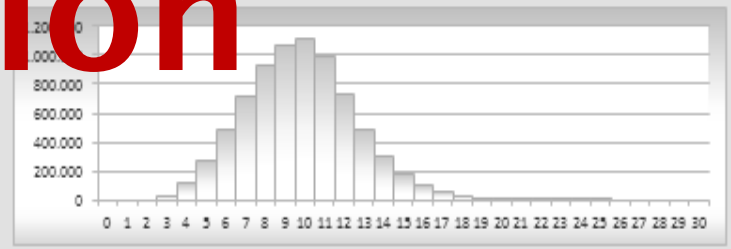
Anlagenbeiwerte

Horns Rev, Dänemark - Offshore

Anzahl der WEA:	**80**
WEA Spezifikation:	**Vestas V80 2MW**
Gesamt-Nennleistung:	**160 MW**
Jährlicher Energieertrag:	**600 GWh**
CO_2 Einsparung/Jahr	**400 000 t**



Energieertrag



Simulation

THANK YOU FOR YOUR ATTENTION

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