The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Workshop on "Physics for Renewable Energy"
October 17 - 29, 2005

301/1679-26

"Wind Energy"

L. Pirozzi
ENEA- Centro Ricerca della Casaccia
S. Maria di Galeria, Rome
Italy

The Abdus Salam
International Centre for Theoretical Physics

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Workshop on *'Physics for Renewable Energy'*
October 17 - 29, 2005

(tel: +39 040 2240227, fax: +39 040 2240558,
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Venue: ICTP Adriatico Guest House - Kastler Lecture Hall

WIND ENERGY

- ***Wind resource - technology - industry - economics***
- ***Wind application - deployment – market: stimulation and constraints***

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Wind resource

Wind resource is the basis of all wind energy developments

About 1 to 2 per cent of the energy coming from the sun is converted into wind energy

Temperature Differences Drive Air Circulation

Wind blows in all countries of the world: onshore and offshore

Wind resource
Wind energy's strategic potential

- **Define the climatic and physical characteristics**
- **Estimate the space available**
- **Estimate the energy yield which can be derived**

Wind energy

Energy in the Wind: Air Density and Rotor Area

The Power of the Wind: Cube of Wind Speed

$$P=\rho/2.c_p.\ \eta.A.v^3$$

P = Air density (kg/m^3)

C_p= Power coefficient

ŋ = Mechanical/electrical efficiency

A = Rotor disk area

V^3 = Wind speed

Wind Speed Measurement: Anemometers

Quality Anemometers are a necessity for wind energy measurement

Wind Speed Measurement in Practice: Tower, Data Logging, Arctic

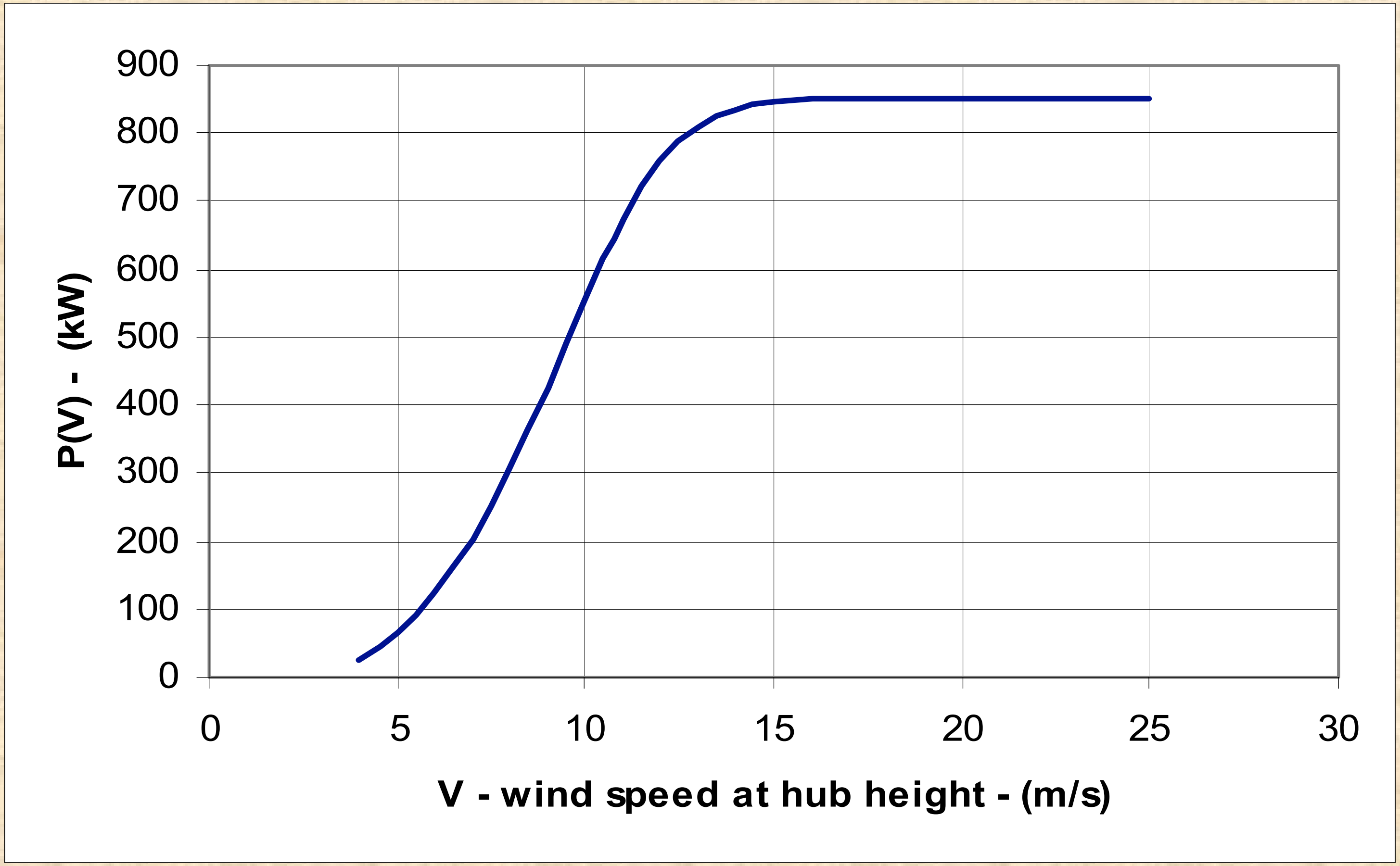
Conditions, 10 Minute Averages

Wind energy

Availability = 98%

Capacity factor = 0.20-0.50

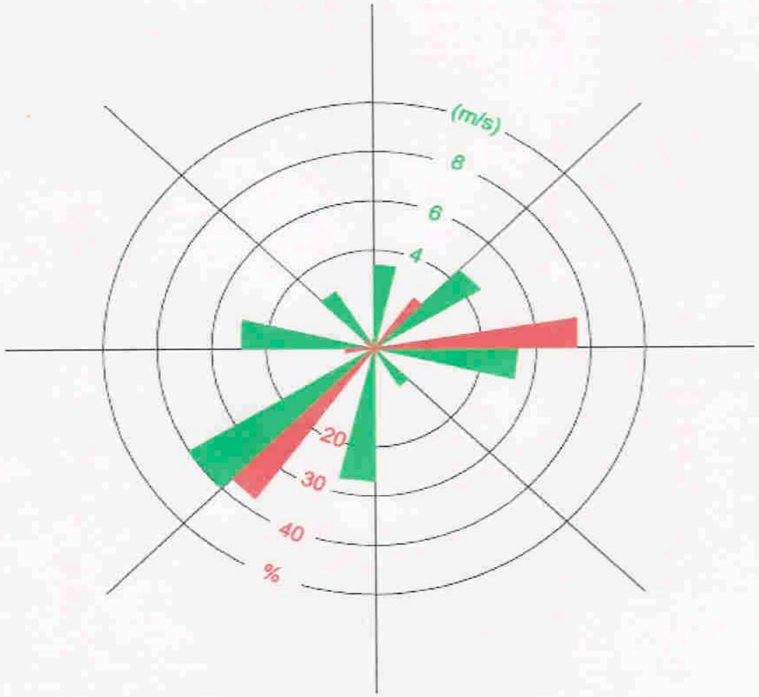
Power curve (Vestas V-52 850 kW)



Wind rose

Stazione anemometrica di Prati Tenetra (AN)

Direzione	fi %	Vm
Nord	1,9	3,4
N-E	12,6	4,6
Est	37,8	5,3
S-E	1,1	1,8
Sud	1,7	5,4
S-O	37,6	8,0
Ovest	5,3	6,5
N-O	2,1	2,7

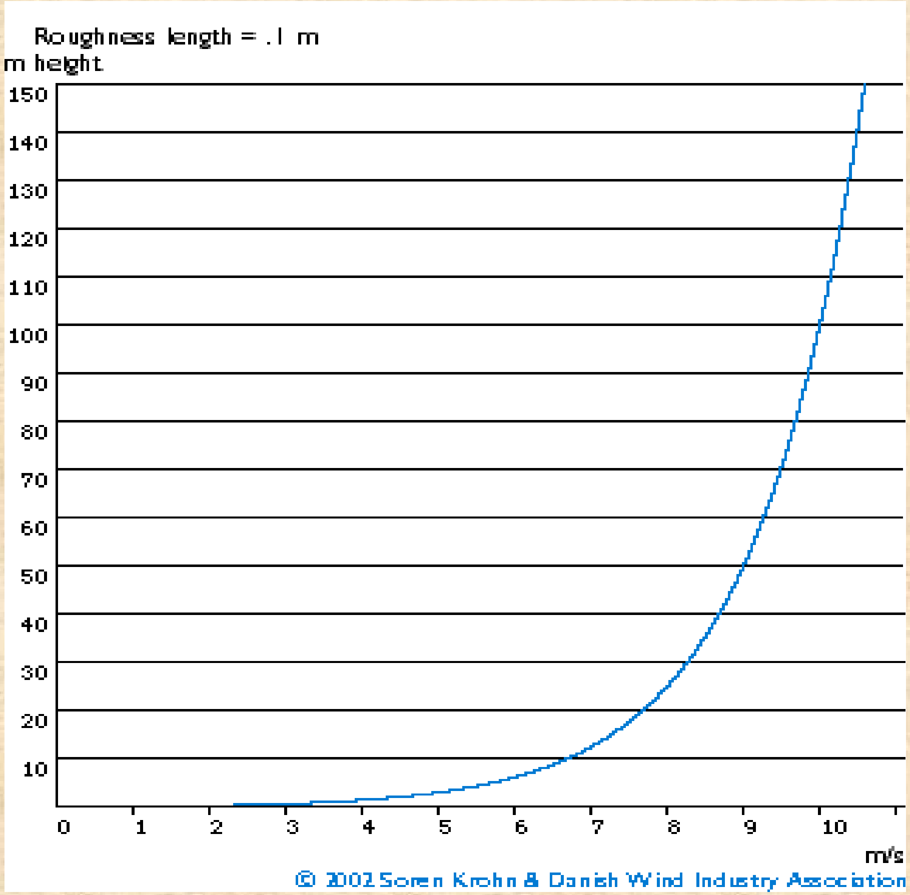


Roughness and Wind Shear

Roughness

Roughness Classes and Roughness Lengths

Wind Shear



Wind Speed Variability

Short Term Variability of the Wind Diurnal (Night and Day) Variations of the Wind

Turbulence

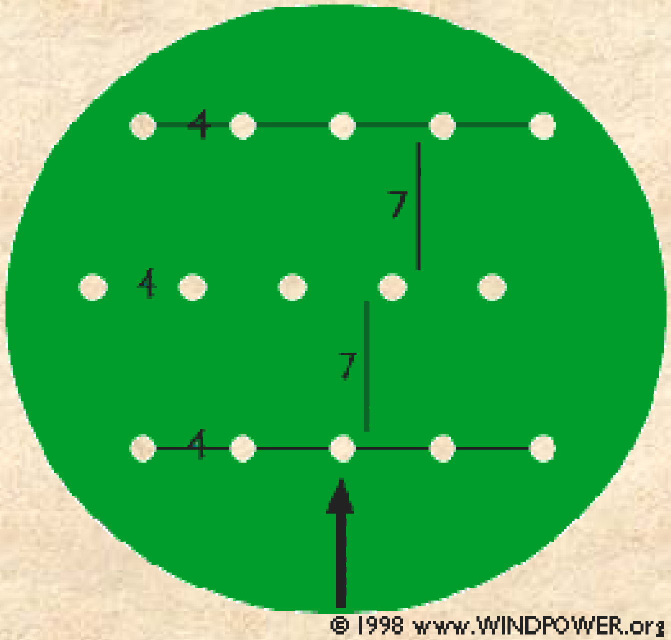
In areas with a very uneven terrain surface, and behind obstacles such as buildings there is a lot of turbulence

Turbulence also imposes more fatigue loads

Park Layout

Energy Loss from the Park Effect

Typically, the energy loss will be somewhere around 5 per cent.



Updated 1 June 2003

http://www.windpower.org/en/tour/wres/park.htm

Speed Up Effects

Tunnel Effect

The air becomes compressed on the windy side of the buildings or mountains, and its speed increases considerably between the obstacles to the wind. This is known as a "tunnel effect“

Hill Effect

A common way of siting wind turbines is to place them on hills or ridges overlooking the surrounding landscape. In particular, it is always an advantage to have as wide a view as possible in the prevailing wind direction in the area. On hills wind speeds are higher than in the surrounding area

Offshore Wind Conditions

Wind Conditions at Sea

Low Wind Shear Means Lower Hub Height

Low Turbulence Intensity = Longer Lifetime for Turbines

Wind Shade Conditions at Sea

Technology

Challenge of modern wind technology:

Producing cost competitive energy through good quality electricity output

Maintenaing a good feeling with the environment

Development of design tools

The unique aspects of wind technology

A remarkable achievement

Size, performance, availability and reliability

Design styles

Horizontal and vertical axes

Number of blades

Pitch or stall control

- **Continuous movement of the blade at fairly high speed.**
- **Regulation at rated and below rated power.**
- **Active stall.**

Variable speed design

Reduce noise, reduce loads and improve energy output

Main components

Rotor

Two or three blades (three more frequent)

Hub

Gear-box

Some configurations are gearless

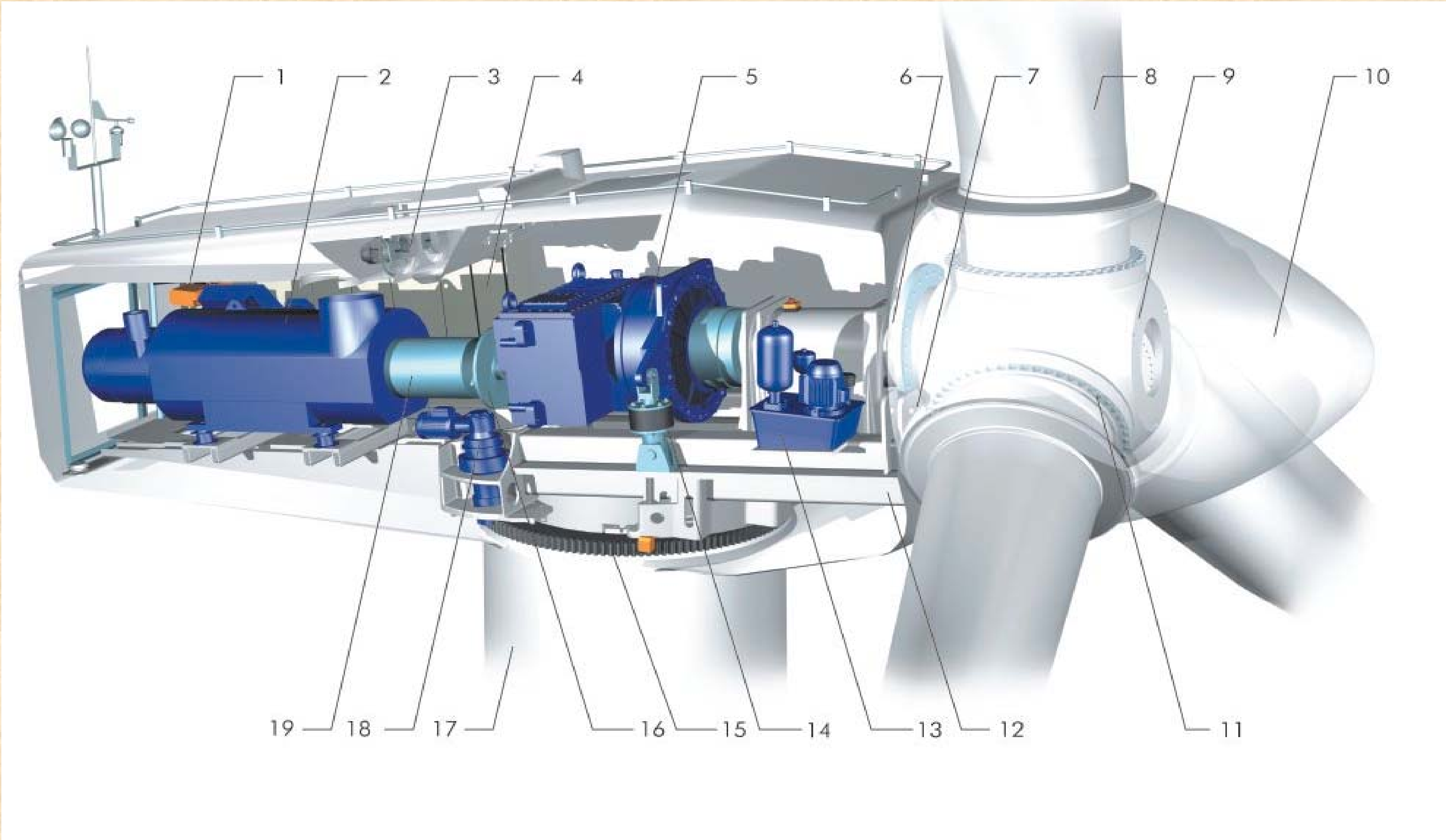
Generator

Tower

Main components

V52 - 850 kW

1. Service crane
2. OptiSpeed™-generator
3. Cooling system
4. VMP-top controller with converter
5. Gearbox
6. Main shaft
7. Rotor lock system
8. Blade
9. Blade hub
10. Spinner
11. Blade bearing
12. Machine foundation
13. Hydraulic unit
14. Gear torque arm
15. Yaw ring
16. Brake
17. Tower
18. Yaw gear
19. Composite disc coupling



Why chose V52-850

Vestas next medium sized turbine well suited for complex terrain.

Easy transport.

Natural update of V47.

Optispeed instead of OptiSlip. 60% speed variation.

Optispeed means

Grid flexibility: Import - Export of reactive power.

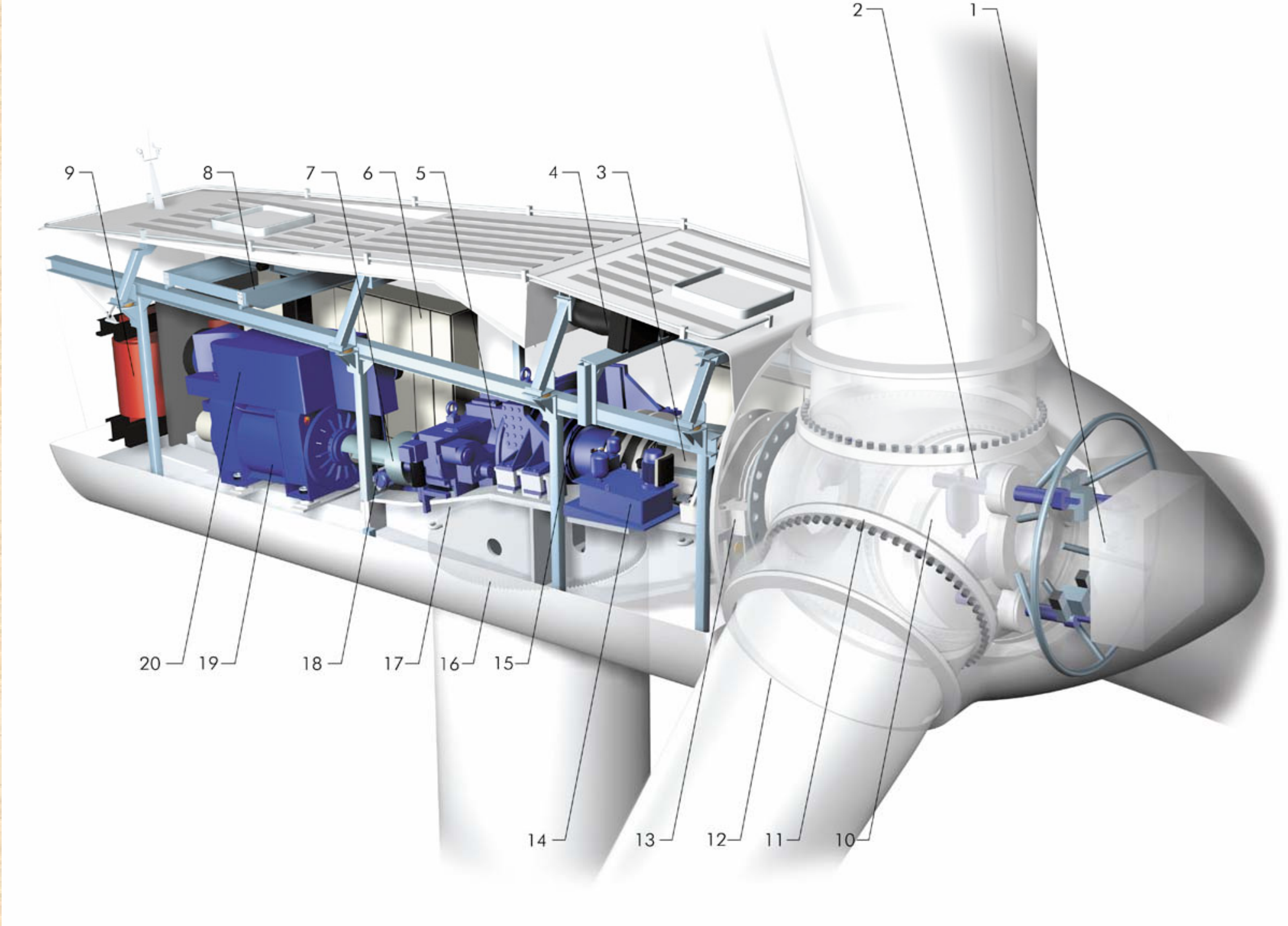
Noise optimization.

