WIND ENERGY

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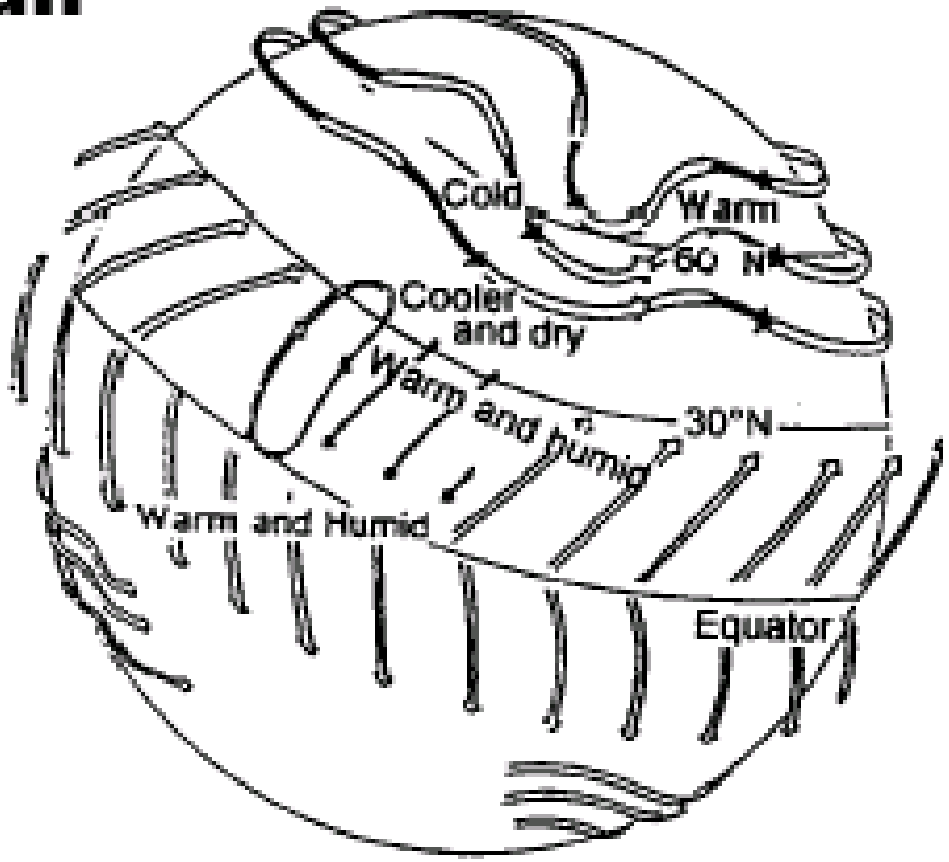
"will we look into the eyes
of our children and confess
that we had the opportunity,
but lacked the courage?
that we had the technology,
but lacked the vision?"

WIND POWER - What is it?

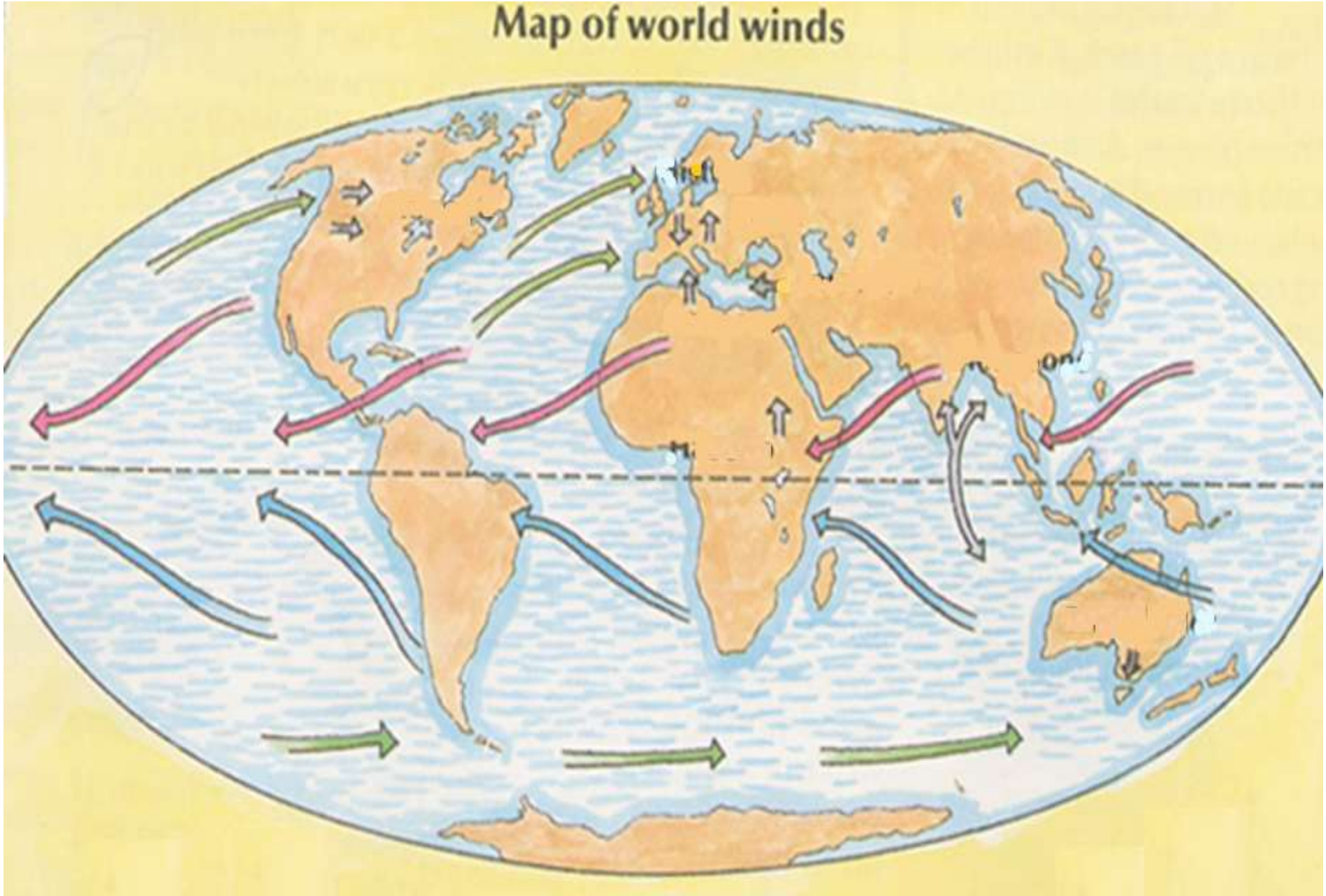
- **The earth receives 1.74 x 10^{17} watts of power (per hour) from the sun**
- **About one or 2 percent of this energy is converted to wind energy**
- **Differential heating of the earth's surface and atmosphere induces vertical and horizontal air currents that are affected by the earth's rotation and contours of the land → WIND.**

The Wind - from heat to motional energy

- **Radiation from Sun**
  > heat
  > pressure gradients
  > motion



Uneven heating of earth's surface and rotation



•A wind turbine obtains its power input by converting the force of the wind into a torque (turning force) acting on the rotor blades.

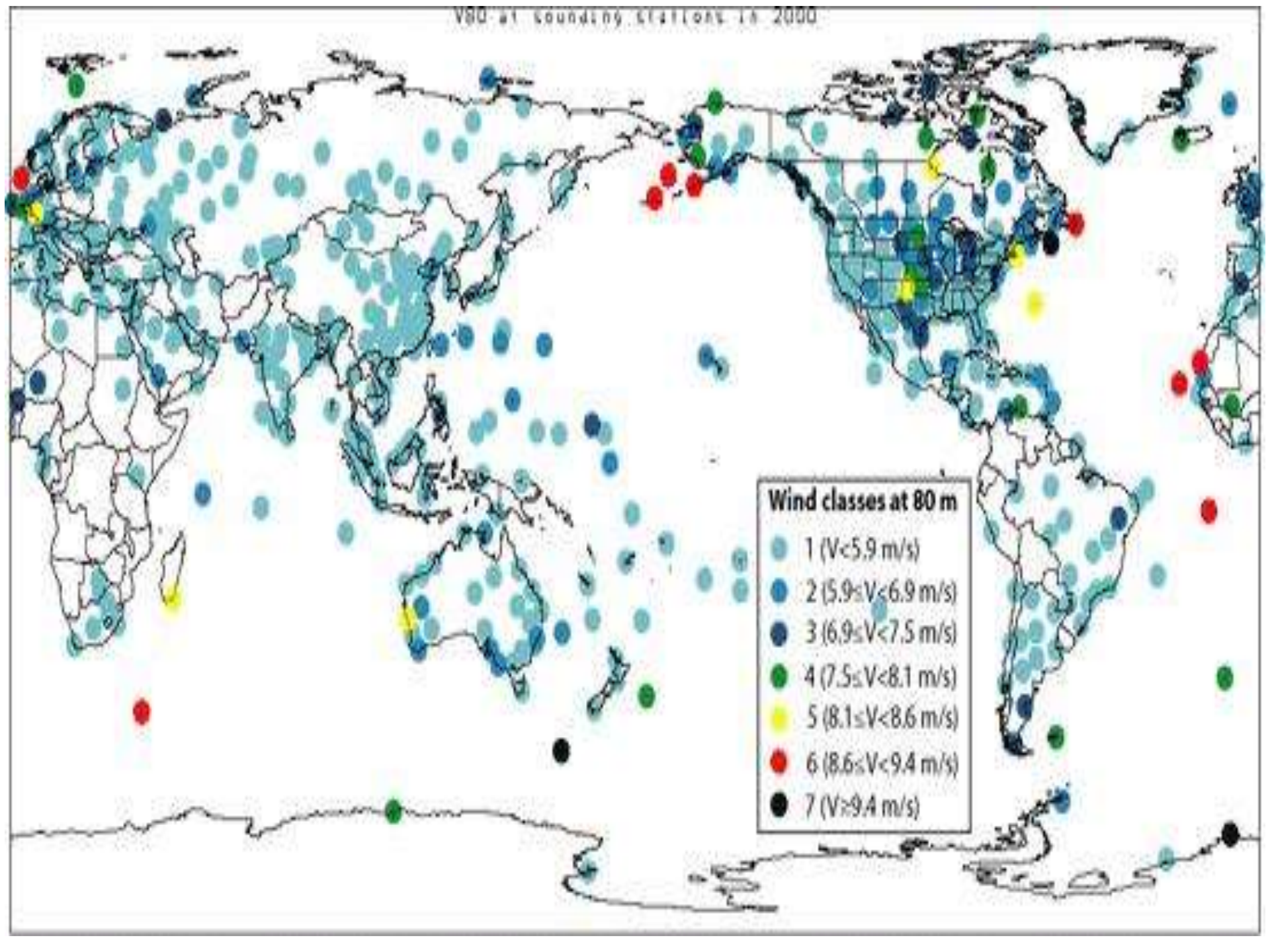
• The amount of energy which the wind transfers to the rotor depends on the **density of the air**, **the rotor area**, and the **wind speed.**

•The kinetic energy in the wind depends on the density of the air, i.e. its mass per unit of volume.