Better production at low wind speed.

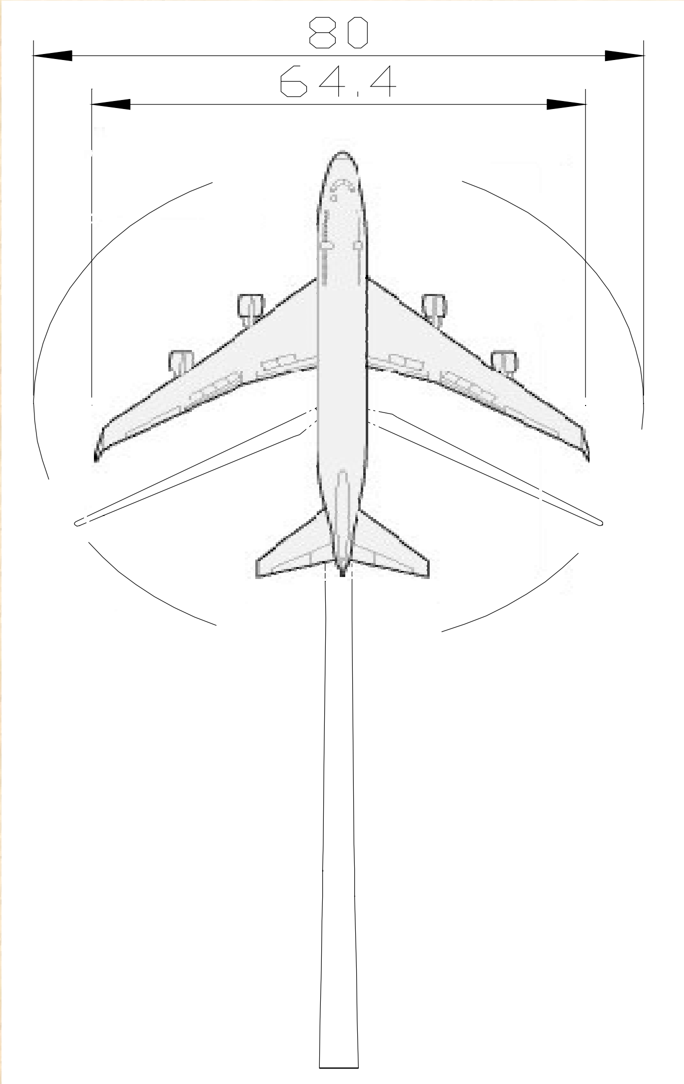
Based on many years of experience with medium sized turbine in complex terrain.

V80 - 2.0 MW

1. Hub controller
2. Pitch cylinder
3. Main shaft
4. Oil cooler
5. Gearbox
6. VMP-Top control
   with converter
7. Parking break
8. Service crane
9. Transformer
10. Blade hub
11. Blade bearing
12. Blade
13. Rotor lock system
14. Hydraulic unit
15. Hydraulic shrink disc
16. Yaw ring
17. Machine foundation
18. Yaw gears
19. Optispeed™-generator
20. Generator cooler

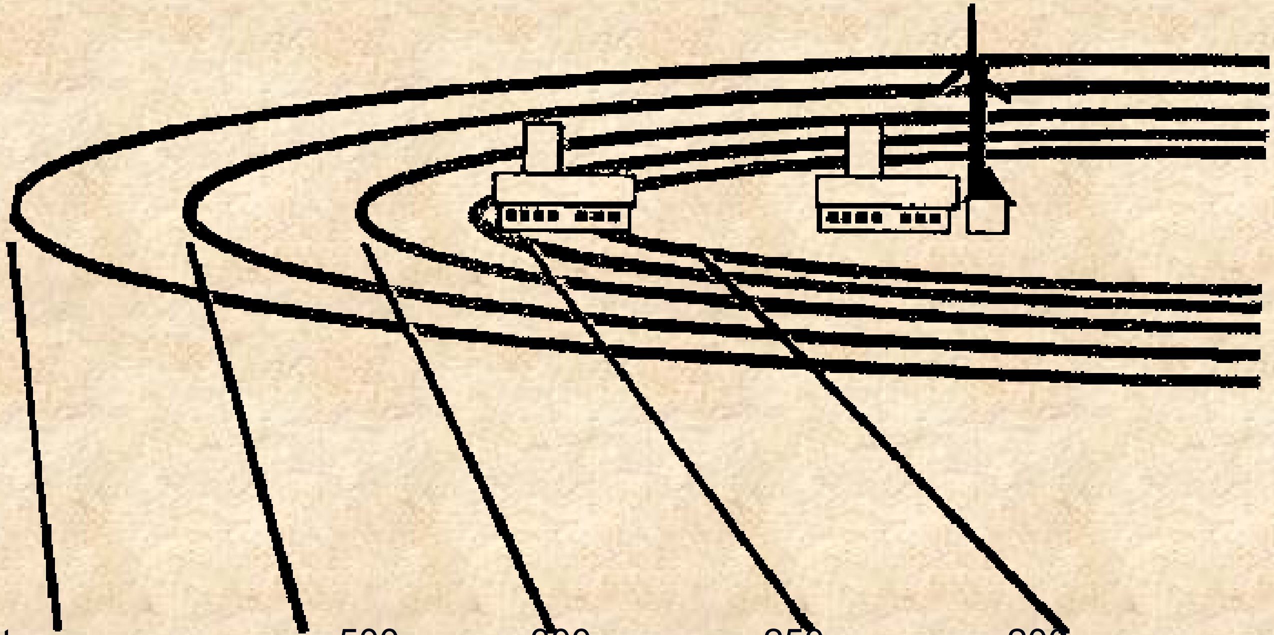


How big is a V80



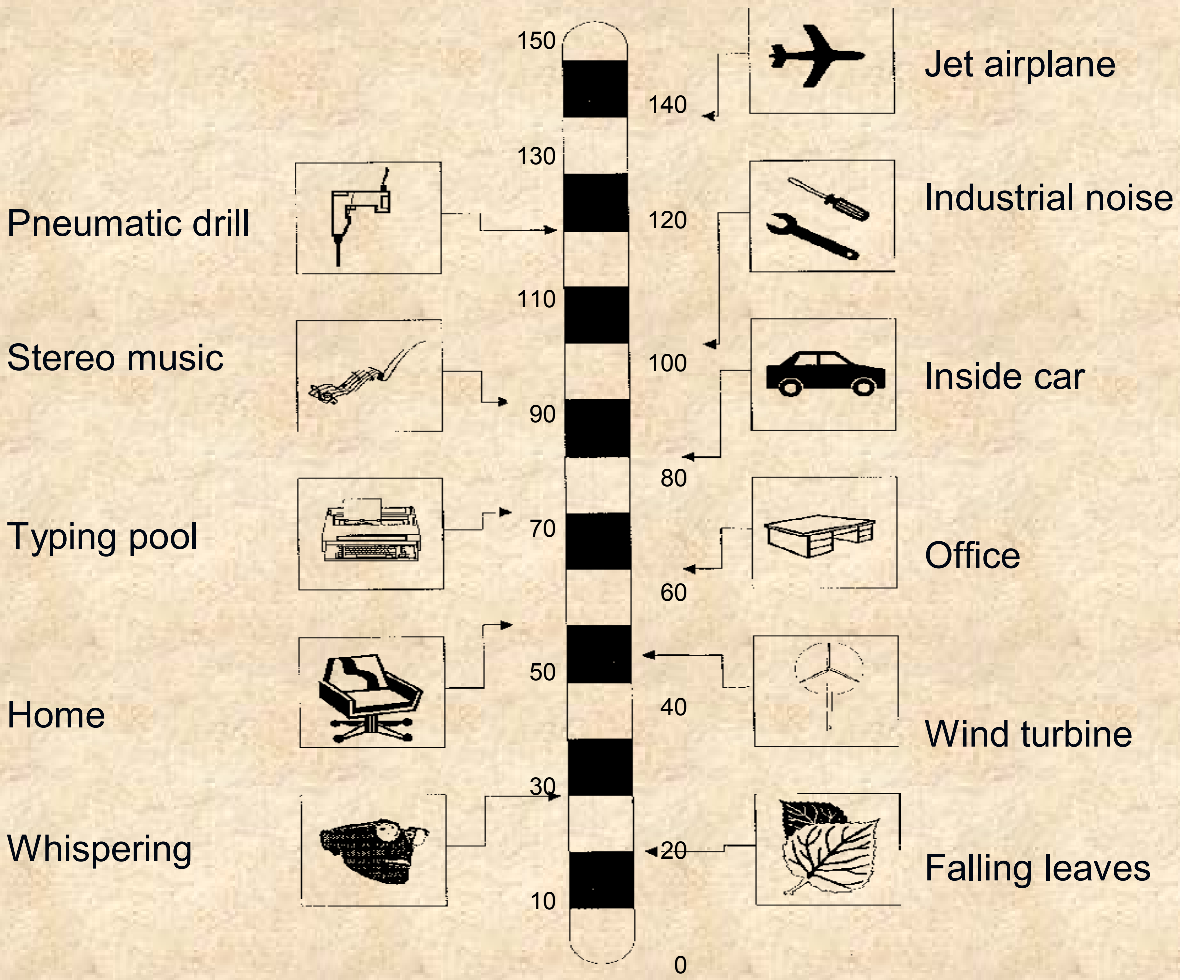
This picture shows how big a V80 2.0 MW is compared with a Boeing 747 400 Jumbo Jet

Noise level around a wind turbine



distance	500 m	300 m	250 m	200 m
660 kW turbine:	37.4 dBA	42.7 dBA	44.4 dBA	46.5 dBA
1650 kW turbine:	37.9 dBA	43.2 dBA	44.9 dBA	47.0 dBA

Noise emission from different sources



Present technology

Small wind turbines

<100 kW rotor diameter <20 m

Medium wind turbines

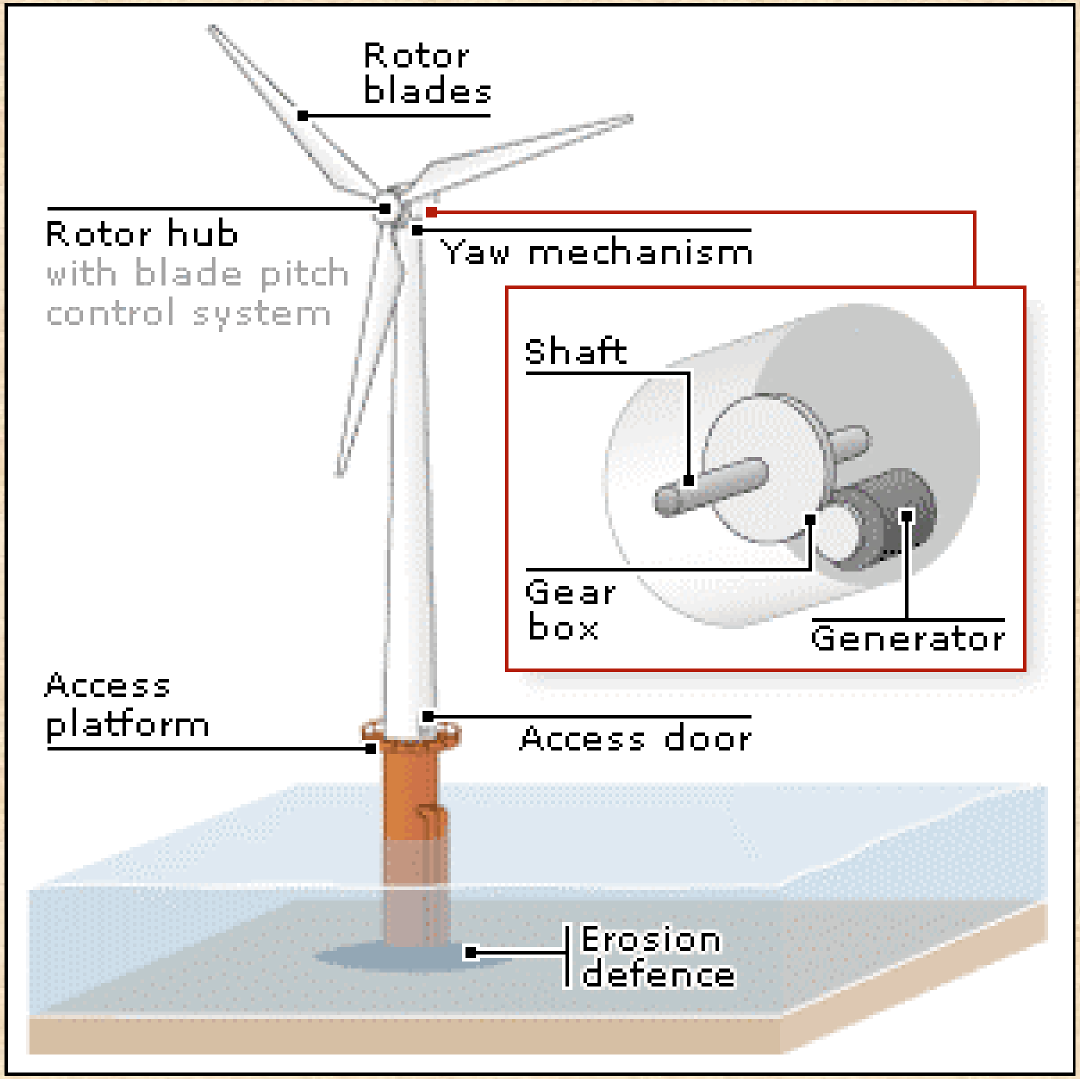
100 – 1000 kW rotor diameter 20 m – 55 m

Large wind turbines

>1000 kW rotor diameter >55 m

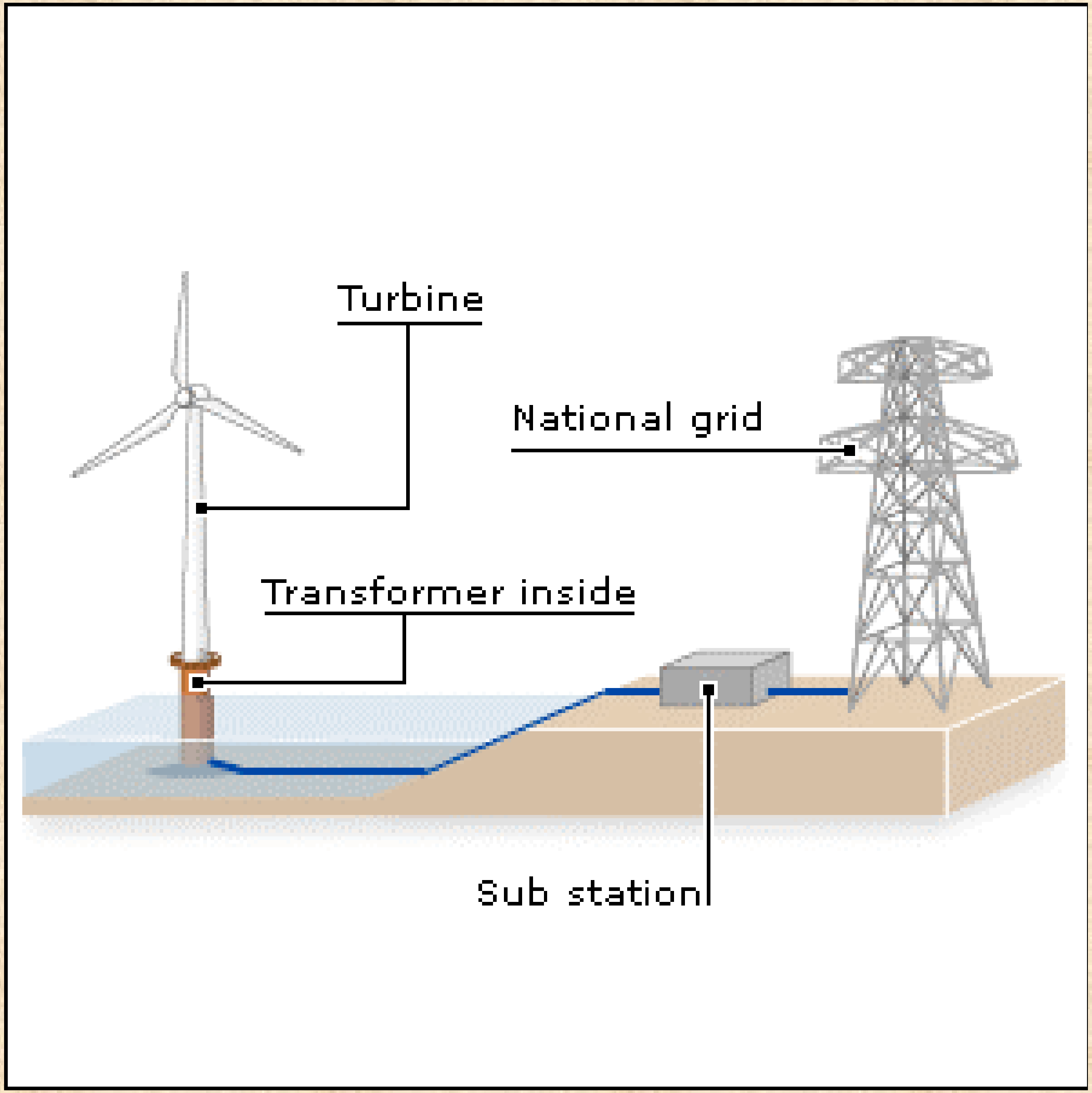
Offshore

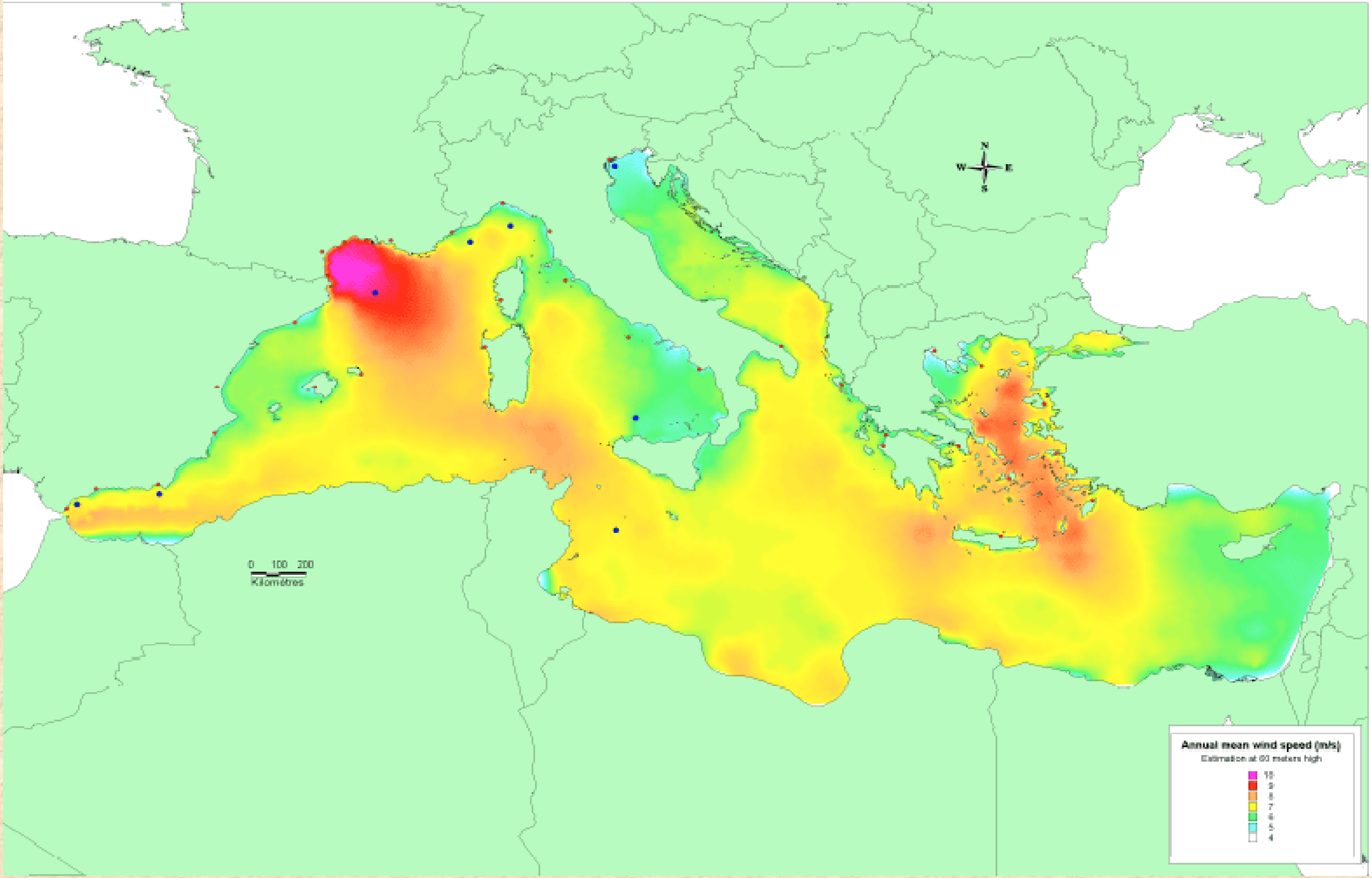
Offshore

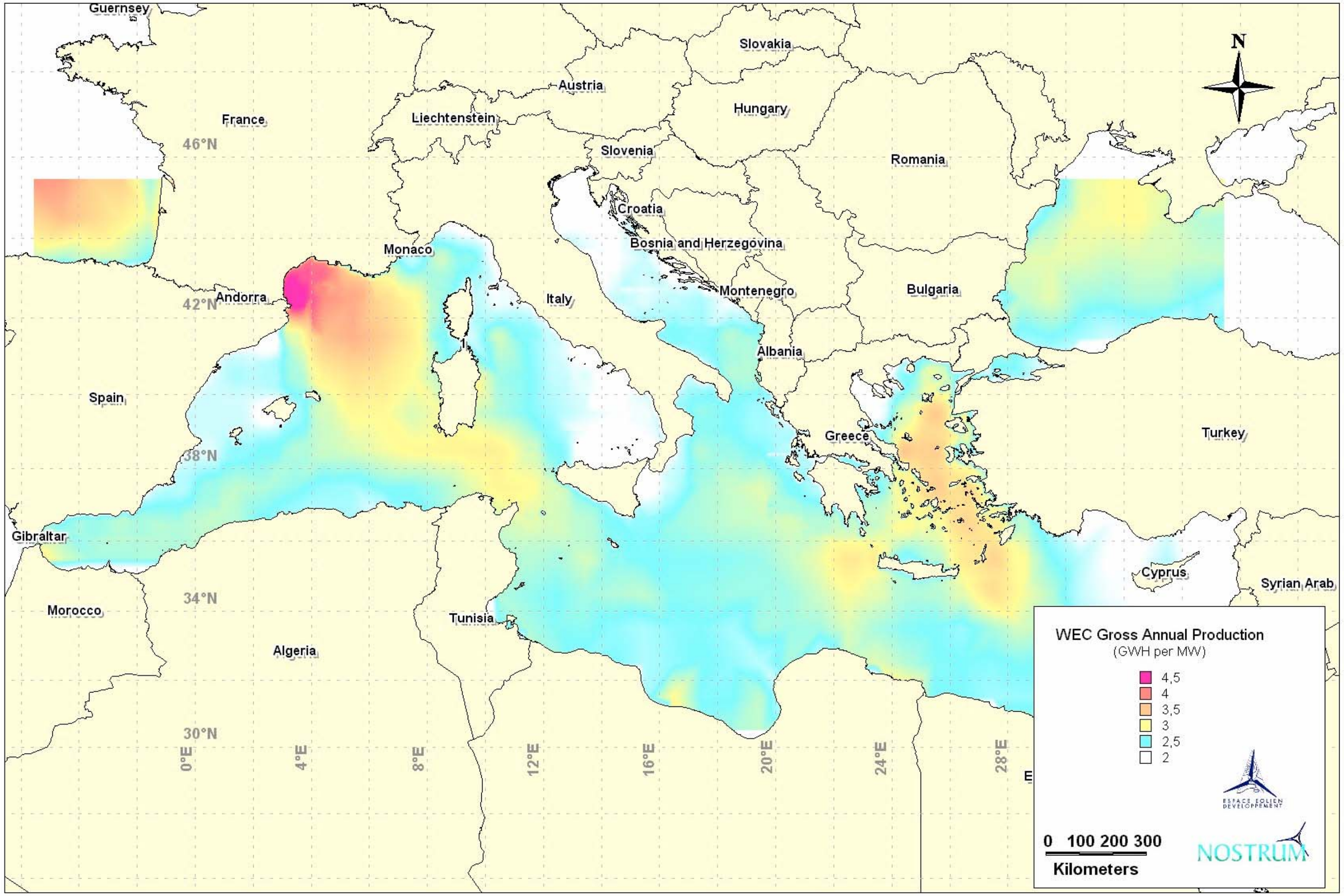


Rotor blades
Rotor hub
with blade pitch control system
Yaw mechanism
Shaft
Gear box
Generator
Access platform
Access door
Erosion defence

Offshore




N
W
E
S
0 100 200
Kilomètres
Annual mean wind speed (m/s)
Estimation at 60 meters high
10
9
8
7
6
5
4


WEC Gross Annual Production
(GWH per MW)
4,5
4
3,5
3
2,5
2
0 100 200 300
Kilometers
ESPACE EOLIEN DEVELOPPEMENT
NOSTRUM
N
Guernsey
Slovakia
Austria
Hungary
France
Liechtenstein
Slovenia
Romania
Croatia
Bosnia and Herzegovina
Monaco
Andorra
Italy
Montenegro
Bulgaria
Albania
Spain
Greece
Turkey
Gibraltar
Cyprus
Syrian Arab
Morocco
Tunisia
Algeria
46°N
42°N
38°N
34°N
30°N
0°E
4°E
8°E
12°E
16°E
20°E
24°E
28°E

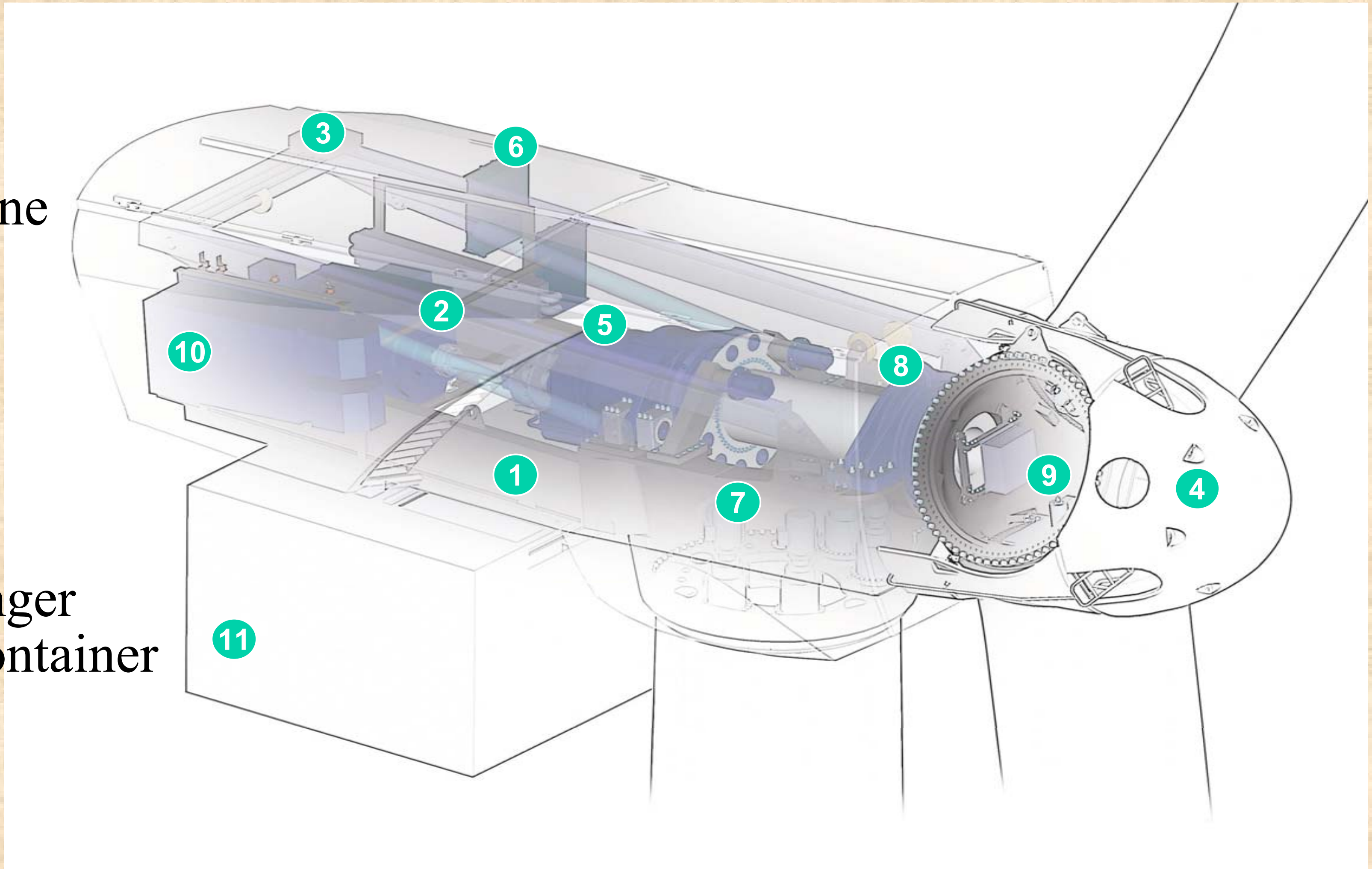

60 MW Offshore wind farm North Hoyle (UK)
30 Vestas 2 MW V-80 turbines

GE Energy 3.6s Offshore

•Model	•3.6s Offshore
•Type Approval	•IEC TC IIA / TC IB
•Rotor Diameter	•104 m
•Rated Capacity	•3.6 MW
•Hub Height	•optional
•Rotor speed	•9.2 – 15.3 U/min
•Power Control	•pitch - control

3.6s Offshore Drawing

1 •Main frame
2 •Generator
3 •Internal Crane
4 •Nose cone
5 •Gearbox
6 •Oil cooler
7 •Yaw drive
8 •Rotor shaft
9 •Pitch drive
10 •Heat exchanger
11 •Offshore Container



Industry - New turbines

Industrial development focused on upsizing and refining the 2 MW plus class of turbines and adapting them to offshore use

Several prototypes are gearless and have a large permanent magnet generator

The wind power generator Leitwind 1.2 MW, is an Italian prototype of the megawatt class. The turbine has three blades, a horizontal axis and a rotor diameter of 62 m.

The following component suppliers carry out additional activities in the Italian wind sector.

- ***ABB-ASI for engines and generators***
- ***Brevini-Bonfiglioli for reduction gears***
- ***Ring Mill for forging***
- ***Colombo-Ariotti for casting***
- ***Magrini-Schneider for transformers***
- ***Pirelli for cables***
- ***Monsud-Leucci-Pugliese for towers***

Industry - New turbines

Aerogenerator Leiwind 1.2 MW

Technical Data LEITWIND 1.2 MW

Producer	LEITNER® AG Italy
IEC Wind Class	1
Maximum Power	1200 kW
Rated Wind Speed	12 m/s
Rotor Diameter	62 m
Hub Height	60 m
Operation Wind Speed on Hub Height	3 - 25 m/s
Life Time	20 years
Type of Blade	LM 29,1P
Power Transmission	Direct Drive (without gear)
Type of Generator	Multipole permanent excited synchronous generator
Tower	Steel, conical

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Industry - New turbines

The Windturbine Leitwind 1.2

- The wind power generator LEITWIND, developed by LEITNER® AG, is a prototype of the megawatt class.

- LEITWIND is designed for wind class I (norm IEC 61400) and for a life of 20 years.

- For three years, a team of 16 persons was occupied with the development of the prototype, representing a total investment of eight million Euros.

Industry - New turbines

Aerogenerator JIMP20

Technical data of the aerogenerator JIMP20

Producer	JONICA IMPIANTI
Rated Power	20 kW
Rated Wind Speed	12 m/s
Rotor Diameter	8 m
Rotor speed	up to 200 rpm
Pitch control	
Blade material and profile	Vinylester resin, glass fibres SG6040-6041
Power Transmission	Direct Drive (without gear)
Type of Generator	Multipole permanent excited synchronous generator
Tower	Steel, 12 m

Industry

Offshore system

Potential

Environment

Acceptance

Infrastructure

Cost

End 2004: almost 600 MW installed

Blades

New materials (now glass polyester or carbon epoxy)

Grid integration

Autonomous systems

Economics

Wind energy prices

Wind energy prices are decreasing continuously. They fell by a factor of four from 1981 to 1996

Items included in energy price:

Planning cost – capital cost of plant - construction costs – interest during construction – land costs – operating costs (O & M), including labour, materials, rents, taxes and insurance) - decommisioning

Value of the global energy market in 2003 and 2004: 8 billion Euros each year

Job creation: more than 150,000

Economics

Current plant costs

Key factors

Installed costs

Turbine prices

Balance of plant costs: foundation costs, electrical interconnection costs, access track

Installed costs and wind speeds

Operational costs

Size of wind farm

Wind energy price

Influence of wind speed

National wind energy prices

Economics

External costs

Hidden costs borne by governments

Costs of damage caused to health

Cost of global warming due to CO_2 emissions

Future price trends

Trend towards larger wind turbines

Falling infrastructure costs

Reduction costs of raw materials

Economics

Conclusions

Wind plant costs have been falling steadily and this trend is likely to continue

No single figure can be assigned to price of wind energy

On best sites, current wind prices are competitive with nuclear and gas plants

External costs of thermal plants need to be taken into account

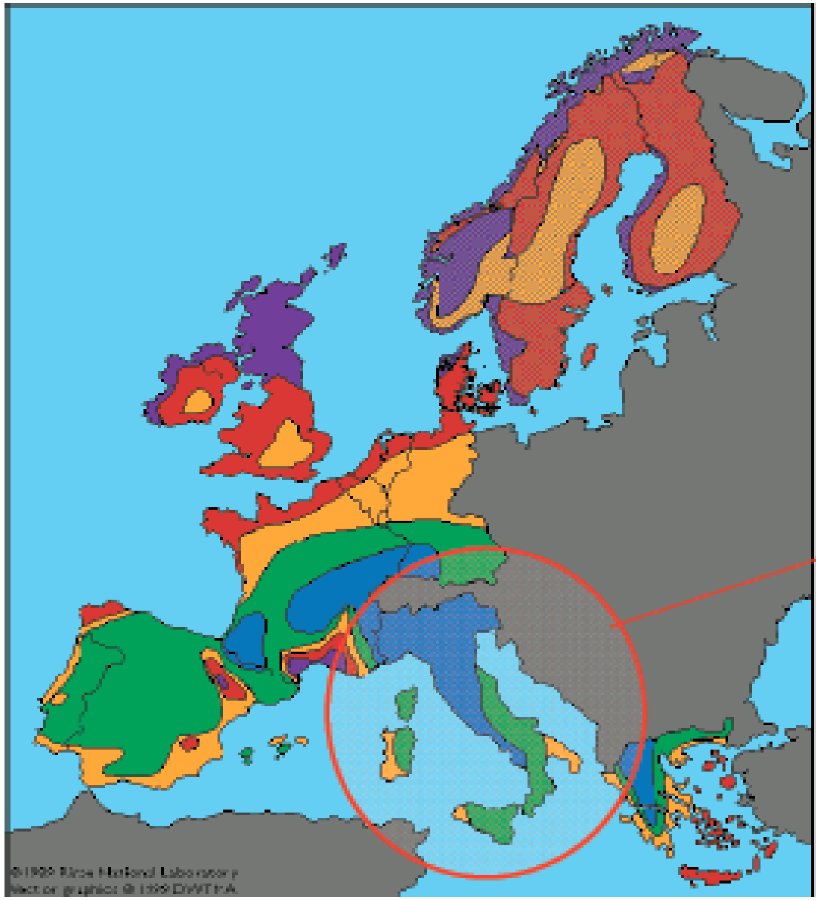
Additional value of wind energy

Offshore wind energy prices are moving down quite rapidly

The MW turbines on the Italian Market

- The Italian wind regime
- Turbines on the Italian market
- The projects in the Italian market
- Choosing the right turbine
- Climatic factors and impact
- Why are the measurements important

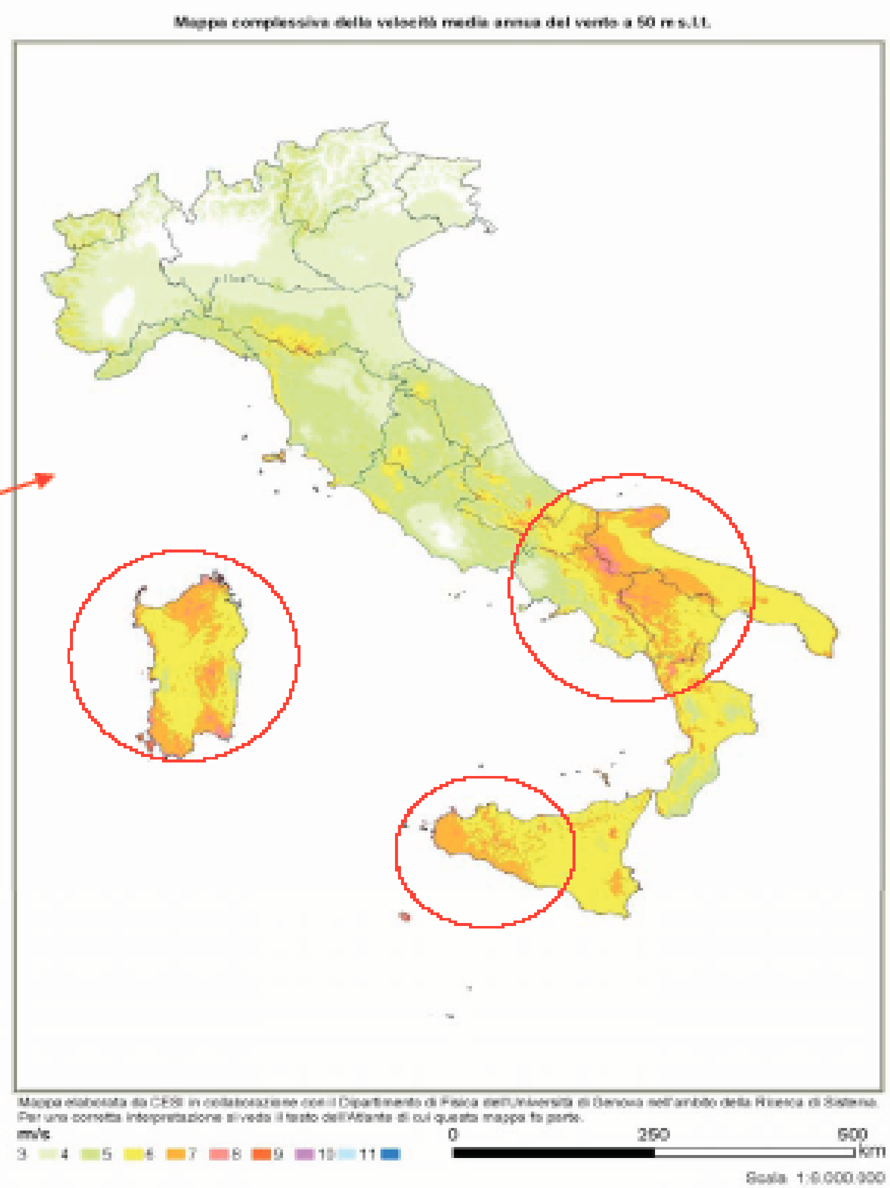
Wind regime of Italy



Wind resources at 50 meters above ground level for five different topographic conditions: 1) Sheltered terrain, 2) Open plain, 3) At a coast, 4) Open sea and 5) Hills and ridges.