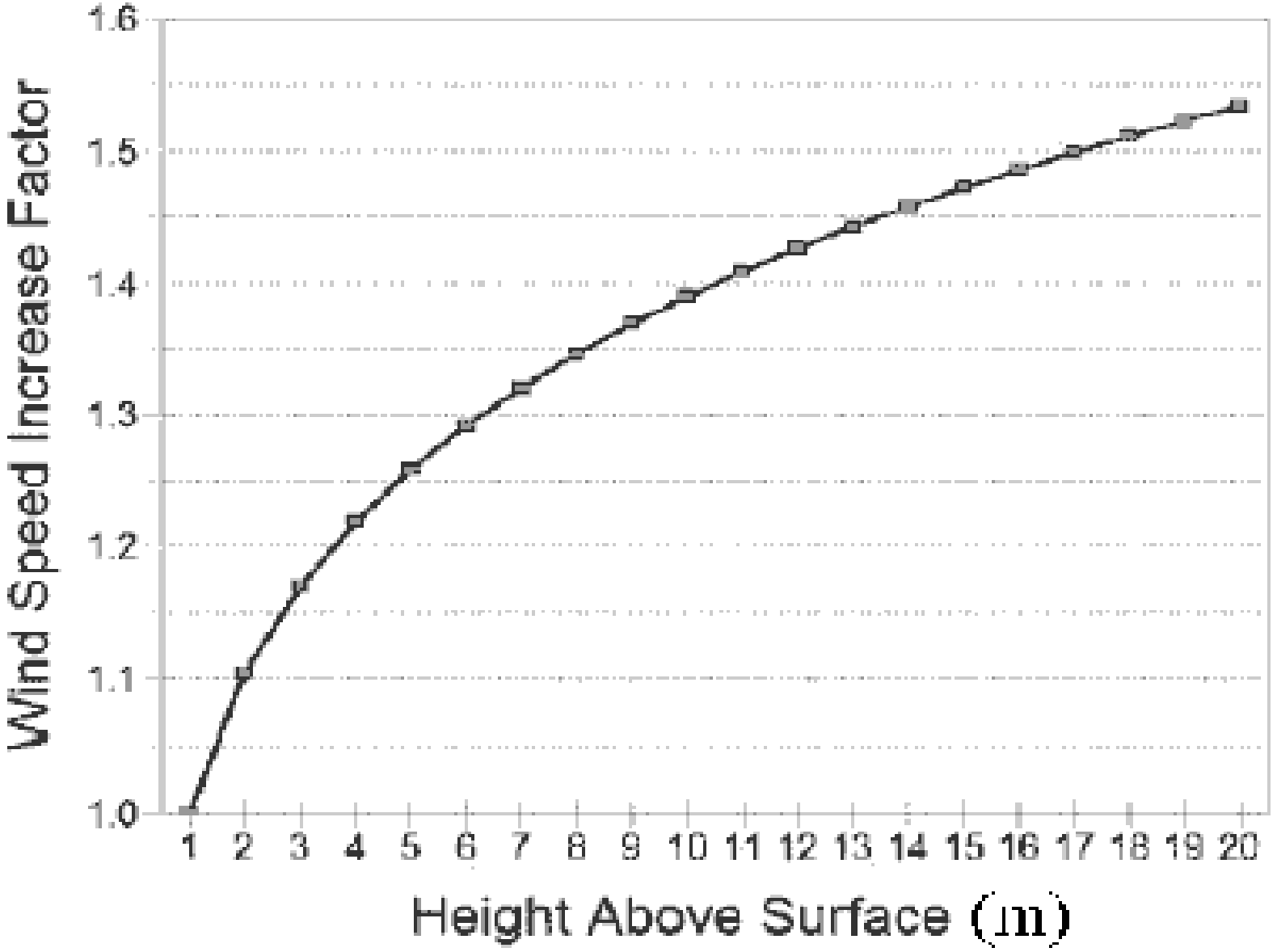
In other words, **the "heavier" the air, the more energy** is received by the turbine.

- A typical 600 kW wind turbine has a rotor diameter of 43-44 meters, i.e. a rotor area of some 1,500 square meters.

- To be considered a good location for wind energy, an area needs to have average annual wind speeds of at least 12 miles per hour.


V80 at sounding stations in 2000
Wind classes at 80 m
1 (V<5.9 m/s)
2 (5.9≤V<6.9 m/s)
3 (6.9≤V<7.5 m/s)
4 (7.5≤V<8.1 m/s)
5 (8.1≤V<8.6 m/s)
6 (8.6≤V<9.4 m/s)
7 (V≥9.4 m/s)

Velocity with Height

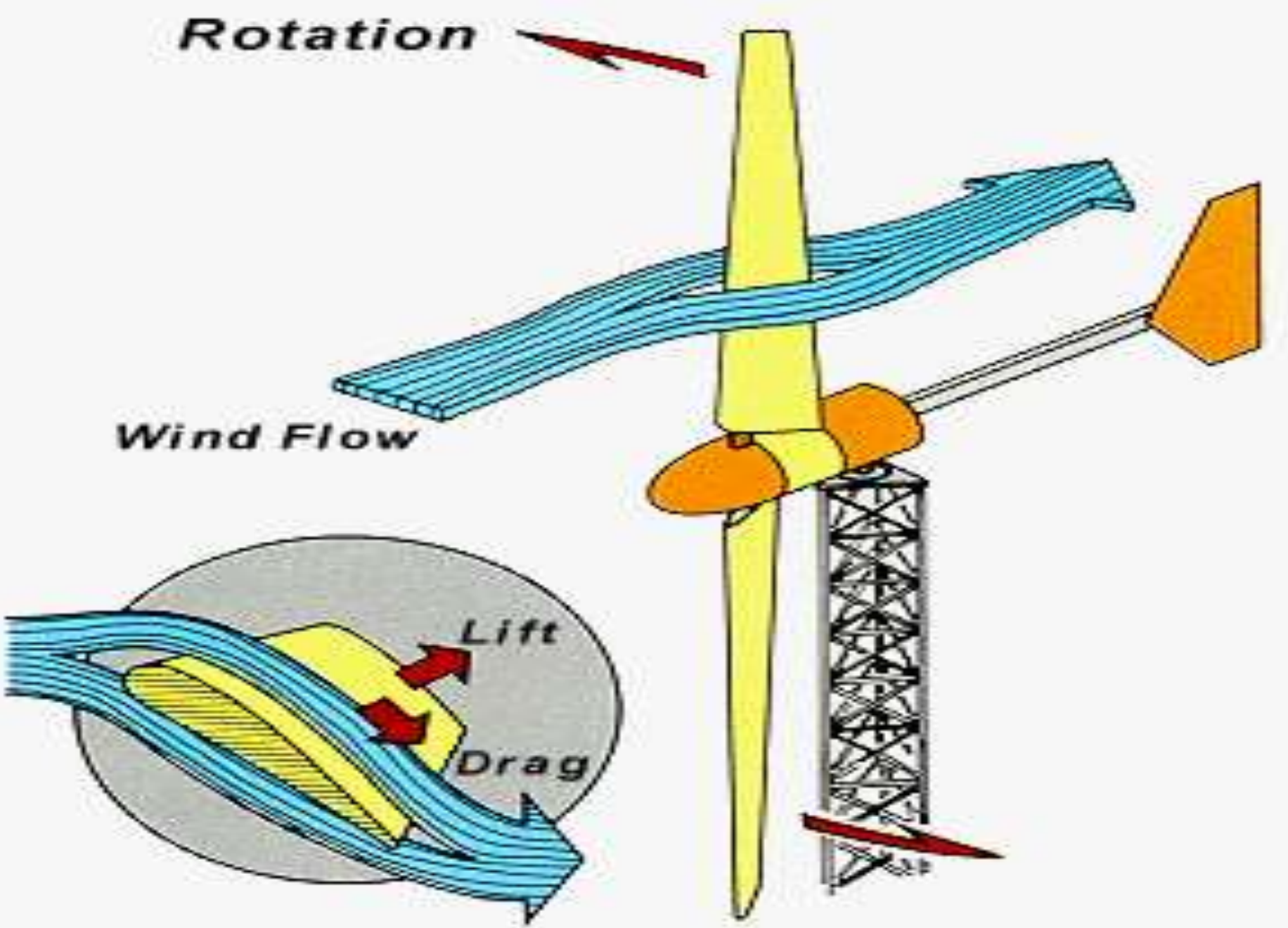


WINDMILL DESIGN

- When designing a windmill, and depending on the required energy output one have to considers

The size of the turbine,

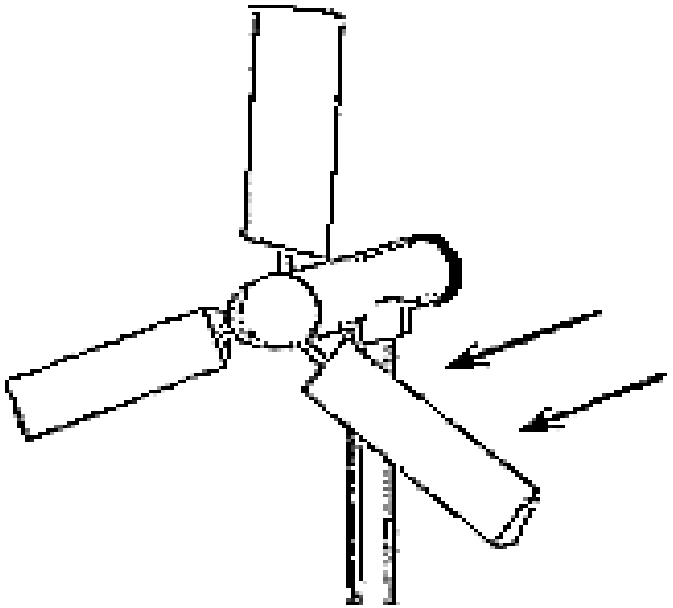
The size of the generator.