	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²
(purple)	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
(red)	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
(orange)	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
(green)	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
(blue)	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400
(purple, hatched)			>7.5							
(red, hatched)			5.5-7.5							
(orange, hatched)			<5.5							

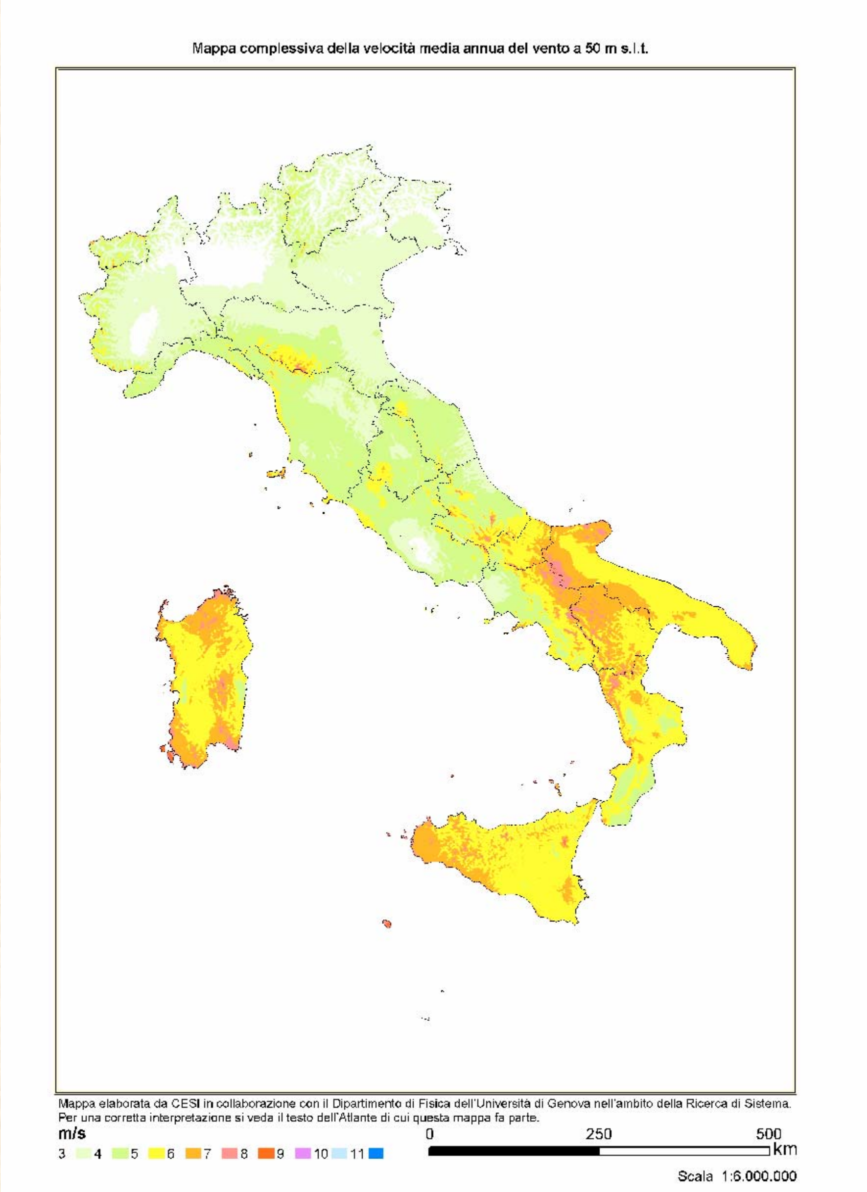
Vector graphics map by courtesy of the Danish Wind Industry Association.

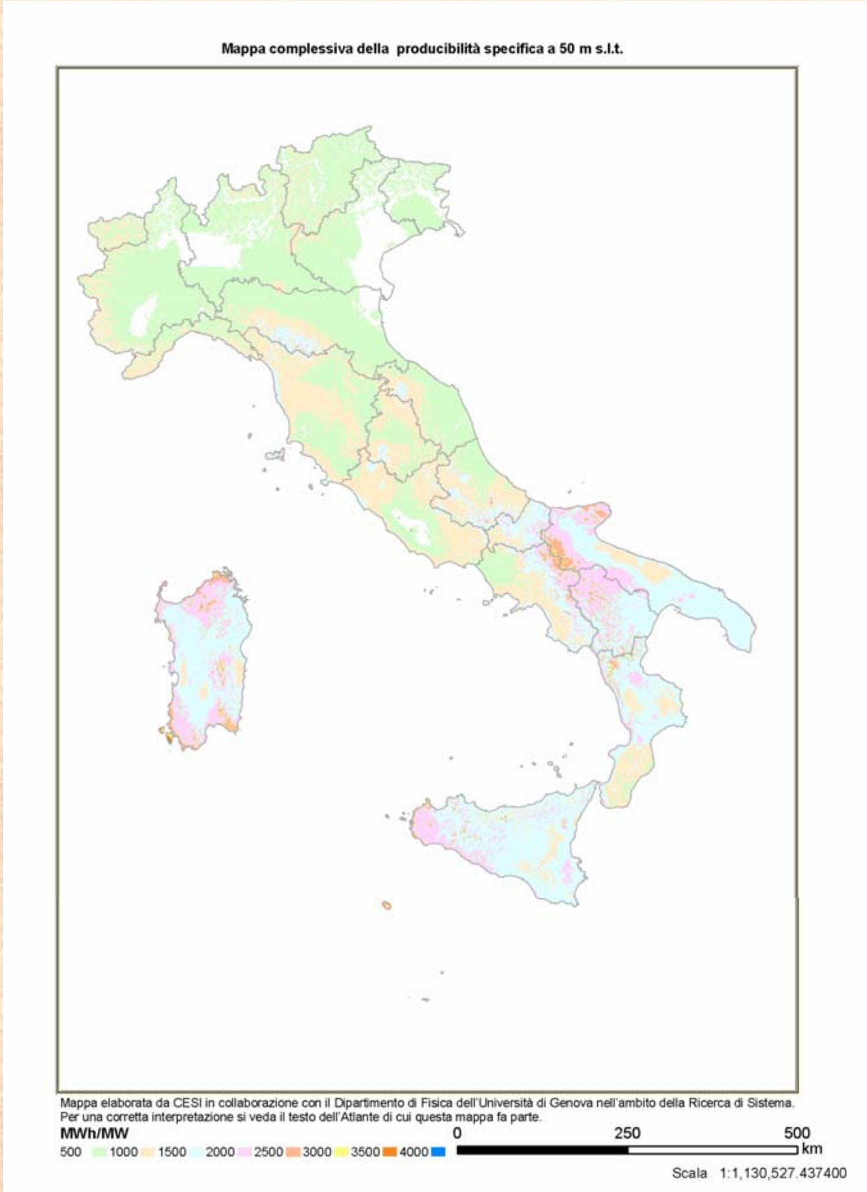


The Wind Atlas of Italy

- **Genoa university obtained preliminary maps by simulating (WINDS) wind flow at various heights on the basis of wind data at 5000 m supplied by met institutes (ECMWF)**
- **CESI adjusted maps by comparison with data measured by 240 wind masts all over Italy**
- **3 series of 27 maps each (1:750,000) giving annual mean wind speeds at 25, 50, 70 m a.g.l.**
- **1 series of maps giving annual energy yields (MWh/MW) of a sample WT with 50 m hub height**
- **Wind Atlas is now published and freely available from www.ricercadisistema.it**

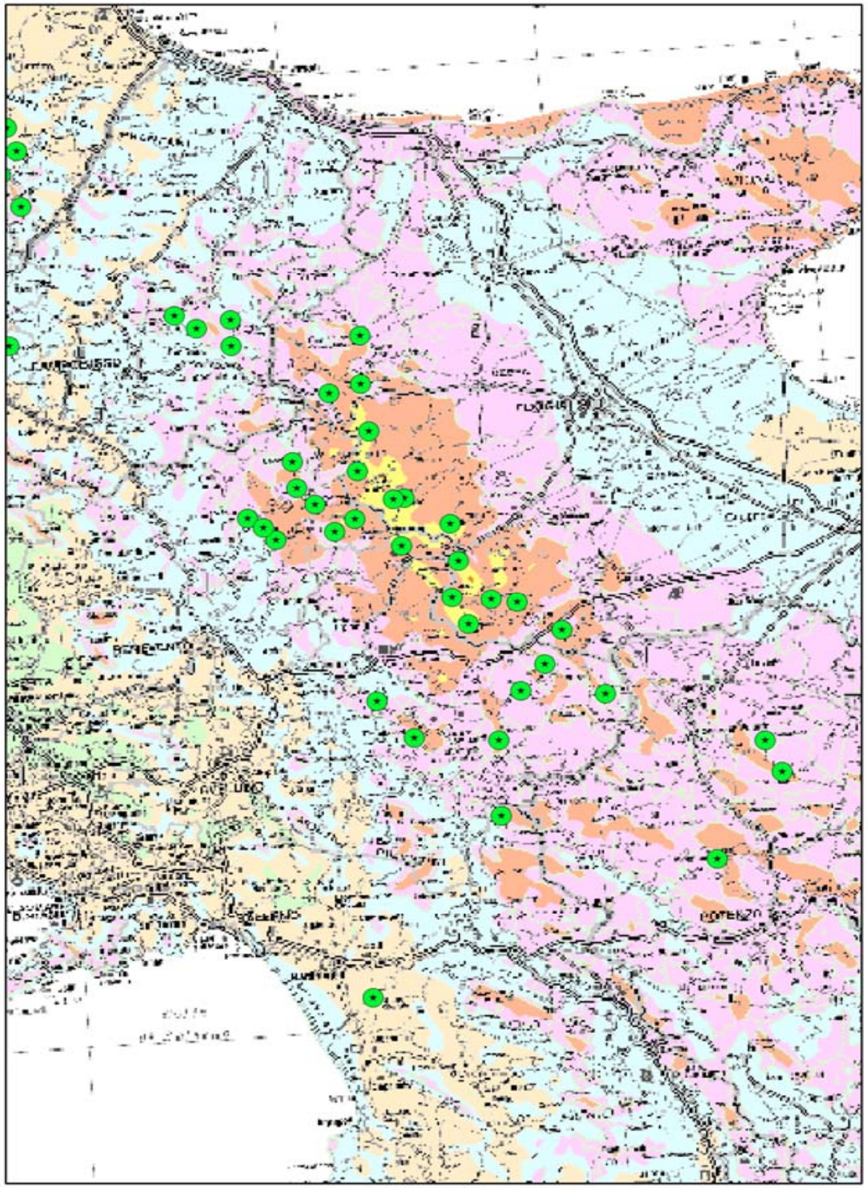
Synthesis Wind Maps at 50 m a.g.l.





CESI

The Wind Atlas and Existing Plants



CESI

Projects

The characteristics of the Italian projects are:

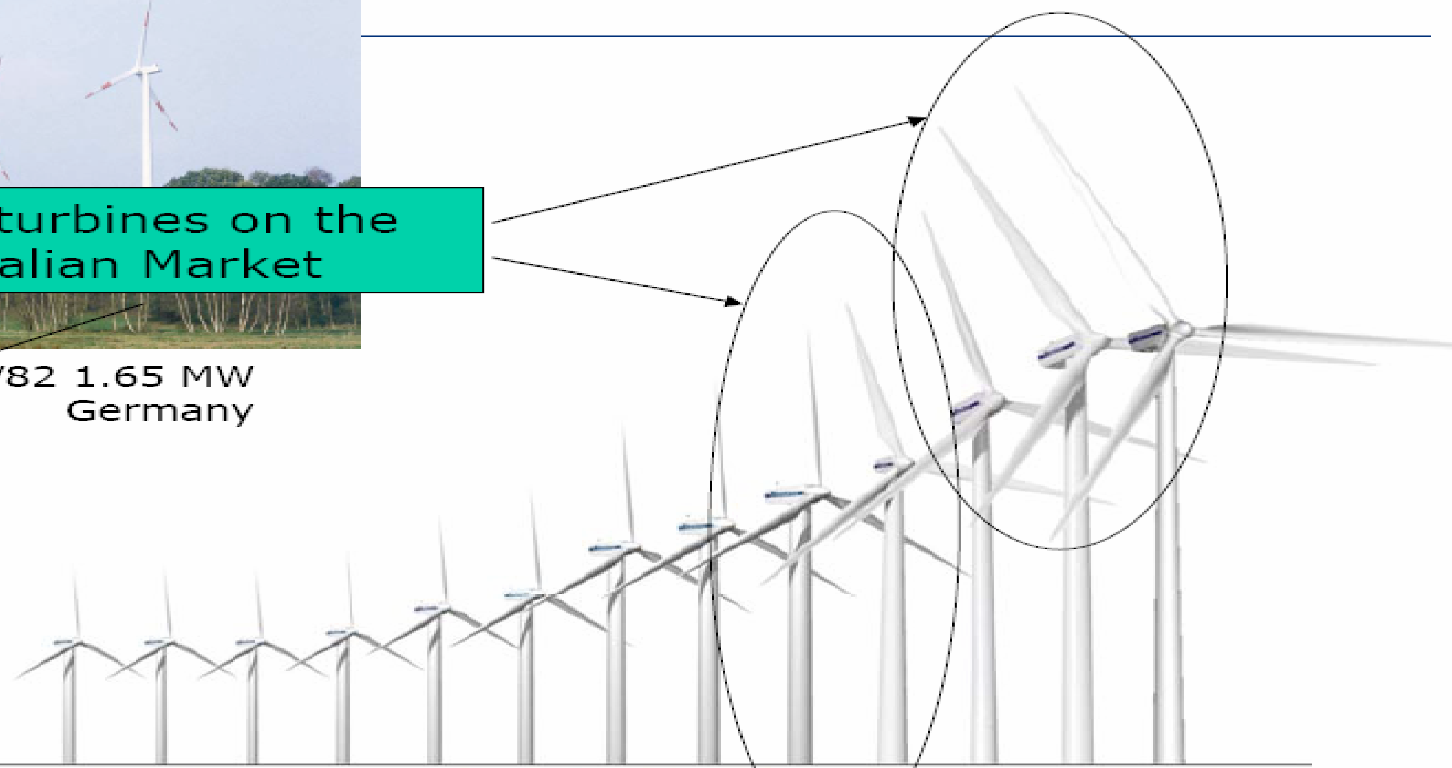
- Located in mountain areas
- Big variation of air density from site to site
- IEC class II sites
- IEC class III sites
- High turbulence
- High temperture