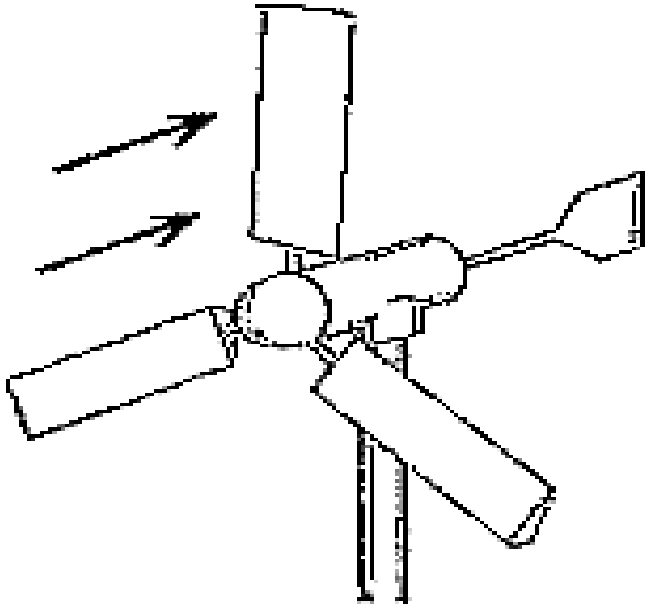
Principles of Wind Turbine Aerodynamic Lift

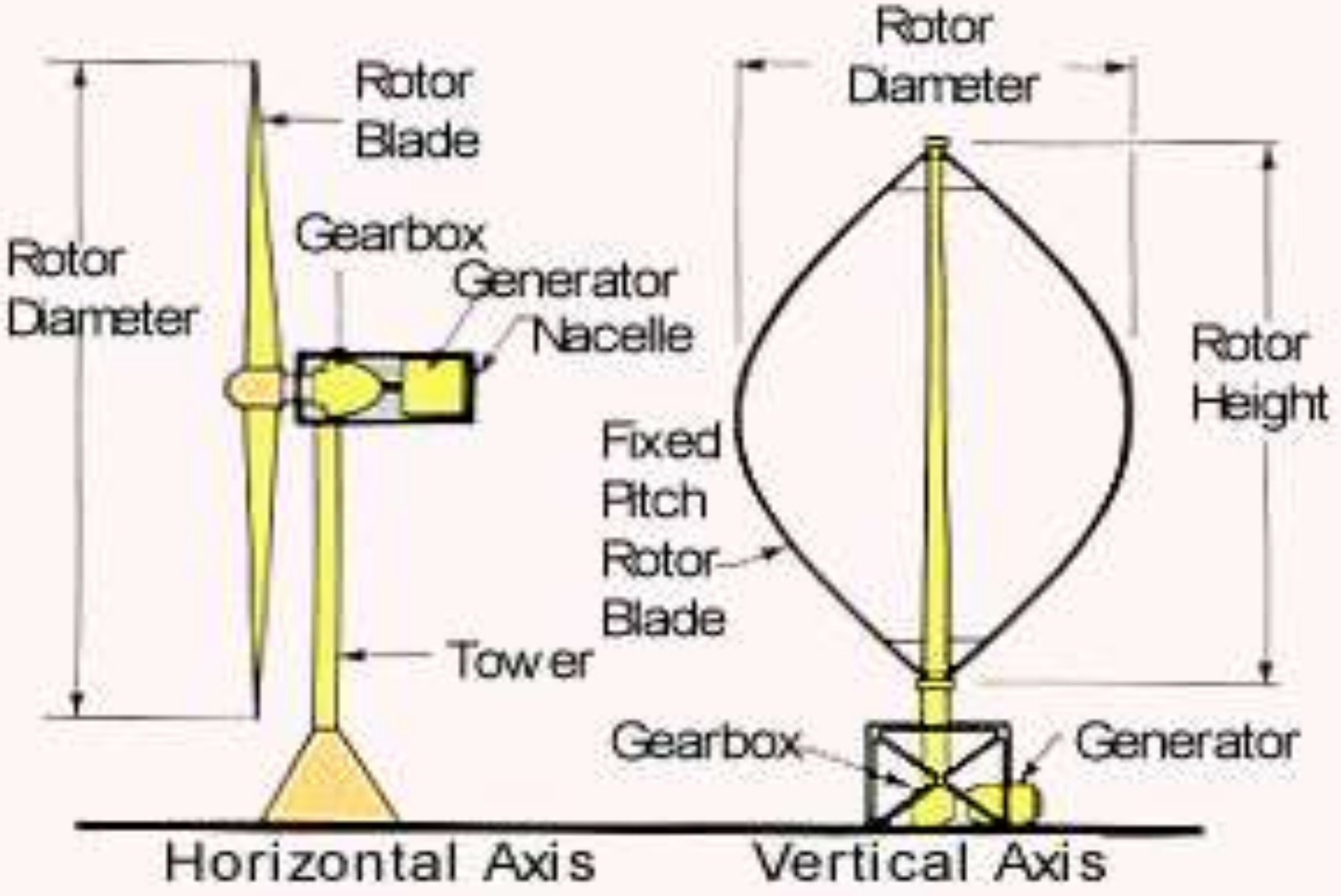
Two types of HAWT

DOWNWIND TURBINE



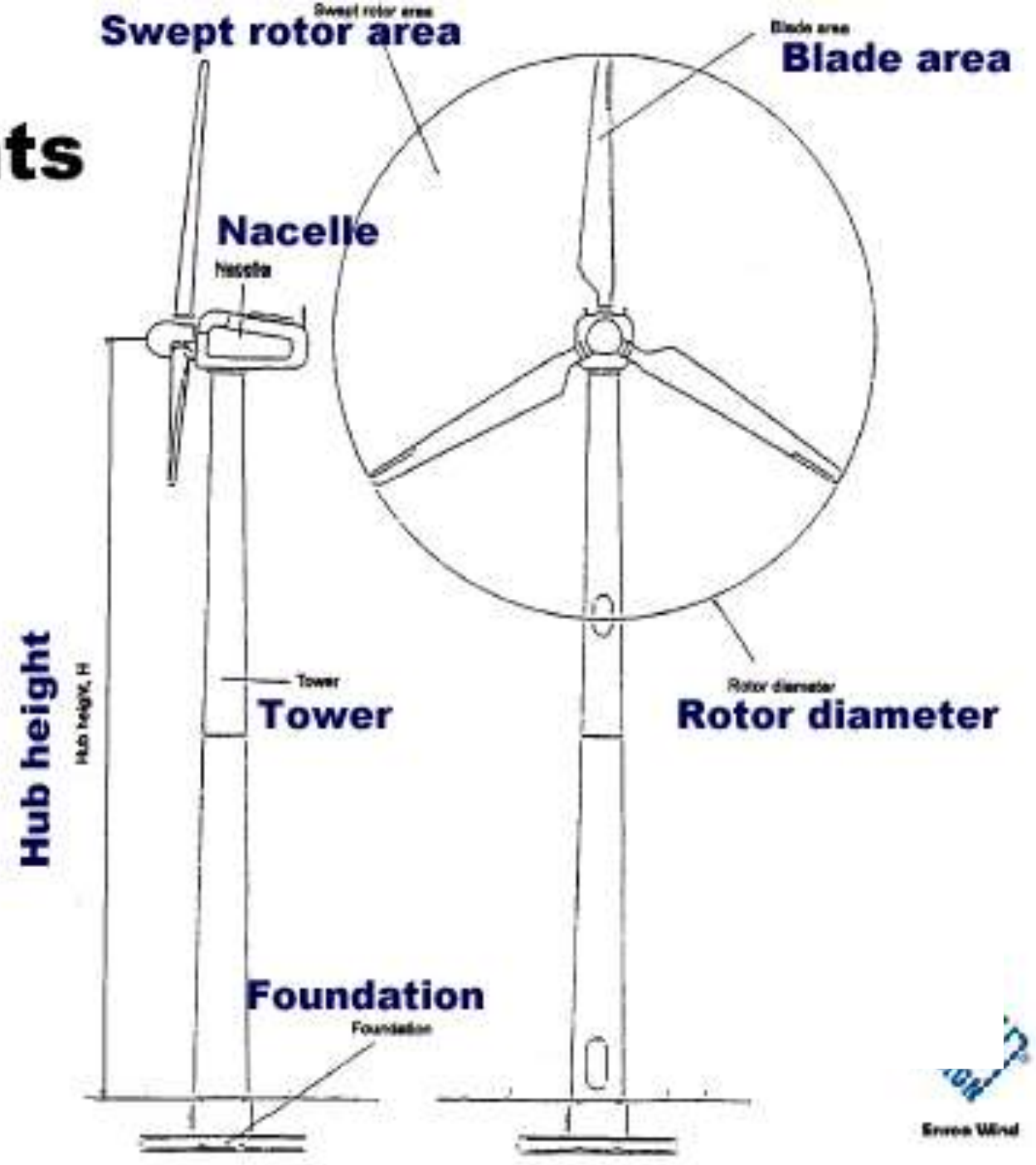
UPWIND TURBINE

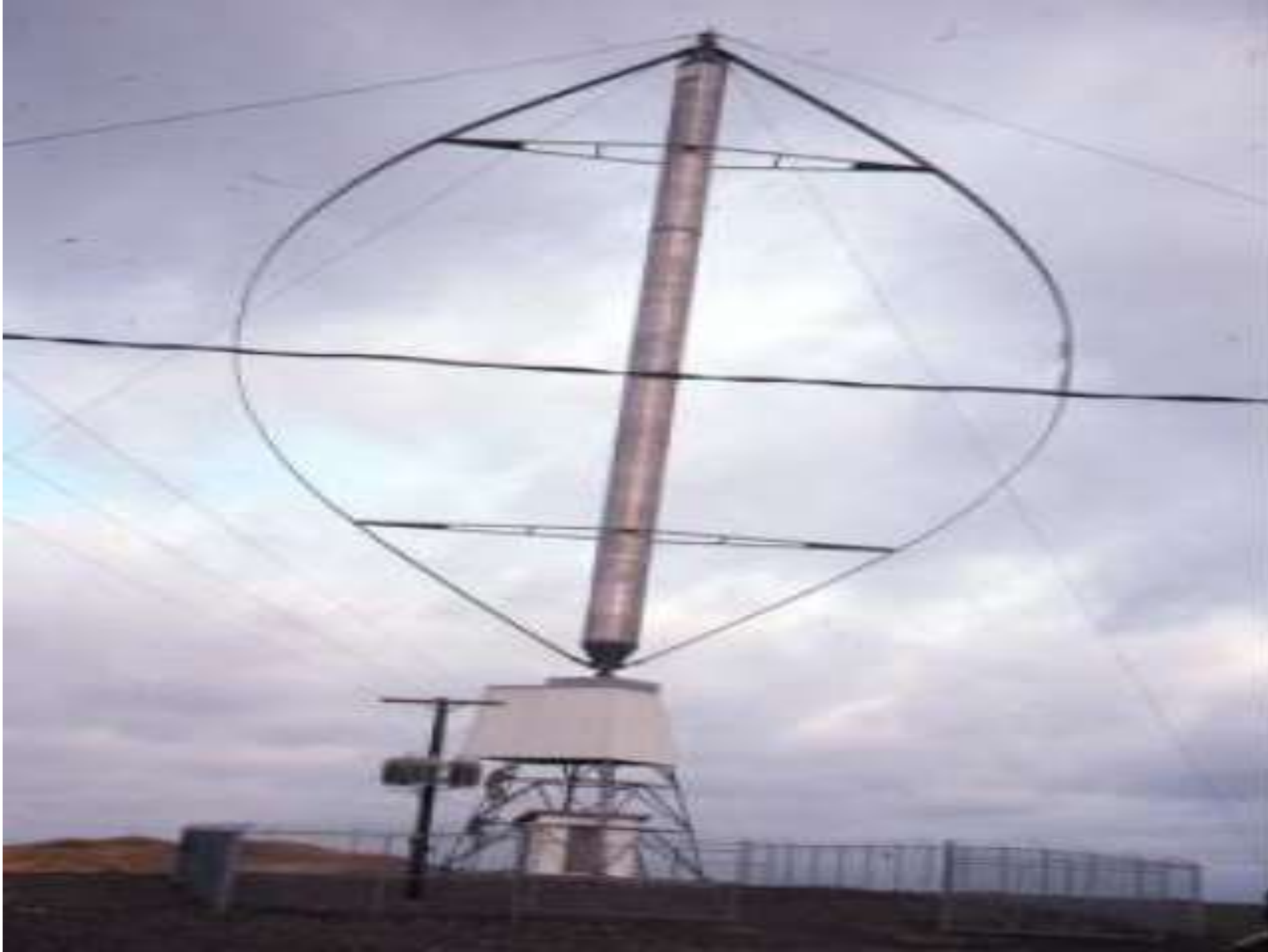




Wind Turbine Configurations

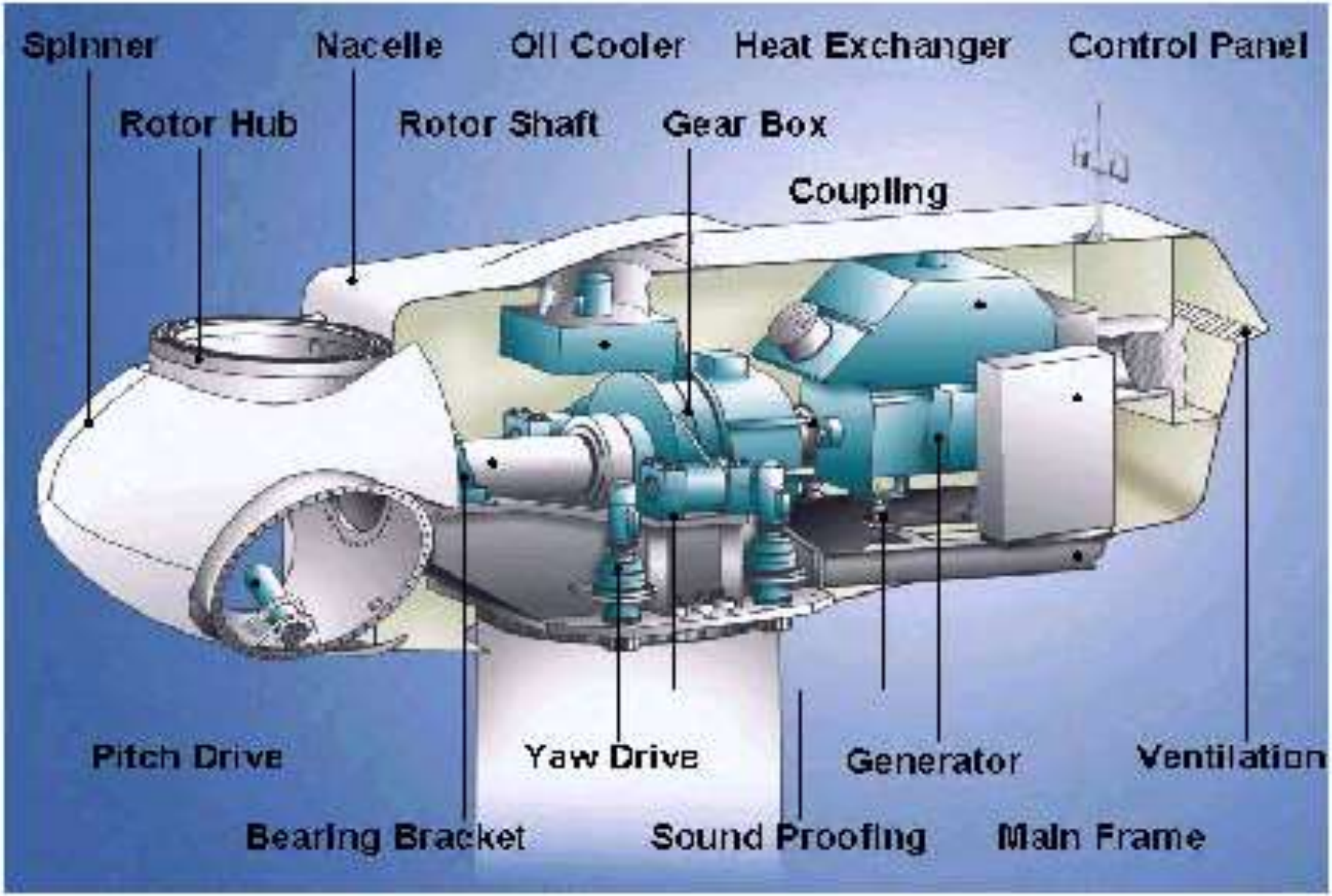
Main Components of a wind turbine





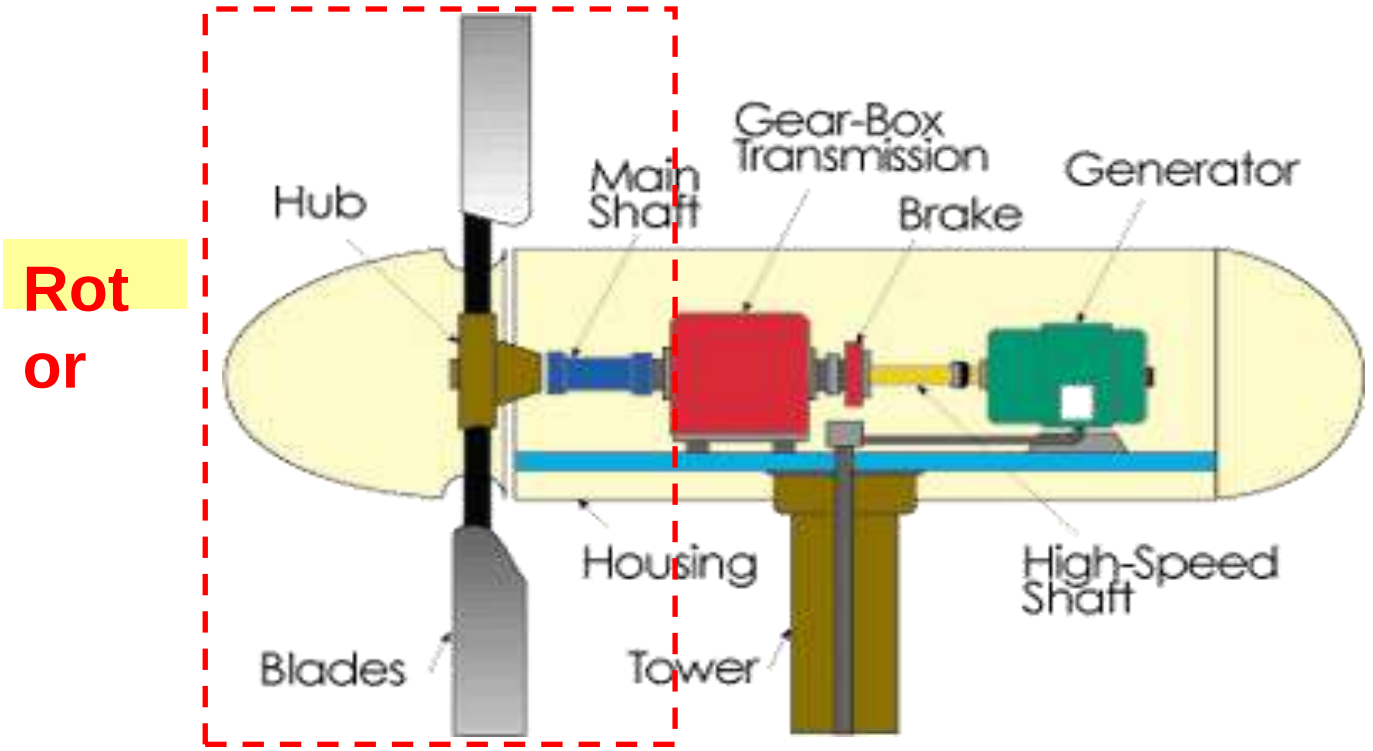
sources. In 1978, National Research Council, the Department of Energy, Mines (now Natural Resources Canada), and Public Works Canada (now Public Works and Government Services Canada) constructed a model home at Rideau falls in Ottawa, Ontario furnished with solar and wind power to educate the visitors about these new technologies. In 1983 and the Vertical Axis Wind Turbine was donated to the Canada Science and Technology Museum.