Development of Vestas turbines

The turbines on the Italian Market

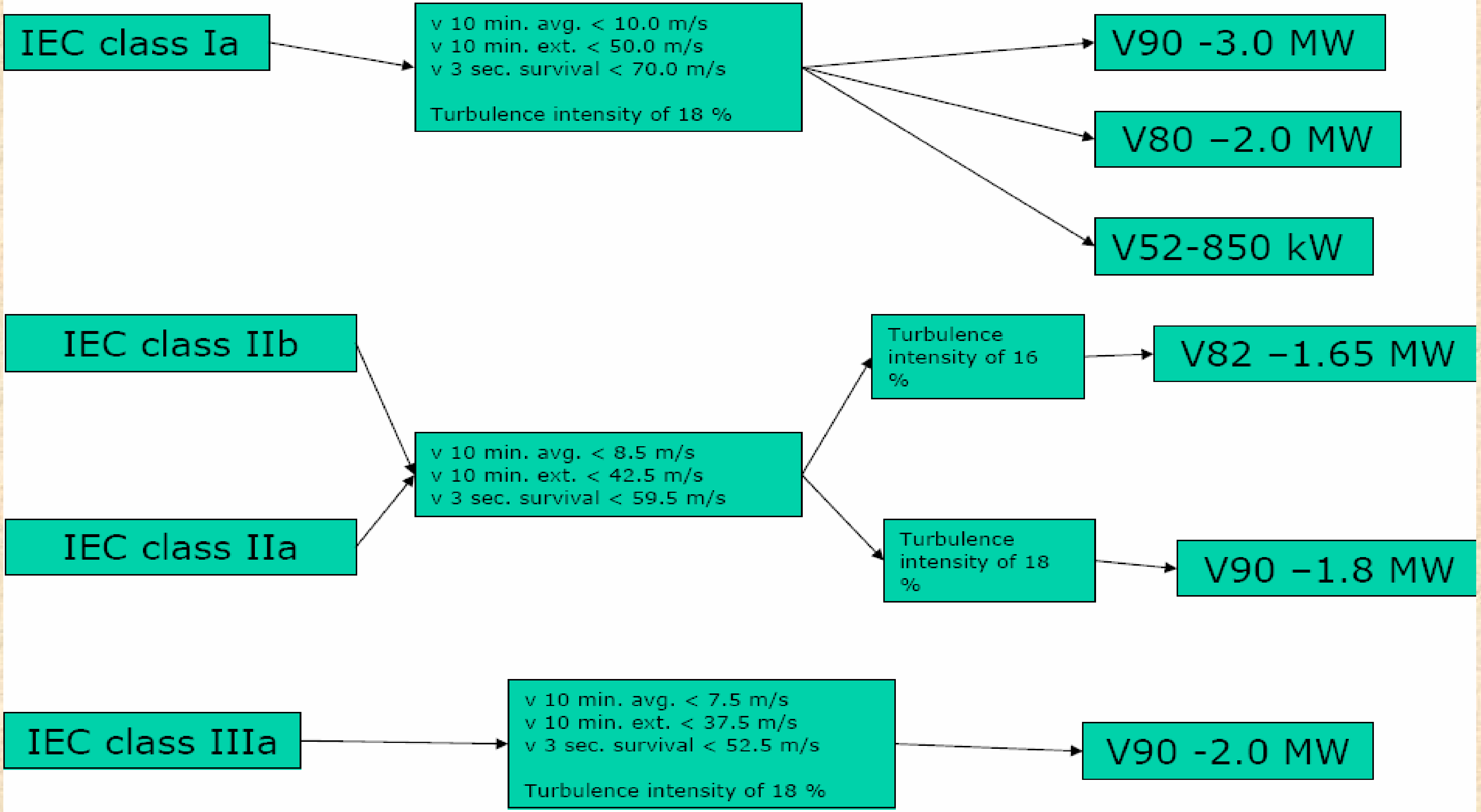
V82 1.65 MW
Germany

V90 -1.8 / 2.0MW
Denmark

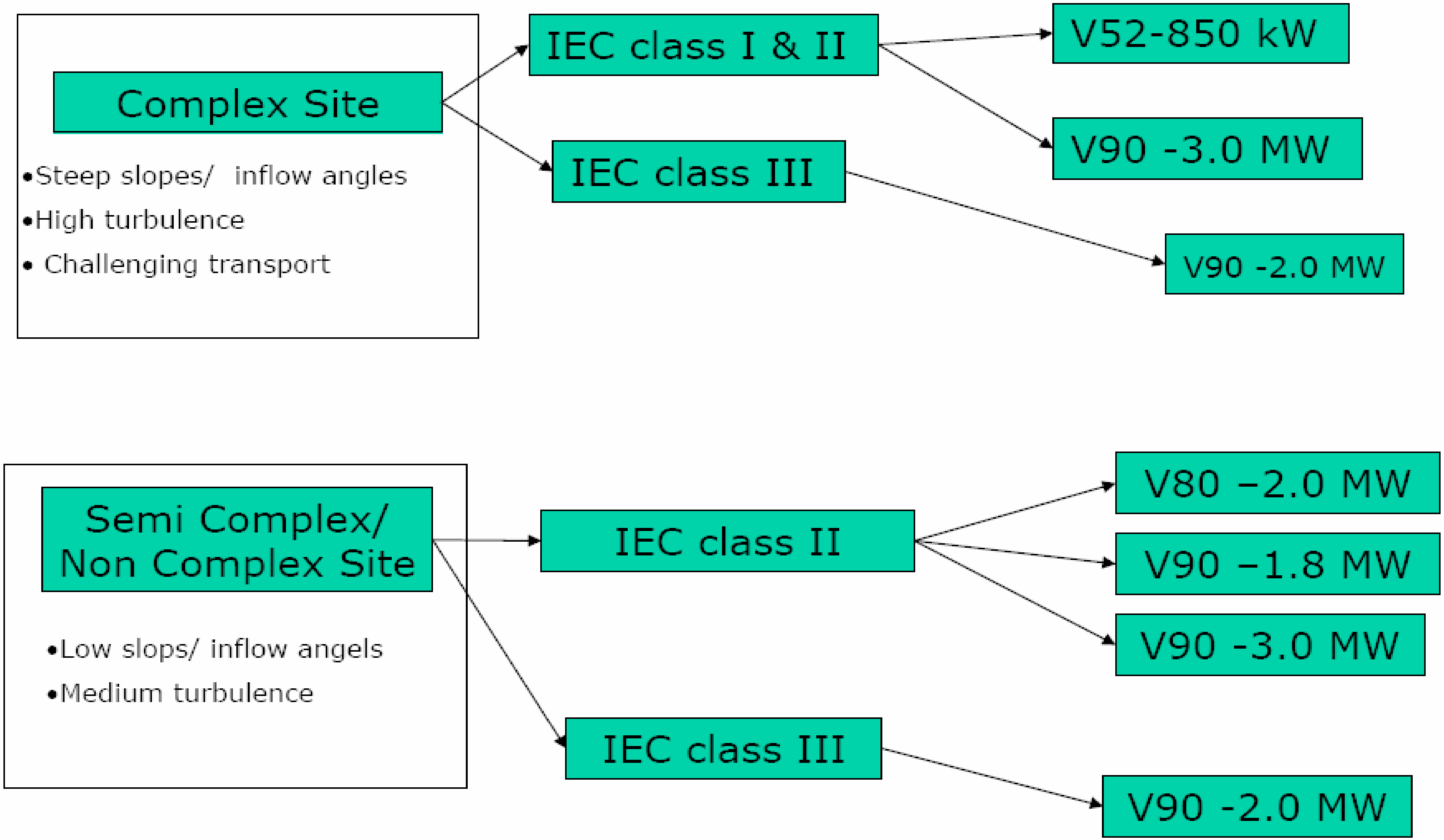


m)	V15	V17	V19	V20	V25	V27	V39	V44	V47	V52	V66	V80	V90
	1981	1984	1986	1987	1988	1989	1991	1995	1997	2000	1999	2000	2002
	55	75	90	100	200	225	500	600	660	850	1750	2000	3000
	217	265	301	346	481	647	1304	1581	1947	2530	4705	6768	–

IEC class of the MW turbines.

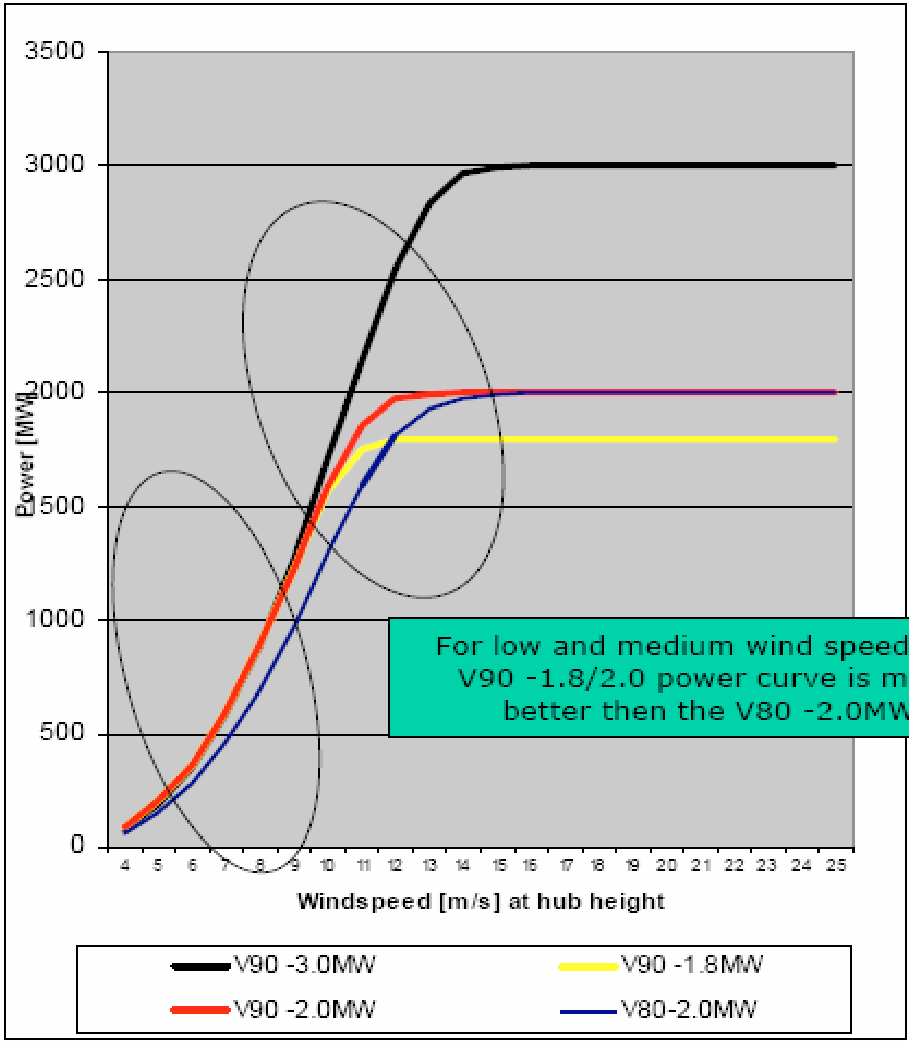


Turbines on the Italian market



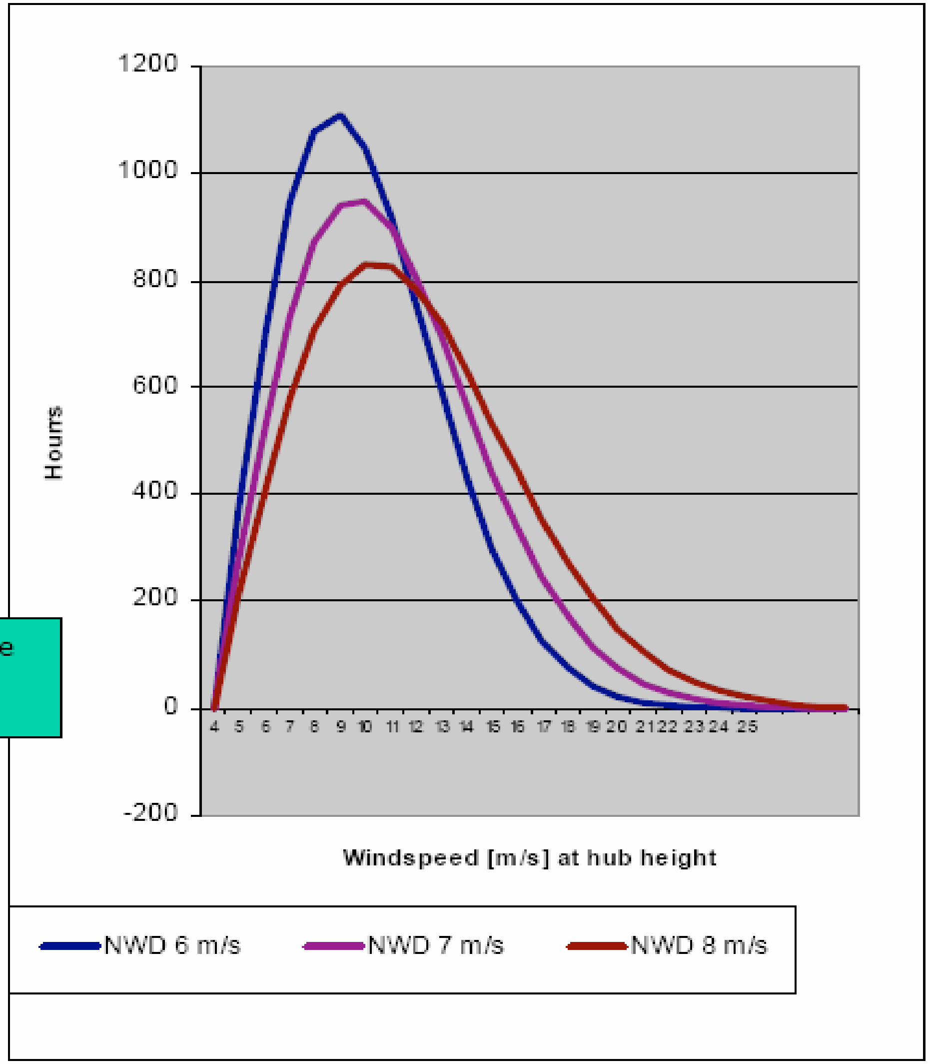
Comparison between the V90 power curves

V90 power curves



For low and medium wind speeds the V90 -1.8/2.0 power curve is much better then the V80 -2.0MW

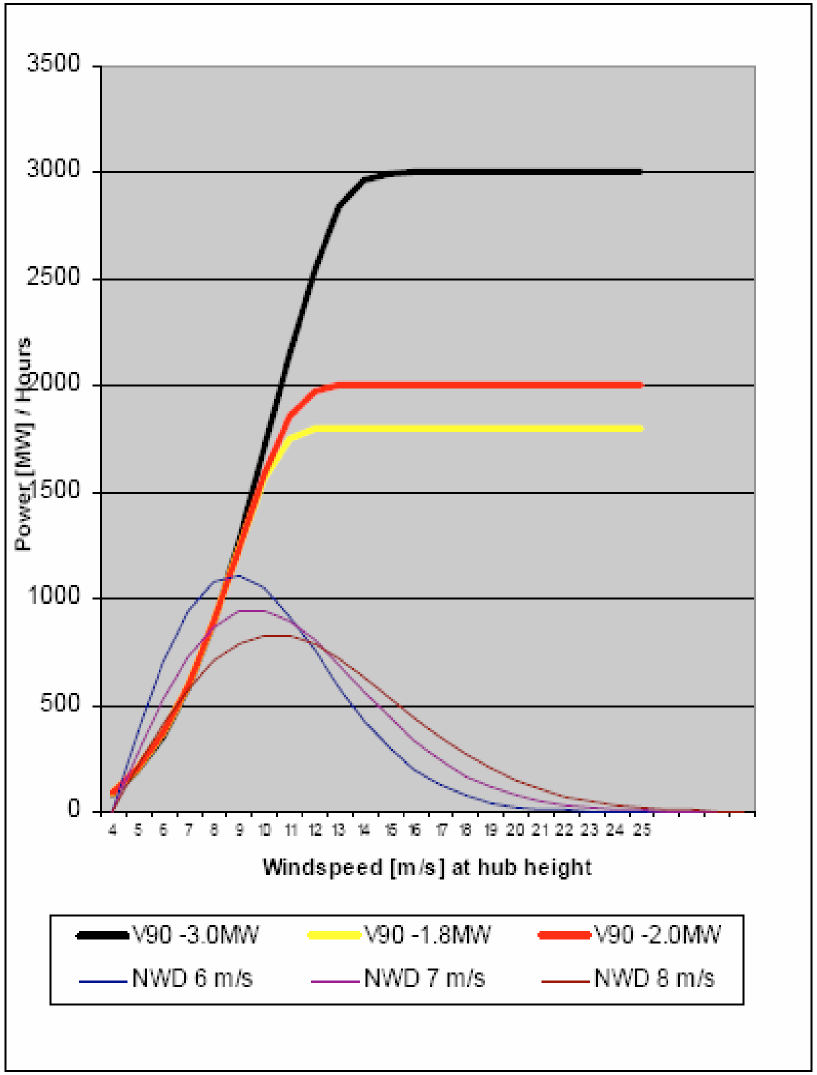
Normal wind distribution (NWD)



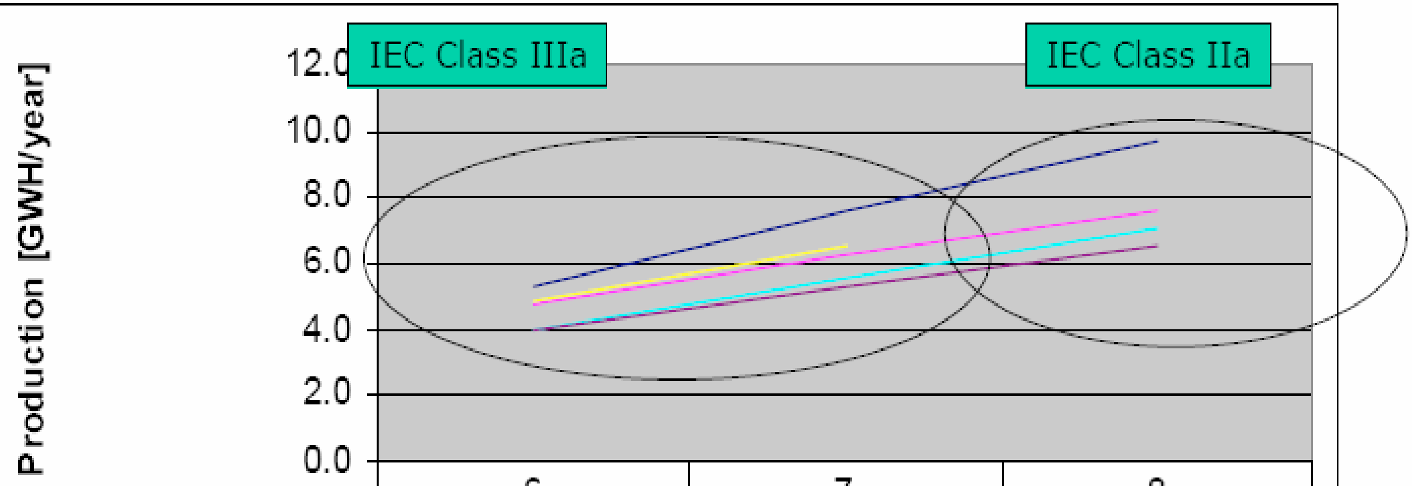
Power curves combined with wind distributions

- The combination of the power curve and the wind distribution give a clear indication of the best turbine for a given wind distribution.

- It is important to have information about the IEC Class of the site in order to, select the best turbine.



Yearly production comparison



	6	7	8
V90 -3.0MW	5.3	7.6	9.7
V90 -1.8MW	4.7	6.3	7.6
V90 -2.0MW	4.9	6.5	
V80 -2.0MW	4.0	5.6	7.0
V82 -1.65MW	4.0	5.3	6.5

Yearly mean wind speed at hub height [m/s]

Selecting the right turbine

In order to select the right turbine the following factor's should be taking into consideration in the project face.

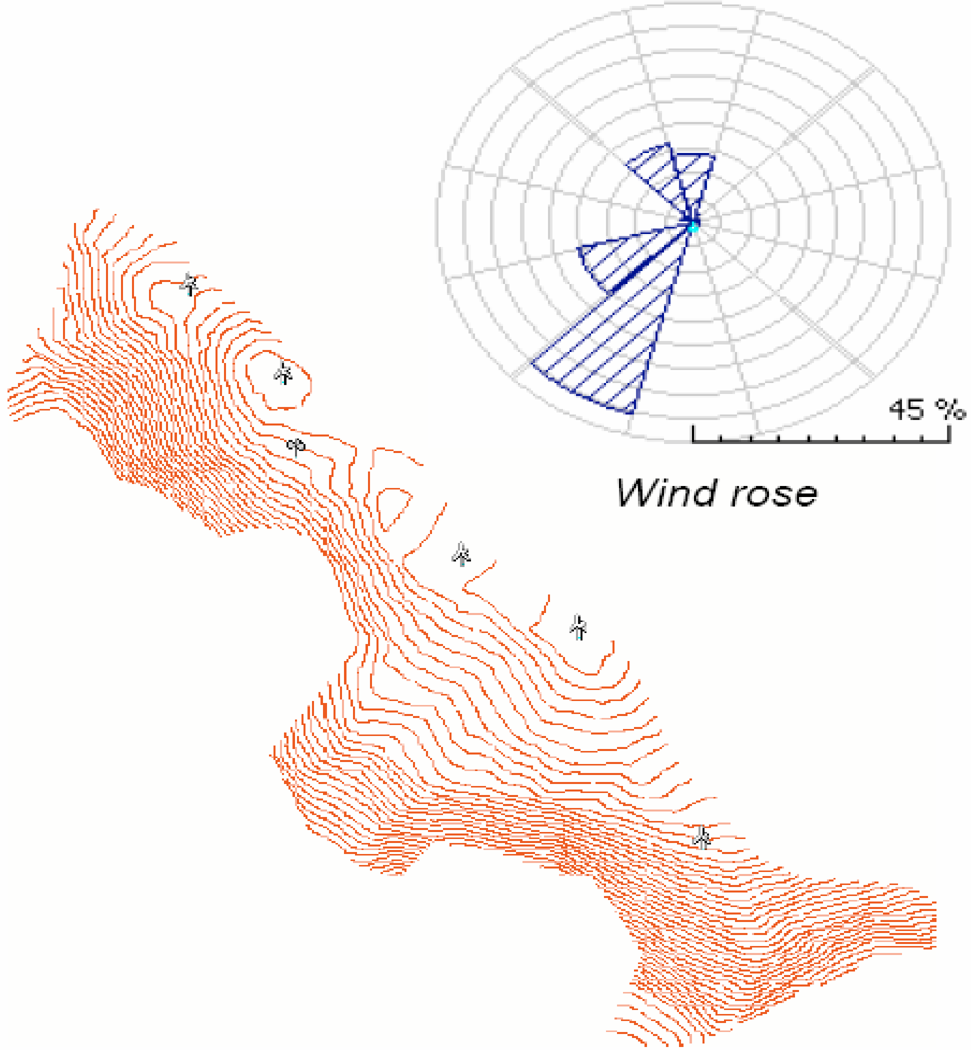
- IEC class of the site
- Turbulence and Spacing of turbines
- Site area – How big is the site
- Installed MW
- Hub height and visual impact
- Sound restrictions

For a good micrositing is needed:

- Min. 1 year of wind data measured on site.
- Wind direction measurements.
- The wind speed measurements must be conducted for at least 2 heights.
- The measuring height should be as close to hub height as possible.
- Turbulence measurements.
- If possible temperature measurements.
- A digital 3-D contour map covering an area of a radius of 5 – 10 km from the site centre.