Components - Turbine Layout

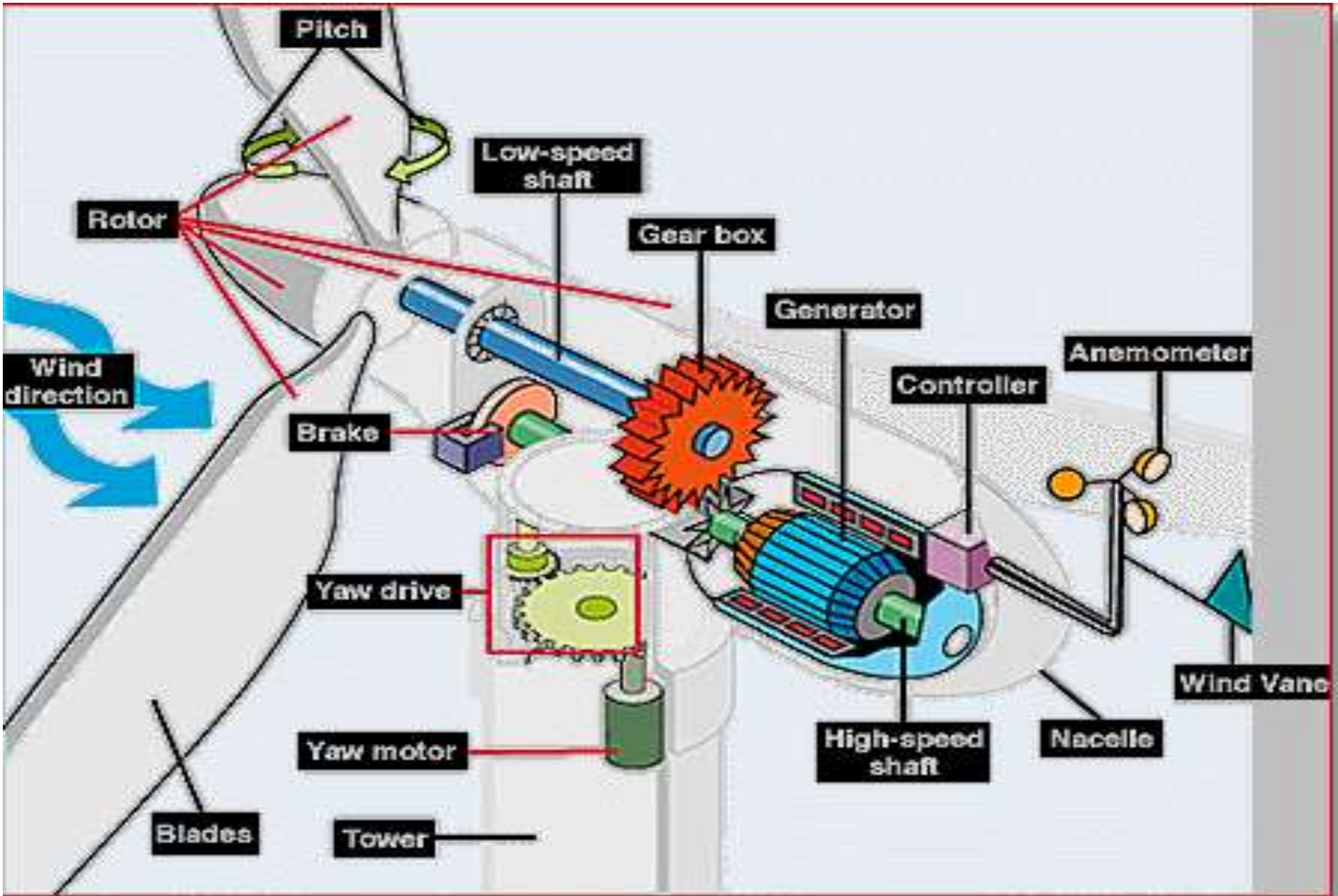


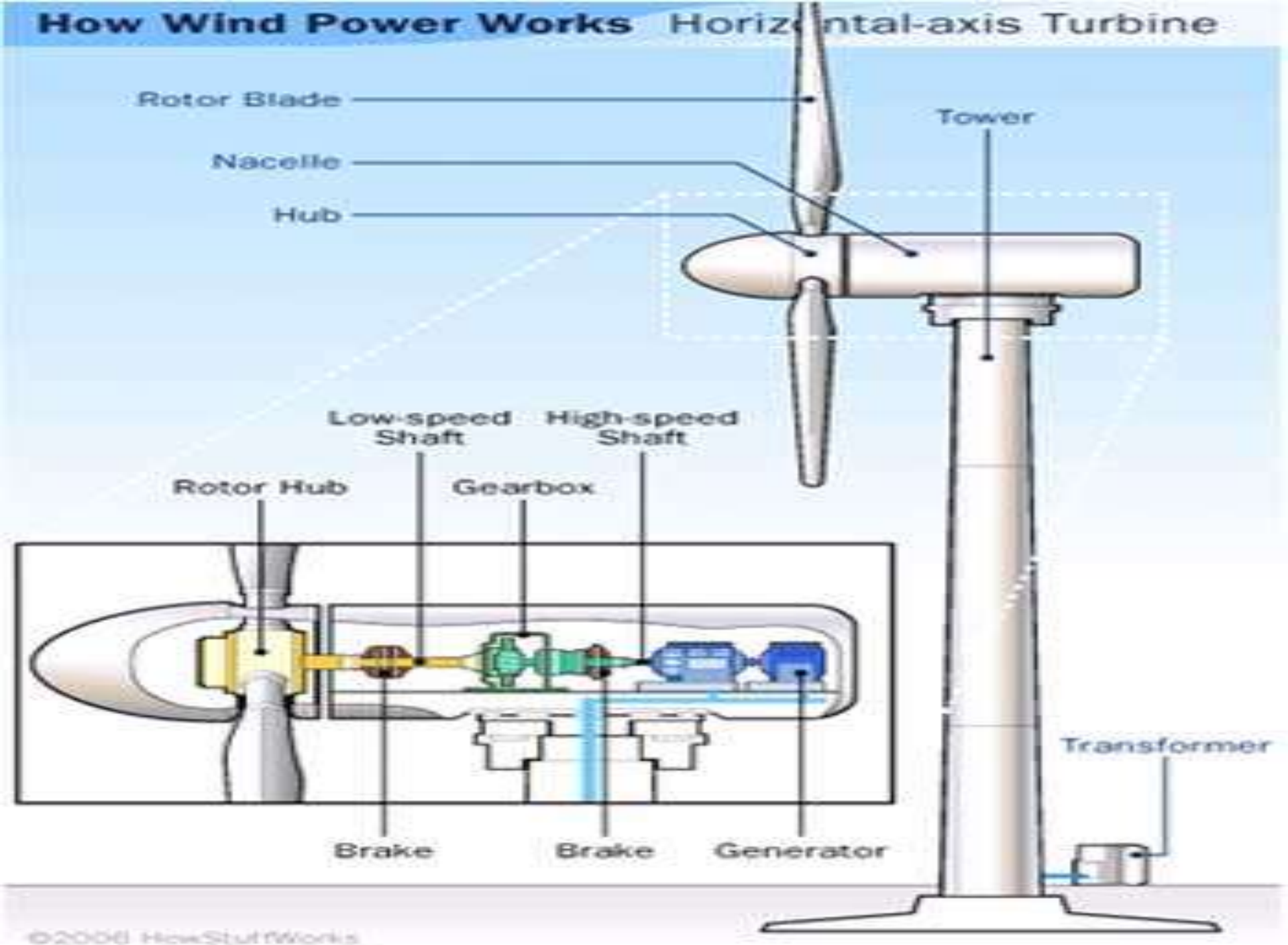
Common HAWT Construction

- **Blades are connected to a hub, which is connected to a shaft**
- **Rotational speed will depend on blade geometry, number of blades, and wind speed (40 to 400 revolutions per minute typical speed range)**
- **Gear box needed to increase speed to 1200-1800 RPM for generator**



A Typical HAWT




How Wind Power Works
Horizontal-axis Turbine
Rotor Blade
Nacelle
Hub
Tower
Low-speed Shaft
High-speed Shaft
Rotor Hub
Gearbox
Brake
Brake
Generator
Transformer
©2006 HowStuffWorks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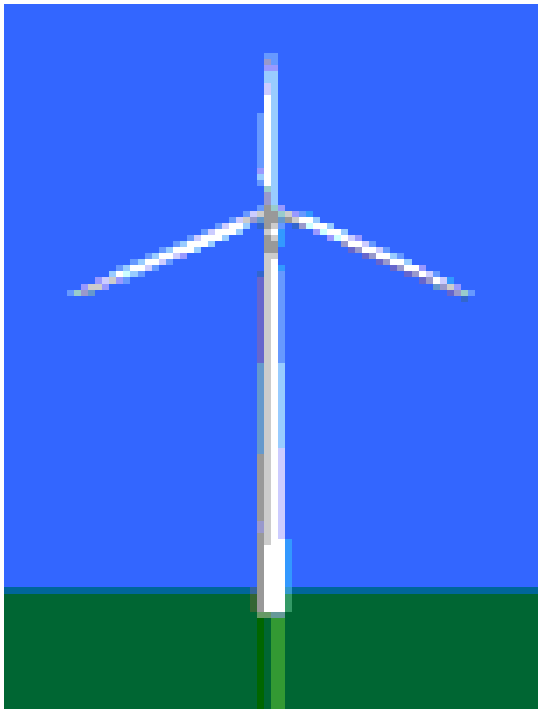
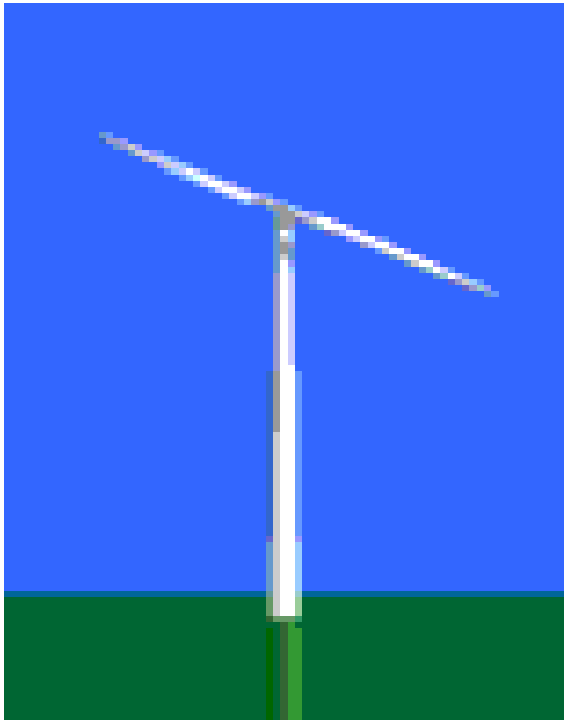
Vestas

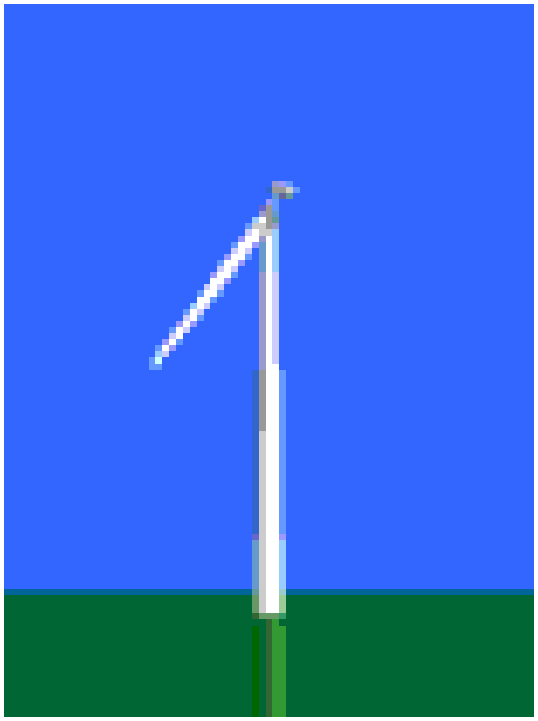
Wind Turbines: Number of Blades

❑ Most common design is the three-bladed turbine. The most important reason is the **stability** of the turbine. A rotor with an odd number of rotor blades (and at least three blades) can be considered to be similar to a disc when calculating the dynamic properties of the machine.

❑ A rotor with an even number of blades will give stability problems for a machine with a stiff structure. The reason is that at the very moment when the uppermost blade bends backwards, because it gets the maximum power from the wind, the lowermost blade passes into the wind shade in front of the tower.





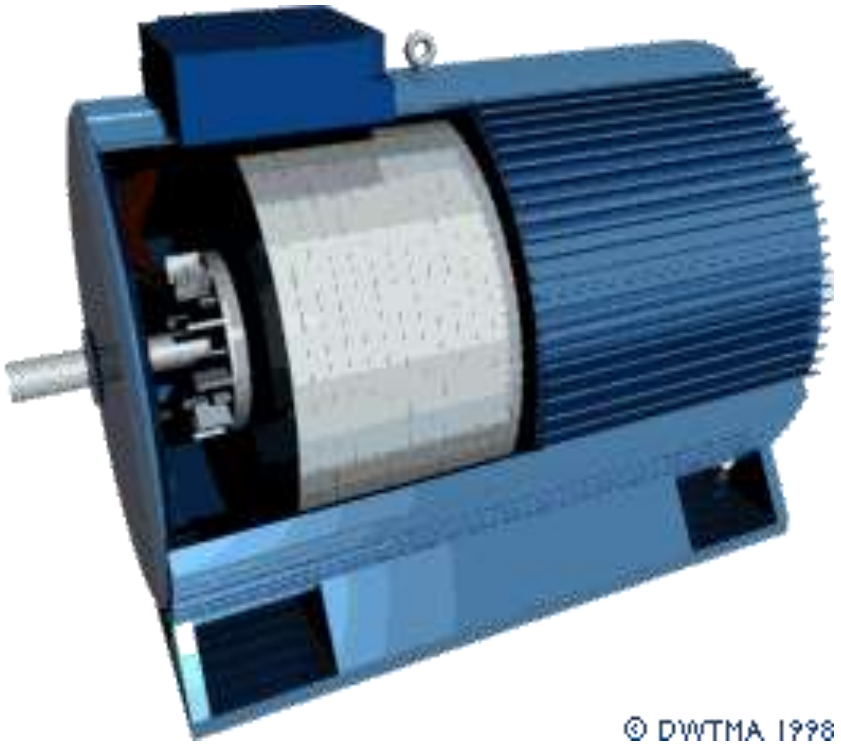


• Wind power generators convert wind energy (mechanical energy) to electrical energy.

• The generator is attached at one end to the wind turbine, which provides the mechanical energy.

• At the other end, the generator is connected to the electrical grid.

• The generator needs to have a cooling system to make sure there is no overheating.



Wind power generator

SMALL GENERATORS:

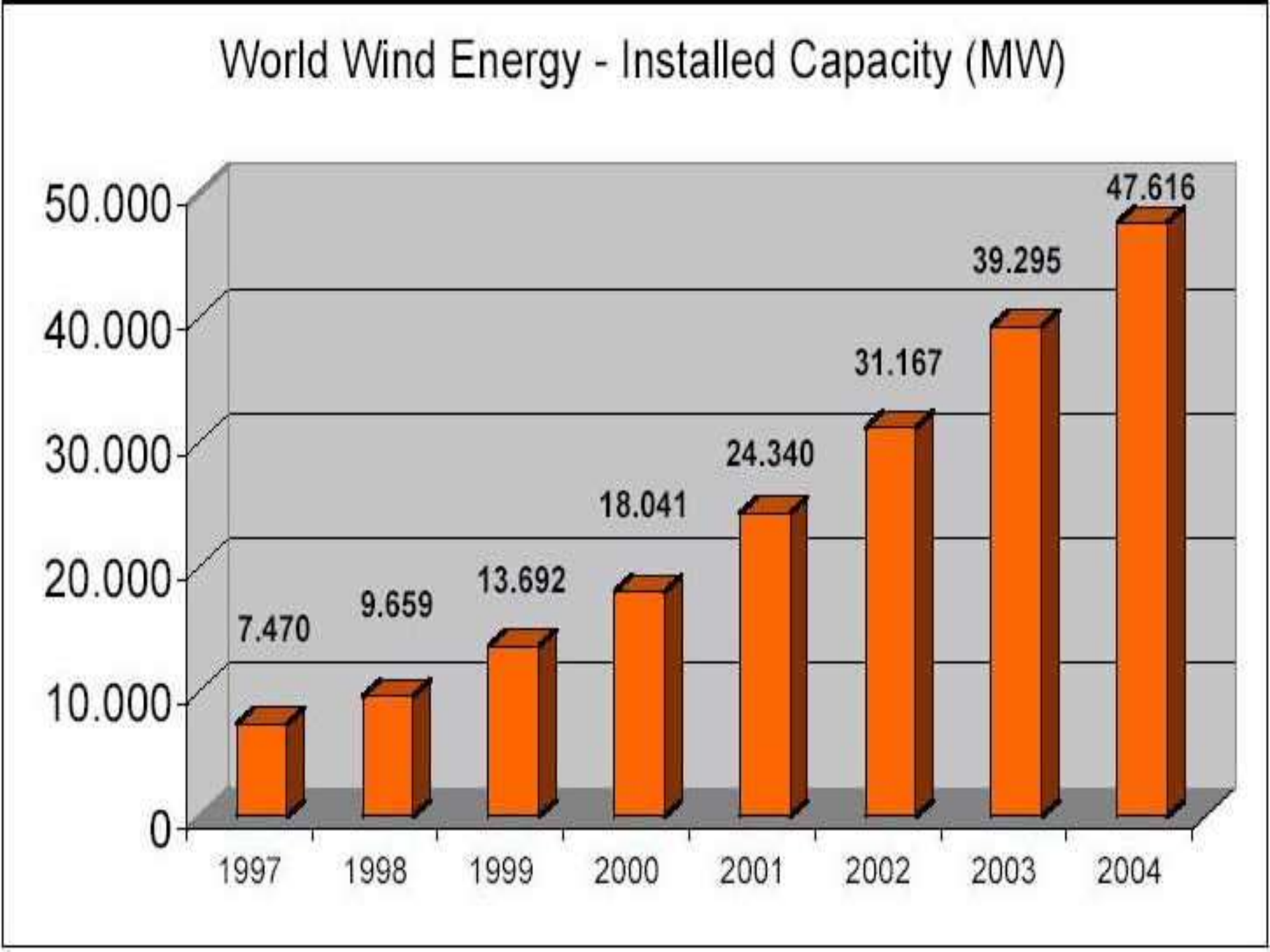
- Require less force to turn than a larger ones, but give much lower power output.
- Less efficient

i.e.. If you fit a large wind turbine rotor with a small generator it will be producing electricity during many hours of the year, but it will capture only a small part of the energy content of the wind at high wind speeds.

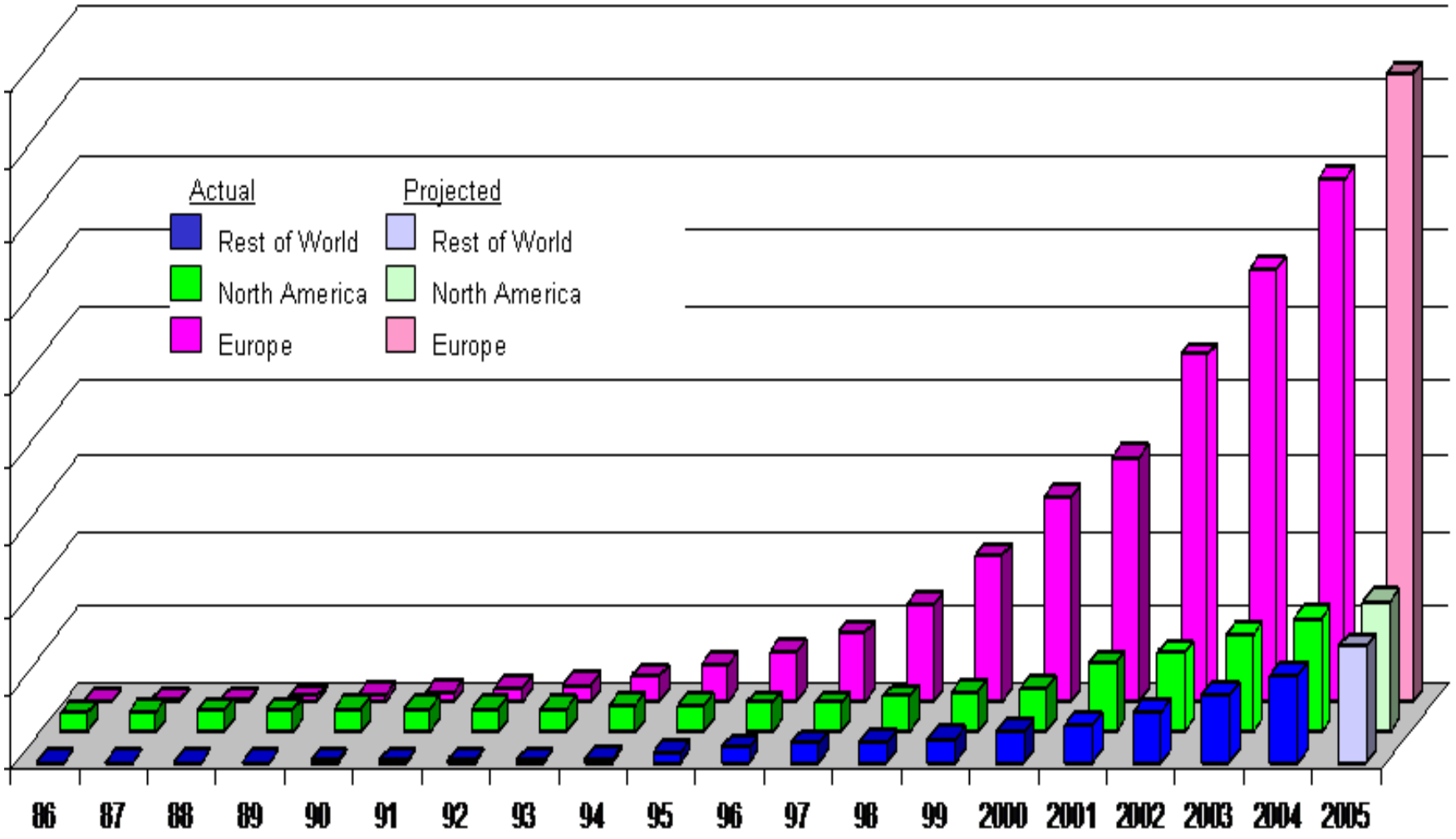
LARGE GENERATORS:

- Very efficient at high wind speeds, but unable to turn at low wind speeds.