In order to do a proper wind assessment - on-site wind measurements are necessary !

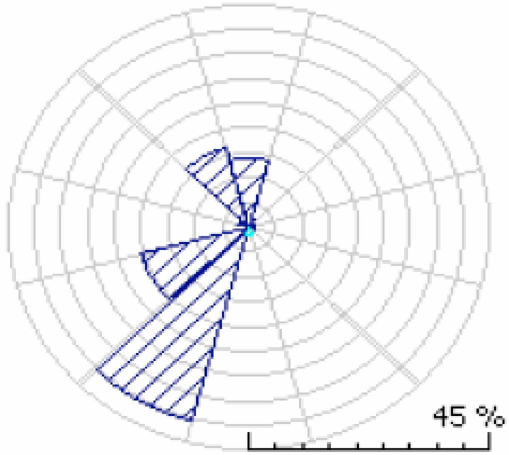
- One full year of measurements are need in order to take all seasonal variations into account
- If more than one year of raw data are used the year to year uncertainty is taken into account.
- If the temperature is measures simultaneity with the wind speed. It is possible to estimate weather or not, a high temperature turbine is needed.
- On site measurements are needed in order to investigate the wind regime on site. Wind shear, turbulence, wind rose, and wind speed. Factors that are known to chance with the complexity of the landscape.



Wind rose

The wind rose

- The wind rose is needed in order to make the optimal layout.
- The optimal layout is perpendicular to the mean wind direction
- More then one wind van should be used, in order to check for errors in the direction data.
- A optimal layout have closer spacing perpendicular to the wind direction and bigger spacing along the mean wind direction.



Example (Wind Rose):

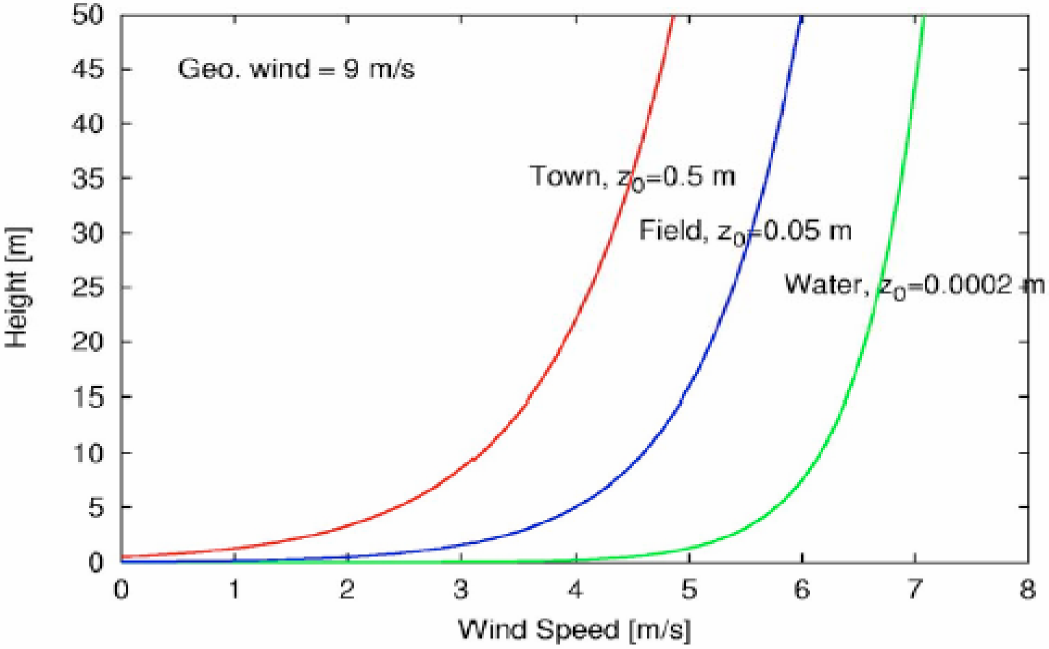
Sector	A-factor	C-factor	Freq.
1	10	1.94	9.61%
2	5.2	1.19	2.43%
3	2.7	1.12	1.25%
4	12.6	2.19	6.95%
5	13.1	2.19	29.47%
6	7	1.63	9.78%
7	4	1.72	3.78%
8	6	1.96	4.12%
9	7.2	1.79	7.68%
10	5.5	1.38	9.49%
11	7.2	1.89	8.20%
12	6.8	2.25	7.24%
Total	**8.7**	**1.48**	**100.00%**

Wind shear on the site

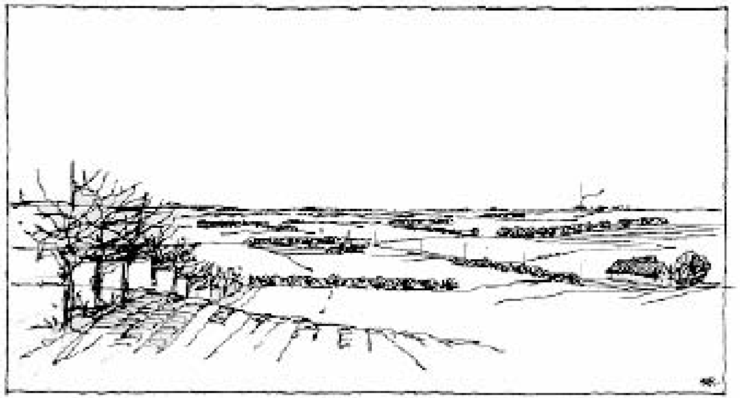
- The wind shear is important due to the interpolation from the measurement height to hub height
- As well as it gives indication about the slopes round the site.
- The wind shear is modelled using the roughness.
- If the difference between the hub height and the measurement height is big, the corresponding uncertainty on the hub height wind speed estimated is equally big.
- Calculating the mean wind speed at hub height 80 meters, using a 10 meter met mast is **'Not Good'**

$$V = (H_0/H)^{alfa} * V_0 \qquad u(z) = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right)$$

Alfa = the windshear factor



Roughness on the site



Example of terrain corresponding to roughness class 2: farm land with wind-breaks, the mean separation of which exceeds 1000 m, and some scattered built-up areas. The terrain is characterised by large open areas between the many windbreaks, giving the landscape an open appearance. The terrain may be flat or undulating. There are many trees and buildings. The roughness length is z_0 = 0.10 m.

Table of roughness lengths

The table below indicates the relation between roughness length, terrain surface characteristics and roughness class given in the European Wind Atlas. The table may serve as a guideline for assigning roughness length values.

z_0 [m]	Terrain surface characteristics	Roughness Class
1.00	city	
0.80	forest	
0.50	suburbs	
0.40		3 (0.40 m)
0.30	shelter belts	
0.20	many trees and/or bushes	
0.10	farmland with closed appearance	2 (0.10 m)
0.05	farmland with open appearance	
0.03	farmland with very few buildings/trees	1 (0.03 m)
0.02	airport areas with buildings and trees	
0.01	airport runway areas	
0.008	mown grass	
0.005	bare soil (smooth)	
0.001	snow surfaces (smooth)	
0.0003	sand surfaces (smooth)	
0.0002		0 (0.0002 m)
0.0001	water areas (lakes, fjords, open sea)	

It should be noted that in general the roughness length as applied in WAsP has to be considered as a climatological parameter because the roughness of an area changes with foliation, vegetation, snow cover and so on. The energy production of a wind turbine must be determined on the basis of climatology, primarily because of the variations of the weather; however, the seasonal variations in the local terrain characteristics can also have a profound influence.

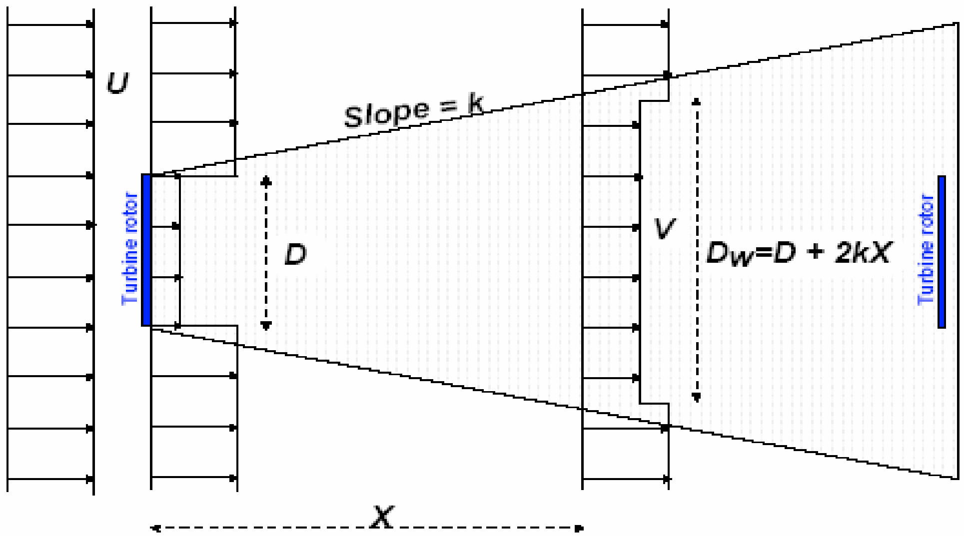
Turbulence

- Wind farm turbulence consists of 2 elements:
  - Back ground turbulence
  - Wake turbulence, turbulence made by other turbines.
- Close spacing give high wake turbulence hence high turbulence.
- High turbulence reduces the turbine life time dramatically.
- Mean goal of micro siting is to reduce loads and optimise production.

The principle of wake effects in wind farms:

k = Wake decay constant

Wake loss should be less then 4-5%



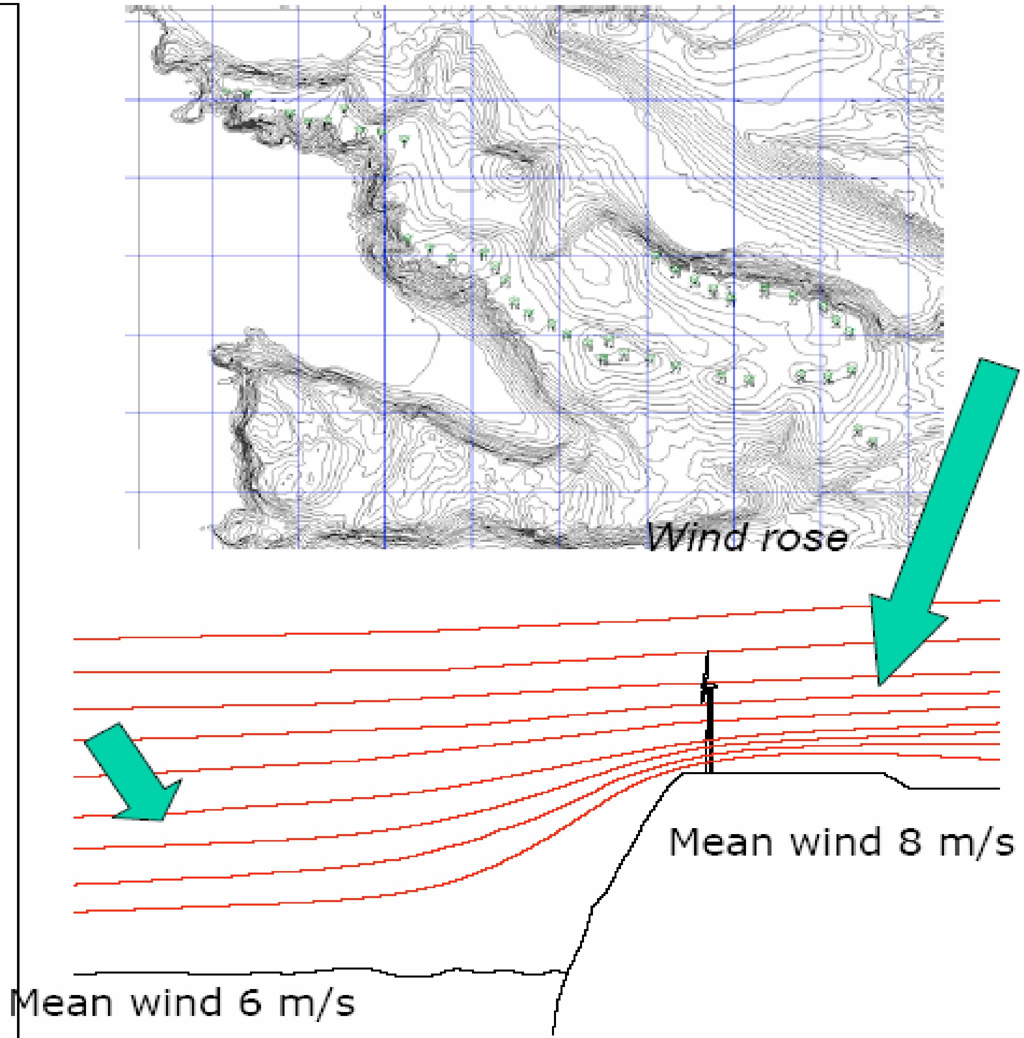
- Mean goal of micrositing is to reduce loads and optimise production.

In order to do a proper wind assessment - A Digital 3d height contour map is needed.

- Digital 3d height contour map, contains information about height for the contour lines. The map should be in the format .Dxf/.Dwg or .Map

- The map is to be used in the software wasp/windpro calculating the wind farm production

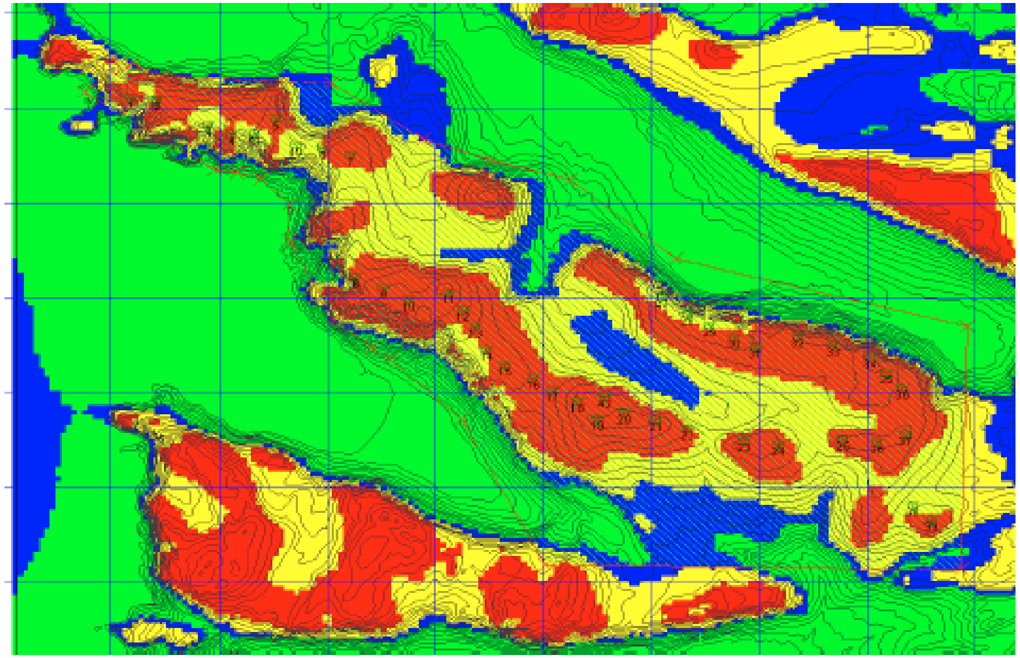
- There is a big difference in wind speed, in front of the hill and on top of the hill, this phenomena is called speed up. The only way to take the speed up into account is by using the height contour maps.



Optimisation of the wind farm

- There are to ways of optimising the wind farm
  1. Chance spacing in order to lower the wake loss
  2. Find the locations with the best wind energy.

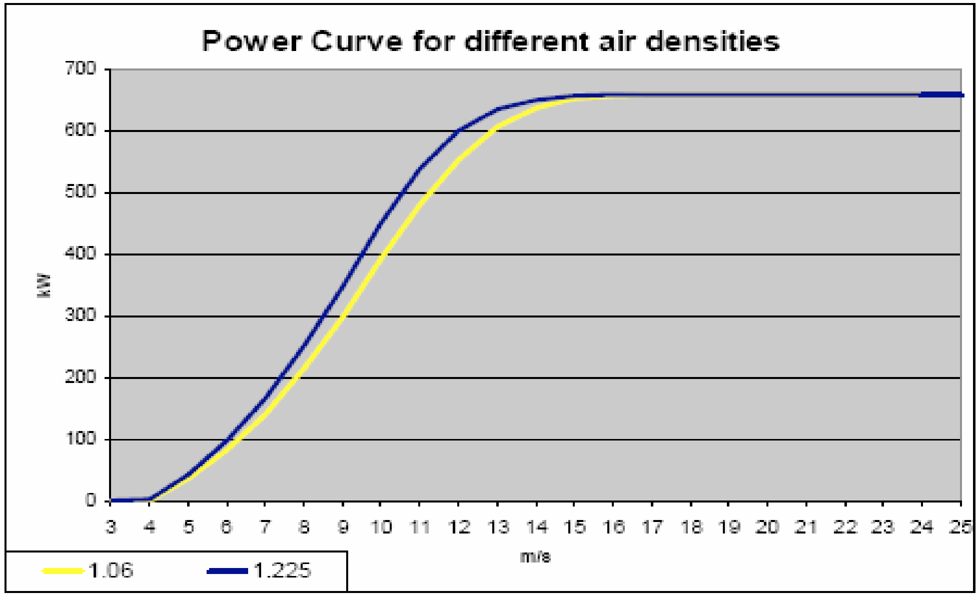
- With onsite measurements and a digital height contour map it is possible to calculate the energy potential of the entire site.



Colour map, indicating the wind recourse at the site.

Temperature / Air density

- Knowing the air density of the site is important. Because the power curve chances with air density.
- From the temperature at the site and the height of the site, the air density can be calculated.