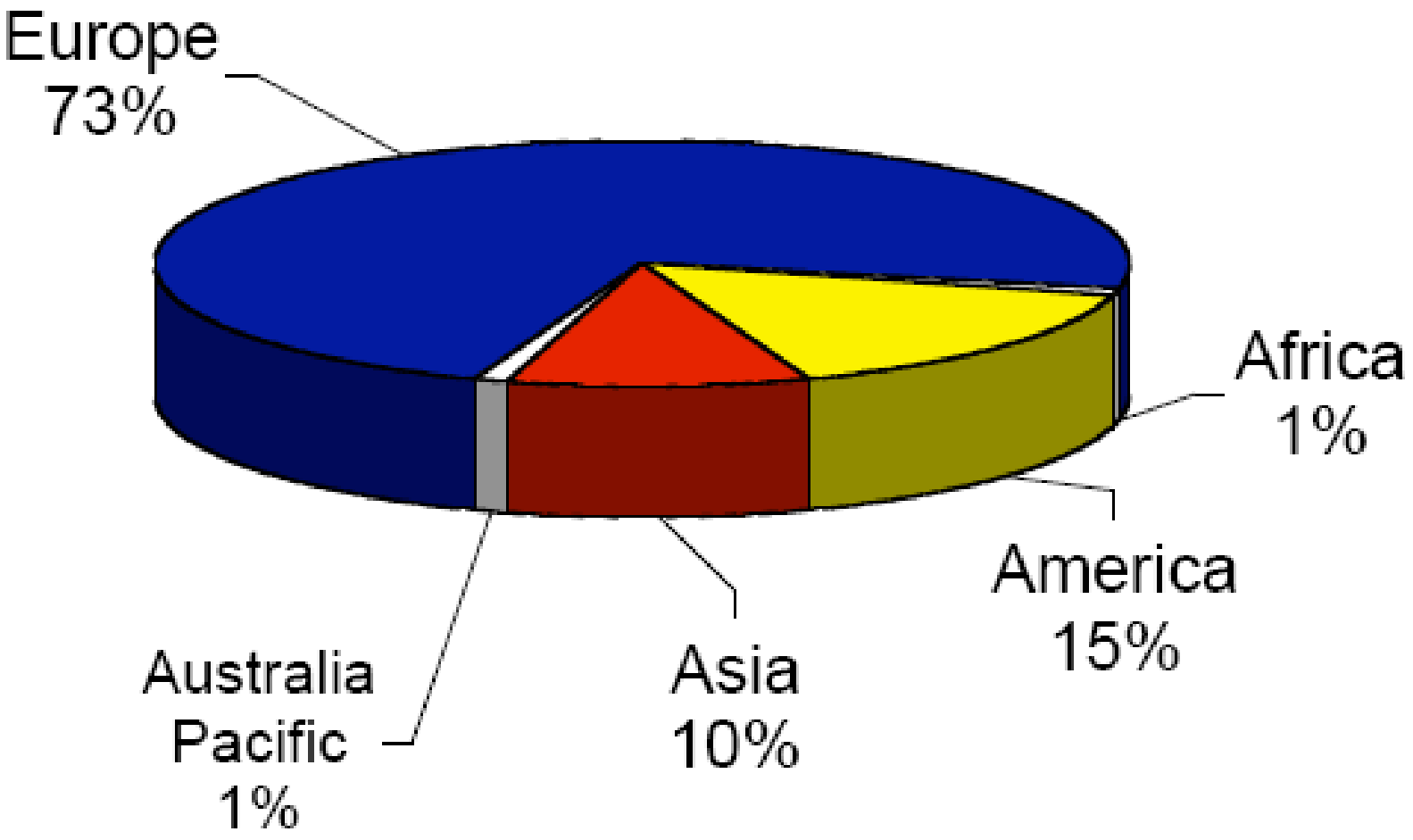
i.e.. If the generator has larger coils, and/or a stronger internal magnet, it will require more force (mechanical) to start in motion.


World Wind Energy - Installed Capacity (MW)
50.000
40.000
30.000
20.000
10.000
0
7.470
9.659
13.692
18.041
24.340
31.167
39.295
47.616
1997
1998
1999
2000
2001
2002
2003
2004