Wind applications (1)

Small wind turbines and hybrid systems

Hybrid system: wind–diesel or wind-photovoltaic-biomass-hydro-diesel in different combinations

Agriculture applications:

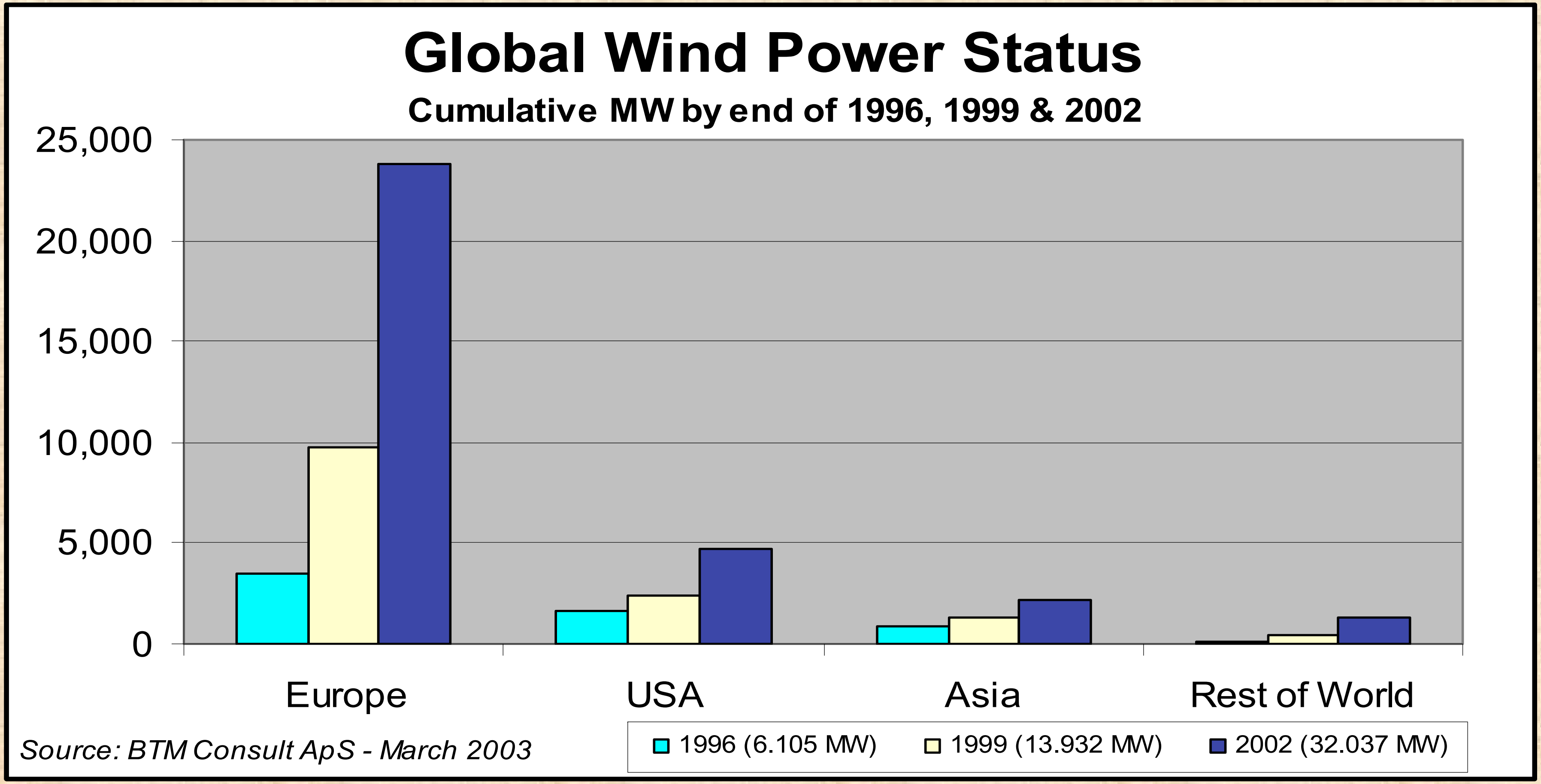
- **Water pumping**
- **Generation of electricity for remote areas**
- **Stand-alone systems or connected to small networks**

Industrial applications: cathodic protection, navigational aid, telecommunications, weather stations, seismic monitoring

Wind applications (2)

Medium and large wind turbines are used alone or more frequently in small and large numbers (wind farms) to produce electricity in offshore (medium sized until 2000) and onshore applications

Wind farms of large wind turbines are used for offshore (from 2001) and onshore applications



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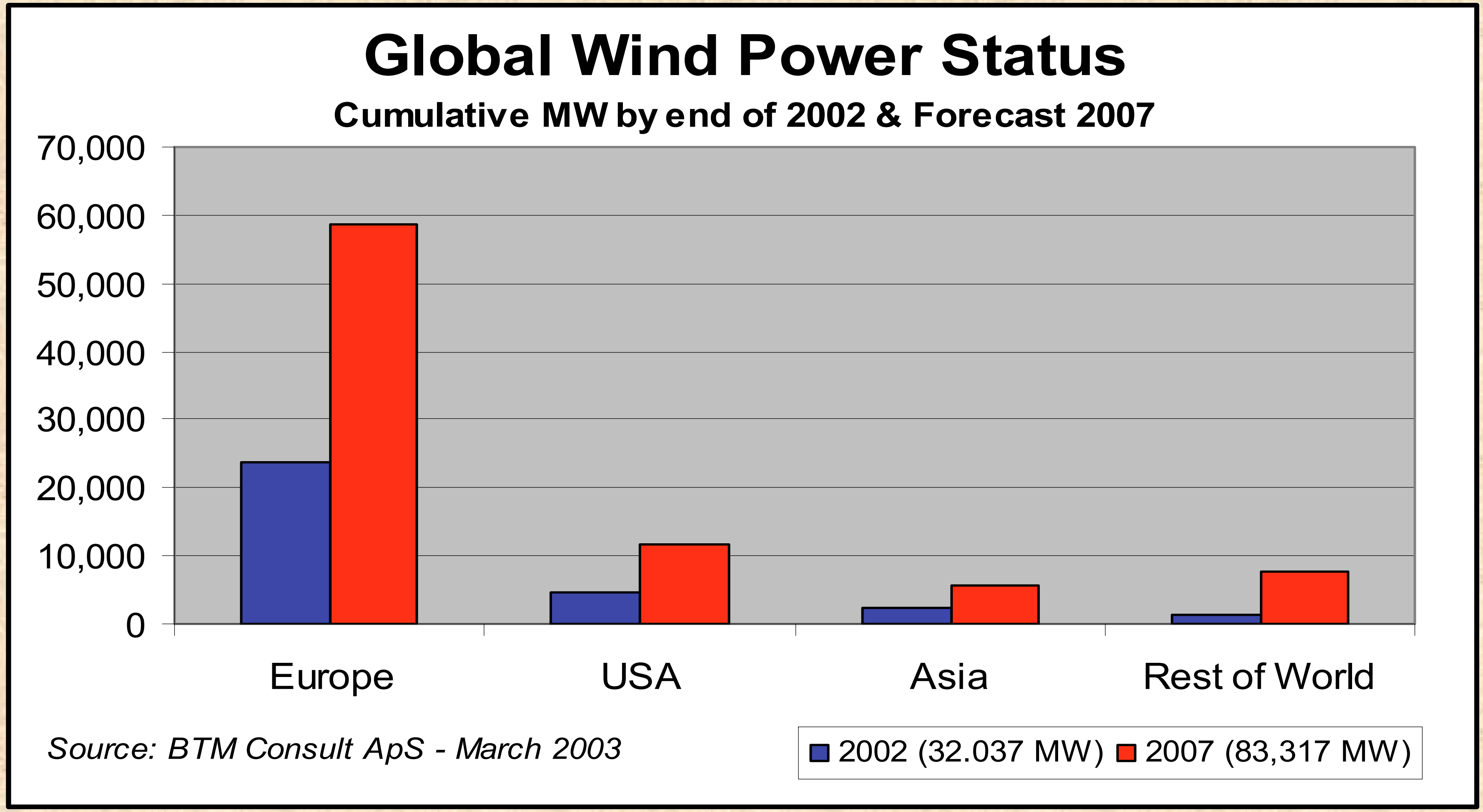

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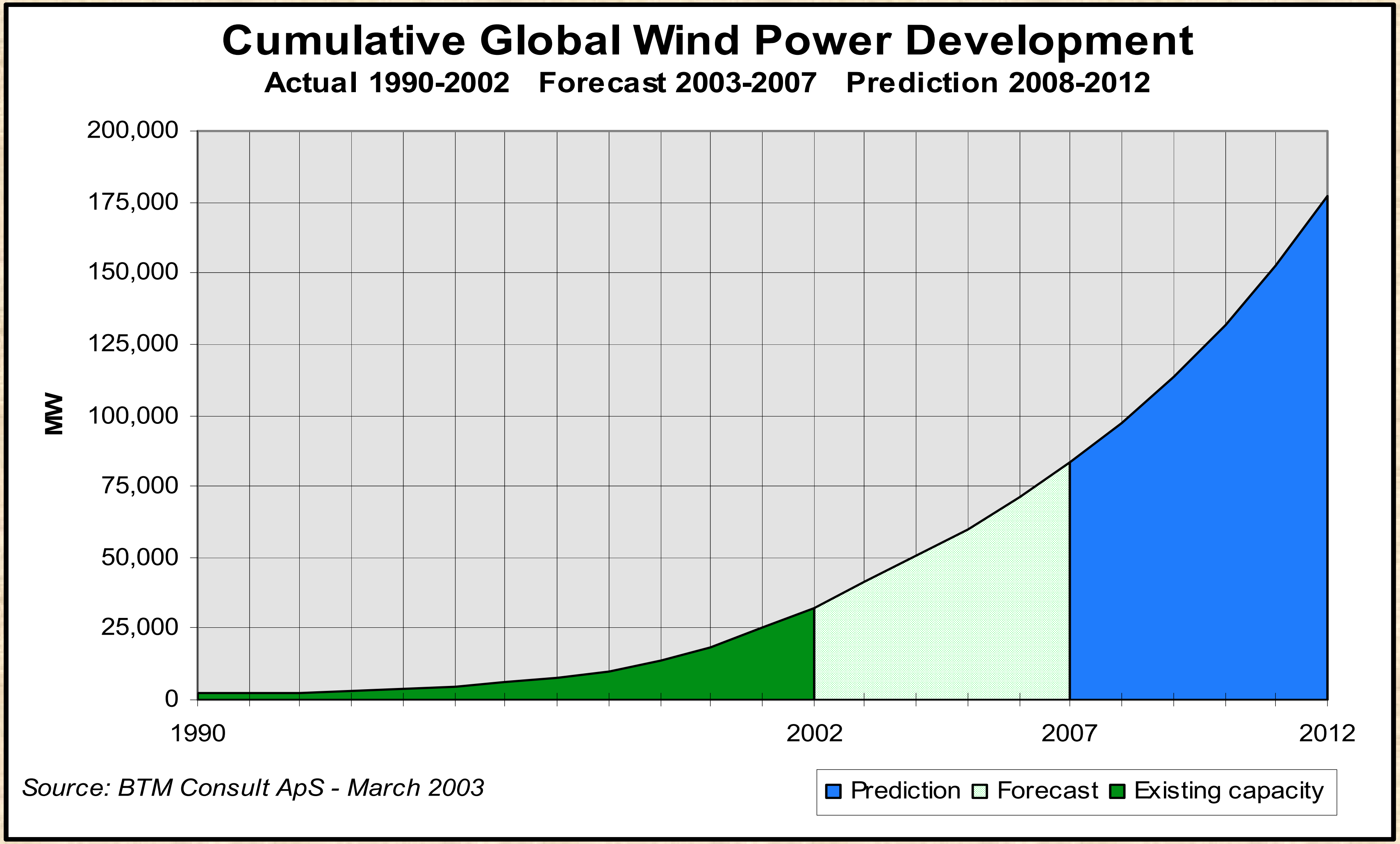

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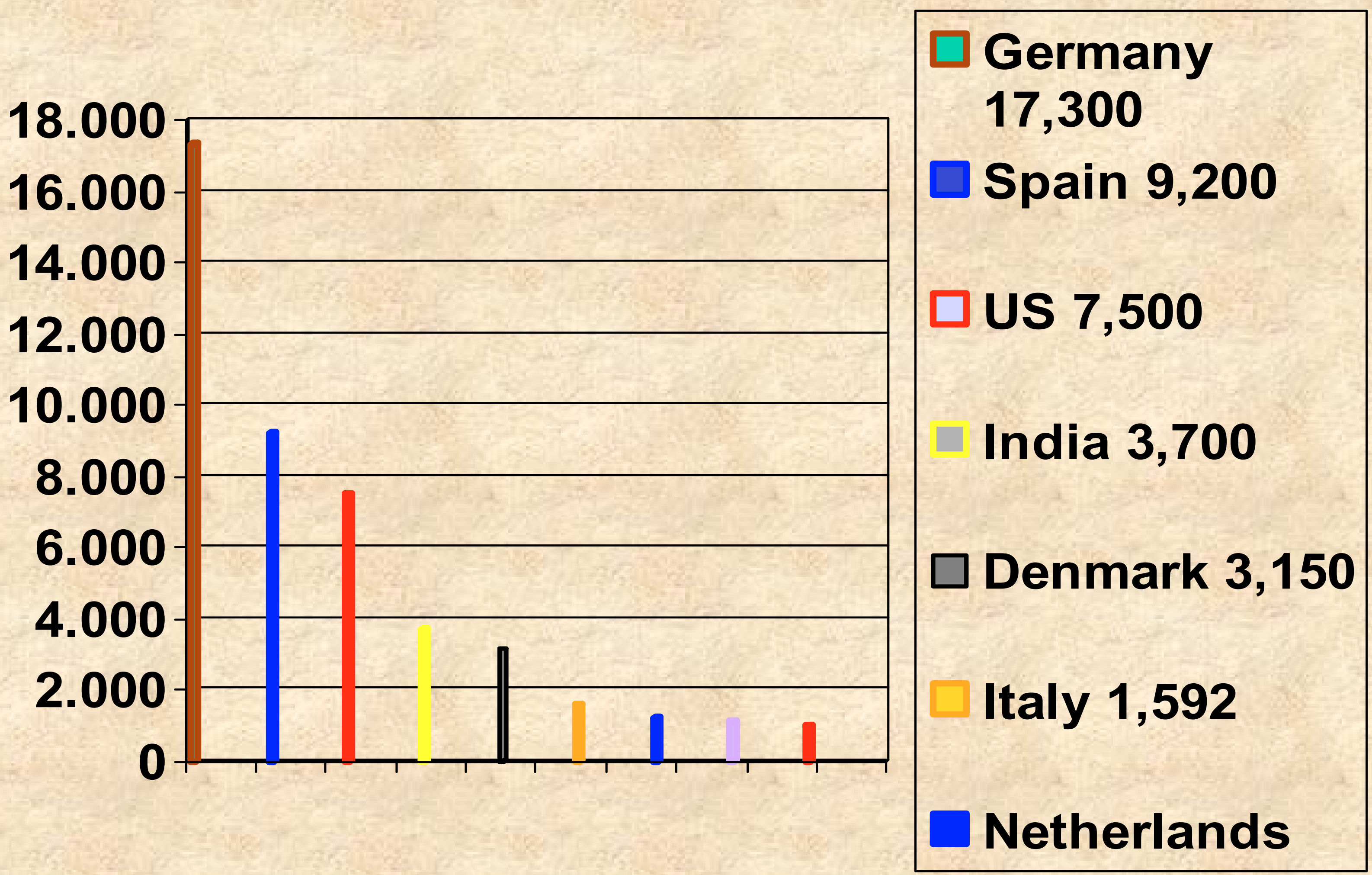
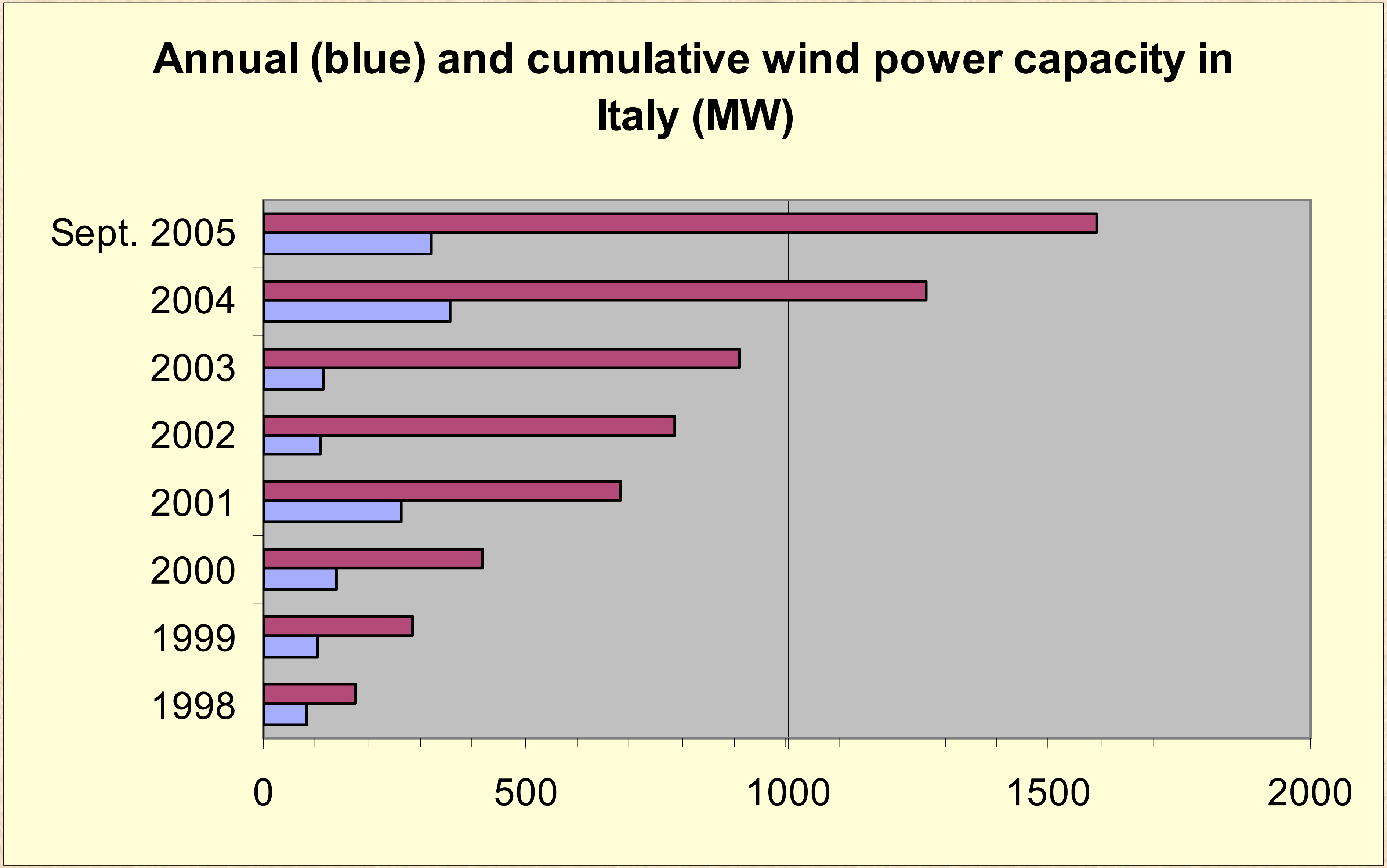
Wind deployment

Operating wind power capacity (September 2005)

World total: 52,000 MW **Europe: 36,000 MW** **Italy: 1,592 MW**

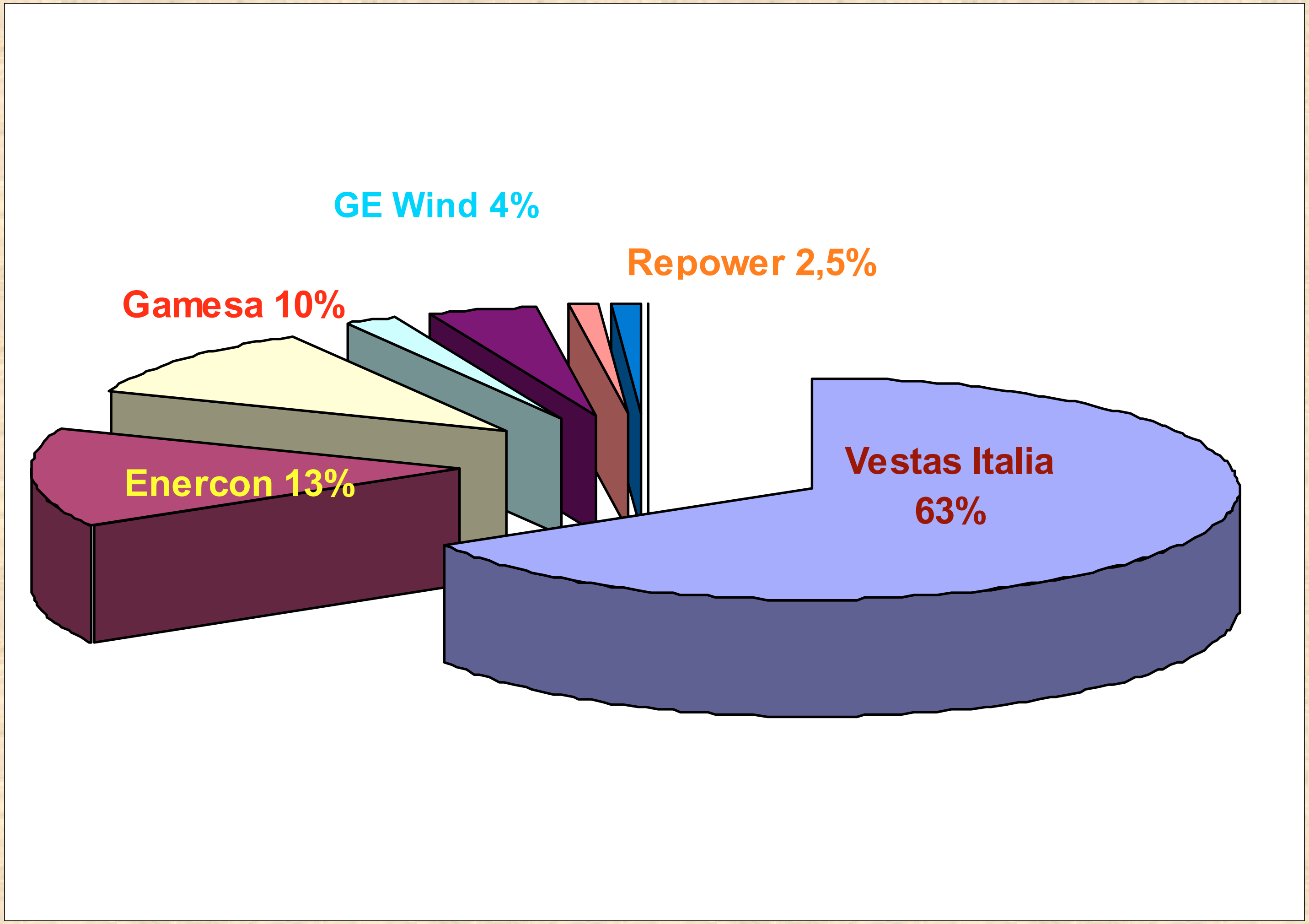



Annual (blue) and cumulative wind power capacity in Italy (MW)
Sept. 2005
2004
2003
2002
2001
2000
1999
1998
0
500
1000
1500
2000

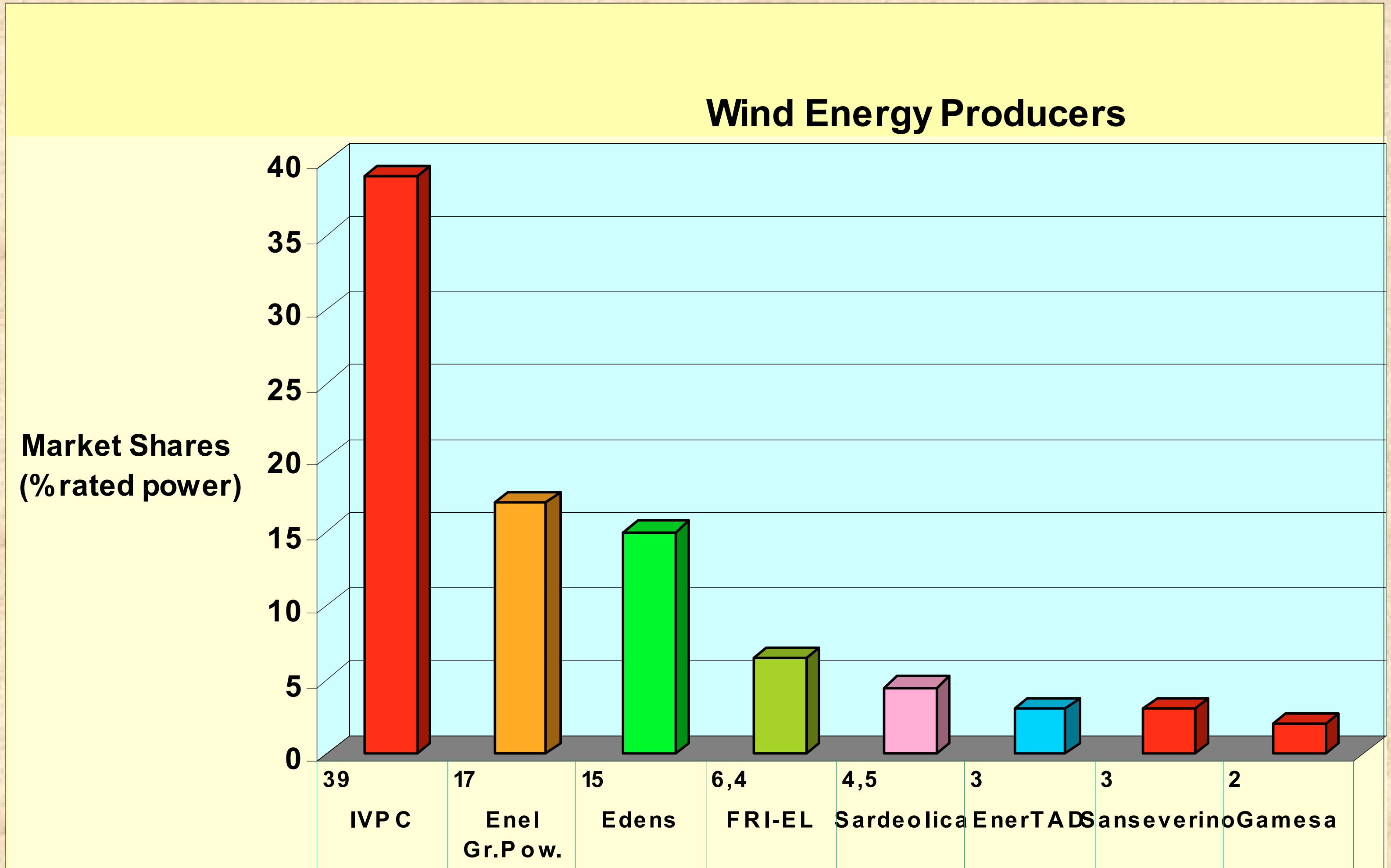
Market Stimulation

Italy: CIP 6/92 feed-in prices 11.7 Euro-cent per kWh for the first 8 years, and thereafter Euro-cent 5.35.
Since 2002 utilities must deliver at least 2%, increased by 0.35% each year since 2004, from renewable energy sources (RES). The support system has thus been changing from a “feed-in price” mechanism to a "RES quota" mechanism based on green certificates. Their price for the 2004 RES production has recently been set at 9.7 Euro-cent/kWh.
Total electricity price from wind energy: Green certificate value plus electricity market price corresponding around 15 Euro-cent/kWh

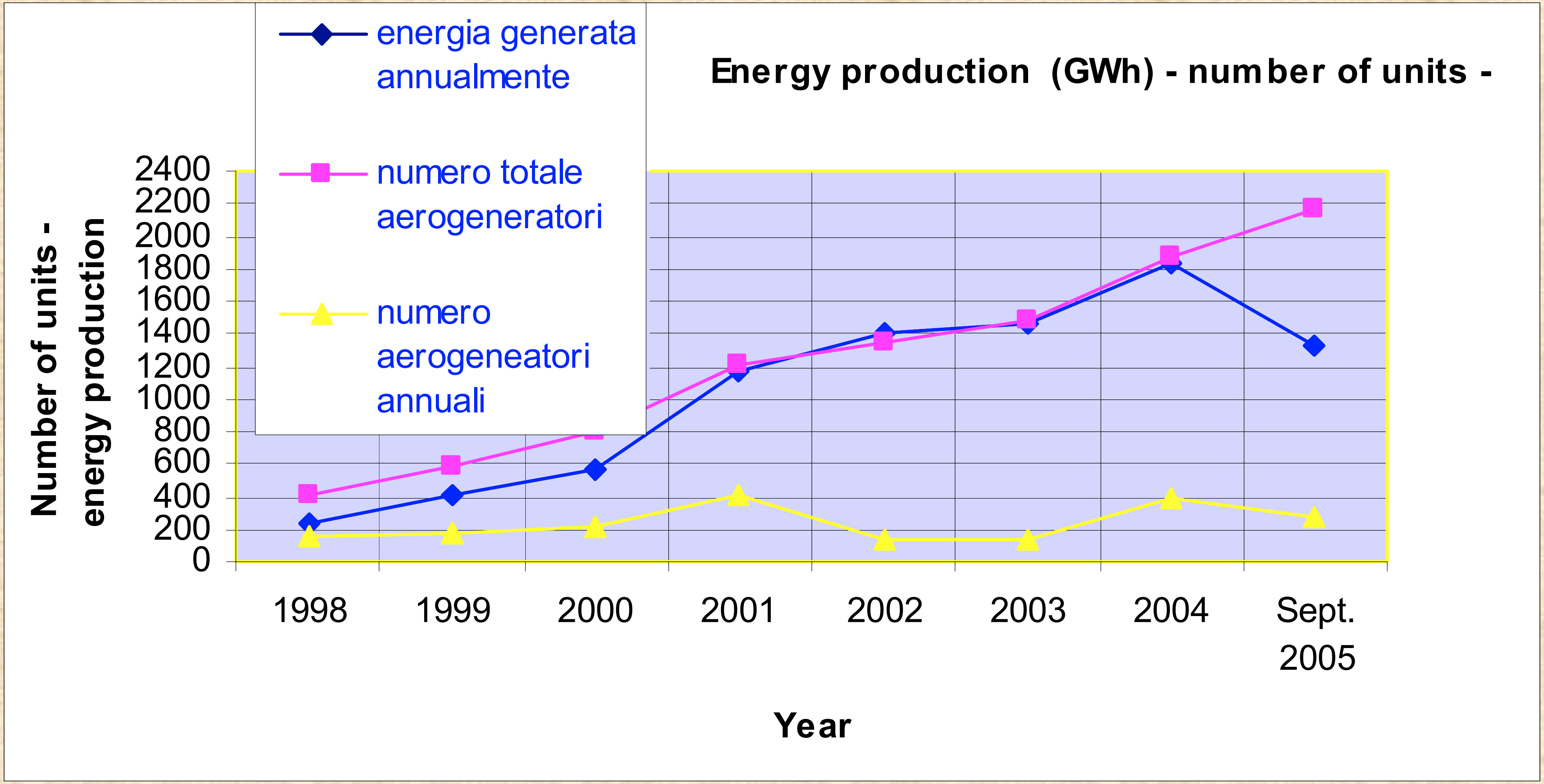
Market share of wind turbine manufacturers in Italy end September 2005



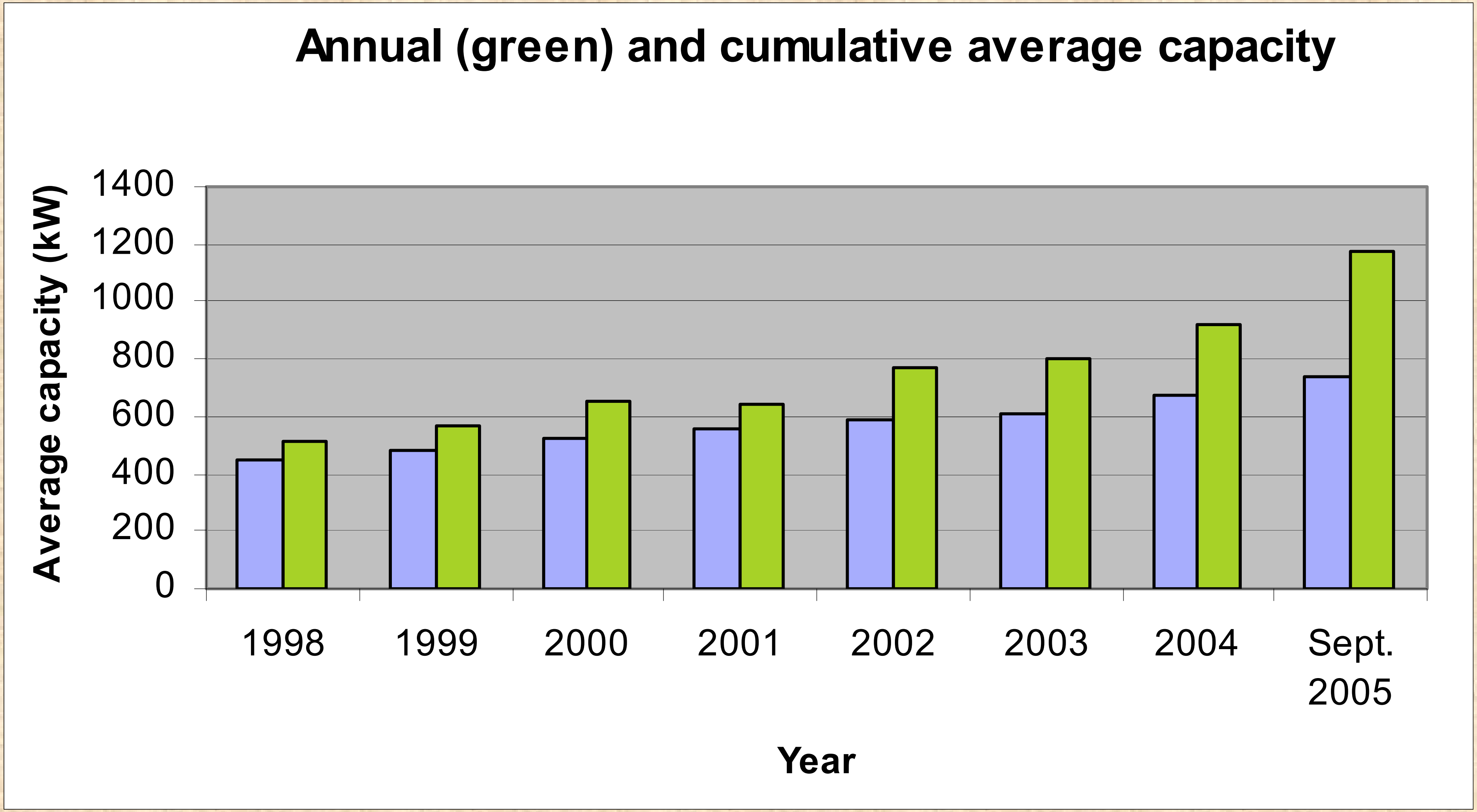
Contribution by electricity producers from wind in Italy
end September 2005



	IVPC	Enel Gr.Pow.	Edens	FRI-EL	Sardeolica	EnerTAD	Sanseverino	Gamesa
%	39	17	15	6,4	4,5	3	3	2



Energy production (GWh) - number of units -
energia generata annualmente
numero totale aerogeneratori
numero aerogeneatori annuali
Number of units - energy production
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1998
1999
2000
2001
2002
2003
2004
Sept. 2005
Year


Annual (green) and cumulative average capacity
Average capacity (kW)
1400
1200
1000
800
600
400
200
0
1998
1999
2000
2001
2002
2003
2004
Sept. 2005
Year

Italian renewable capacities (MW)

Source	Year 2003	Year 2004	Incr. %
Hydropower	16,970	17,043	+0.4%
Wind	908	1,265	+39%
PV	7	7.1	-
Geothermal	707	681	-3.7%
Biomass	1,086	1,150	+5.9%
Total	19,678	20,146	+2.37%

Italian wind farms
main chararacteristics

- **Location:** Southern and islands regions generally rural mountain areas
- **Capacity:** < 1 MW up to 72 MW
- **Medium sized turbines :** 600 kW - 660 kW - **850 kW (80.4%)**
- **Large sized turbines:** 1 MW - 1.5 MW - 2 MW **(19.6%)**

Wind power at regional level

• Campania	360 MW
• Apulia	320 “
• Sicily	274 “
• Sardinia	234 “
• Abruzzo	157 “
• Basilicata	85 “
• Molise	35 “
• Lazio	9 “
• Others	18 “
Total	**1,592 MW**

Apulia moratorium on the evaluation of environmental impact and authorization procedures regarding wind energy plants

Regional law No. 9 August 11, 2005

Suspension of the evaluation and authorization procedures of new wind initiatives until end June 2006 when the regional energy and environmental plan will be defined and approved

A few exceptions of the law:

- Single plant not exceeding 1 MW
- Wind turbines for a total capacity of 60 kW with a single unit equal or less than 30 kW

Wind projects presented before May 31st, 2005 are excluded by this law

Interventi prioritari previsti nel piano di sviluppo della rete elettrica 2005-2009

GRTN Gestore Rete Trasmissione Nazionale

* Riclassamento a 380KV
** Nuovo intervento di sviluppo

Renewable incentives

Estimated value

	2002	2003	2004	2007
Green certificate demand (TWh)	3.3	3.5	4.0	6.4
Green certificate supply by				
Private investors	0.9	1.5	2.9	6.0
GRTN (TSO)	2.4	2.0	1.1	0.4
Reference price (Green certificate GRTN)	0.084 Euro/kWh	0.082	0.097	

Market stimulation

- **Policy**

1. **legislative measures and targets**
2. **capital cost and feed-in price incentives**

- **Environmental benefits**
- **Other incentives**
- **Domestic resource**
- **Job creation**

Market Constraints

Cost and price constraints

Policy/market stability

Planning policy

Grid limitations

Resource

Environmental constraints

Cost and price constraints

Level of supplement required to make wind energy competitive varies with the base cost of electricity

Lower cost of conventional energy and surplus of generation capacity increase difficulties for wind energy

Policy/market stability

Lack of stability and policy changes have a strong influence on investments

Planning policy

Authorization procedure

Building consent

Objections are often on the grounds of environmental concern

Visual effect

Grid limitations

Lack of grid

Weak grid

Integration of large-scale wind energy into electricity network

Difficulties in getting permission to build new electricity lines

Resource

Availability of good sites

Exploitation of lower wind speed sites

Difficult conditions

Environmental constraints

Bird strikes

Noise emissions

Visual impact