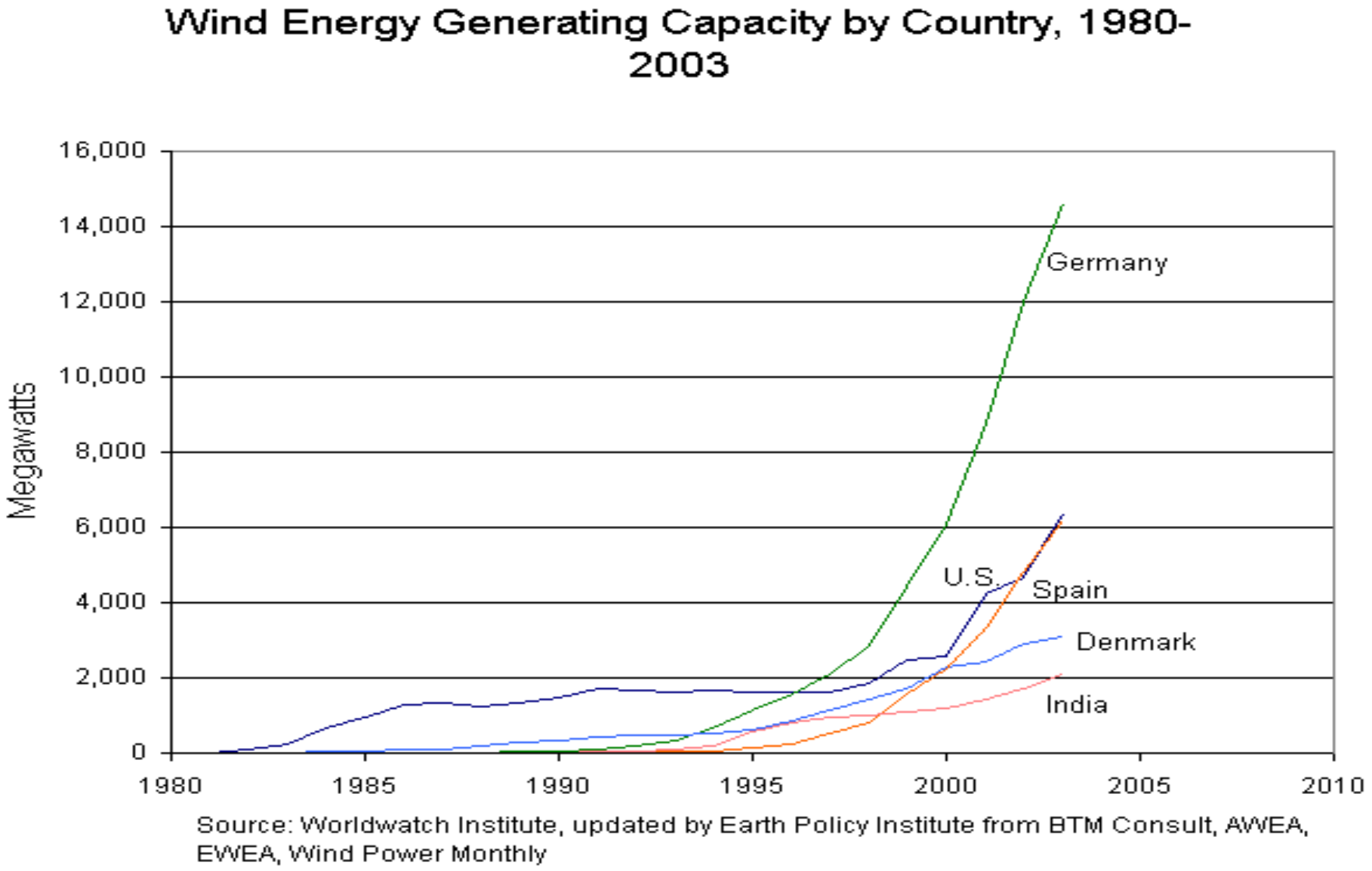
Growth of Wind Energy



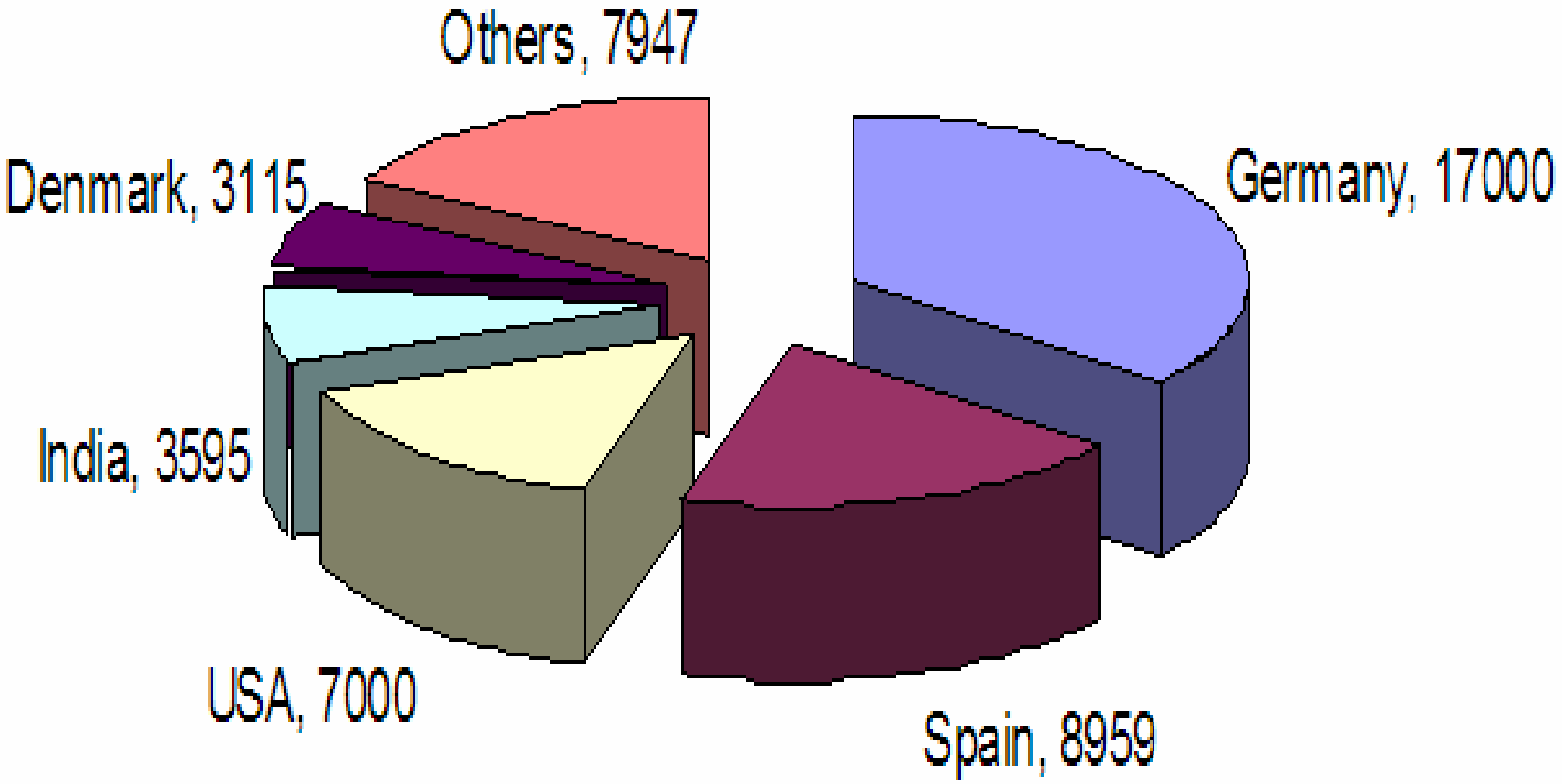
Wind Energy – Installed Capacity by Continent 2004 (total: 47,6 GW)



Wind Energy generating capacity by country, 1980-2003

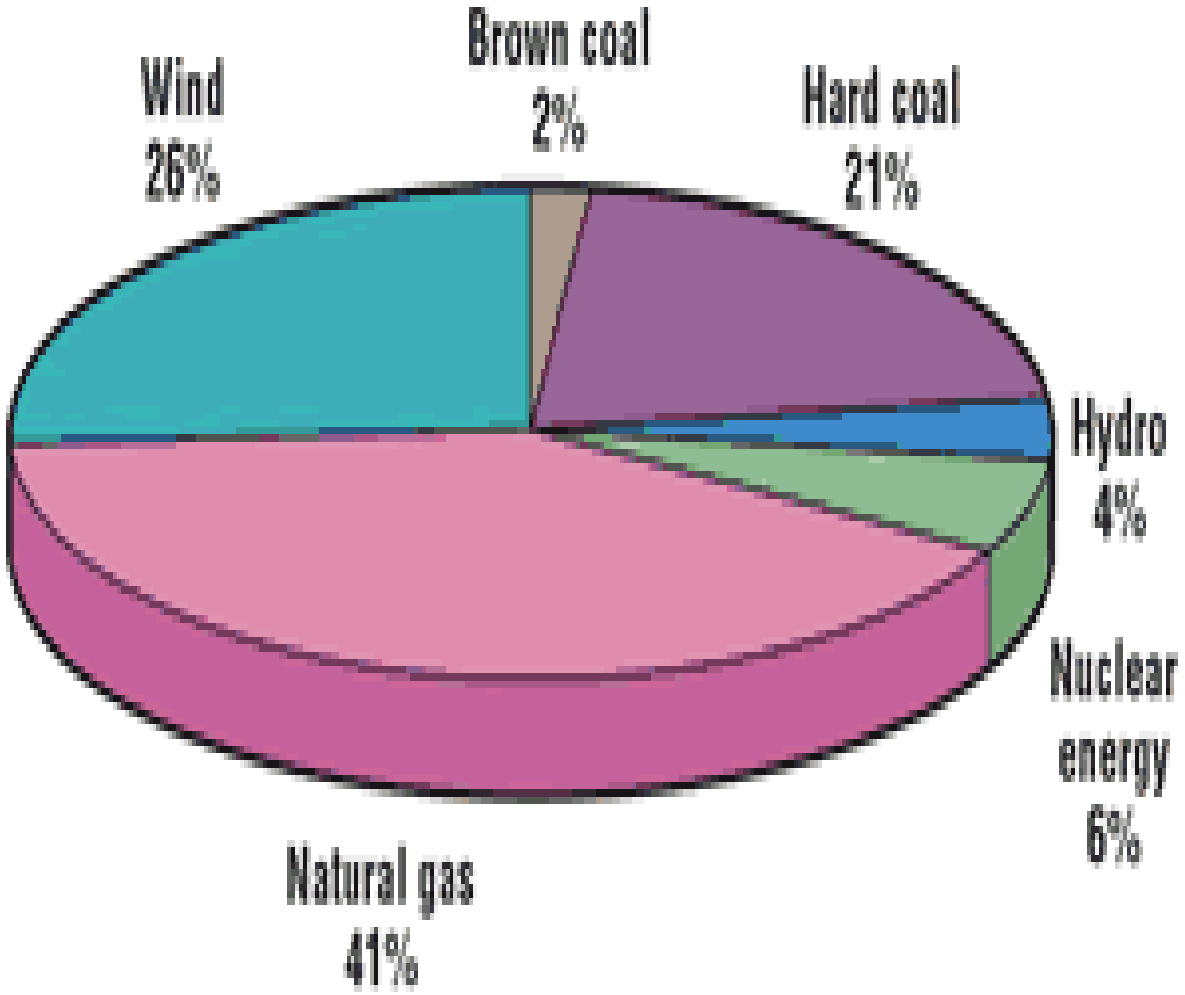


Installed Capacity (MW) in 2005



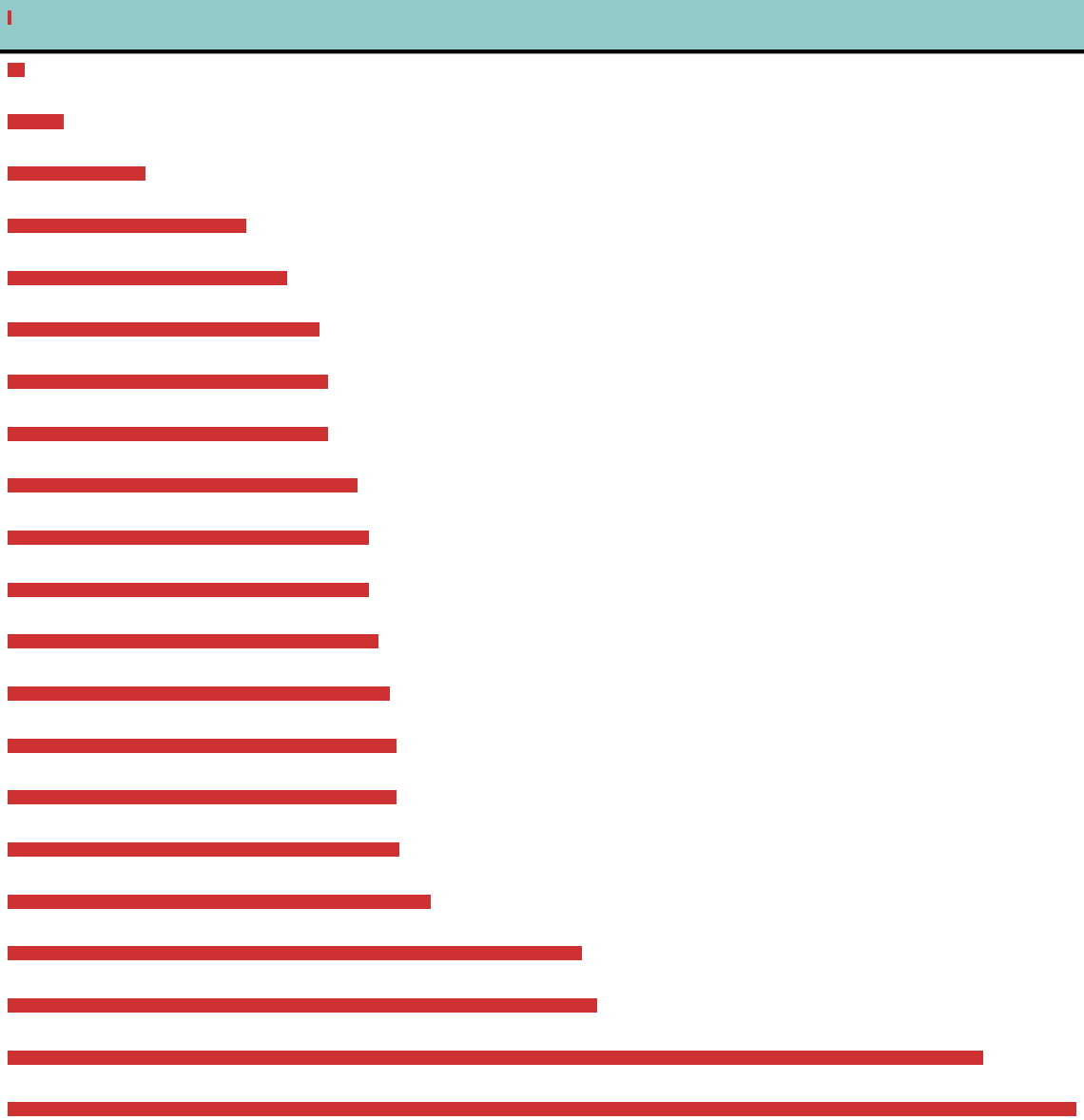
Germany now and 2020

- By 2020 it is expected to go up to 26%



U.S. Installed Capacity (Megawatts) 1981-2002

Year	MW
1981	10
1982	70
1983	240
1984	597
1985	1,039
1986	1,222
1987	1,356
1988	1,396
1989	1,403
1990	1,525
1991	1,575
1992	1,584
1993	1,617
1994	1,656
1995	1,697
1996	1,698
1997	1,706
1998	1,848
1999	2,511
2000	2,578
2001	4,275
2002	*4,685

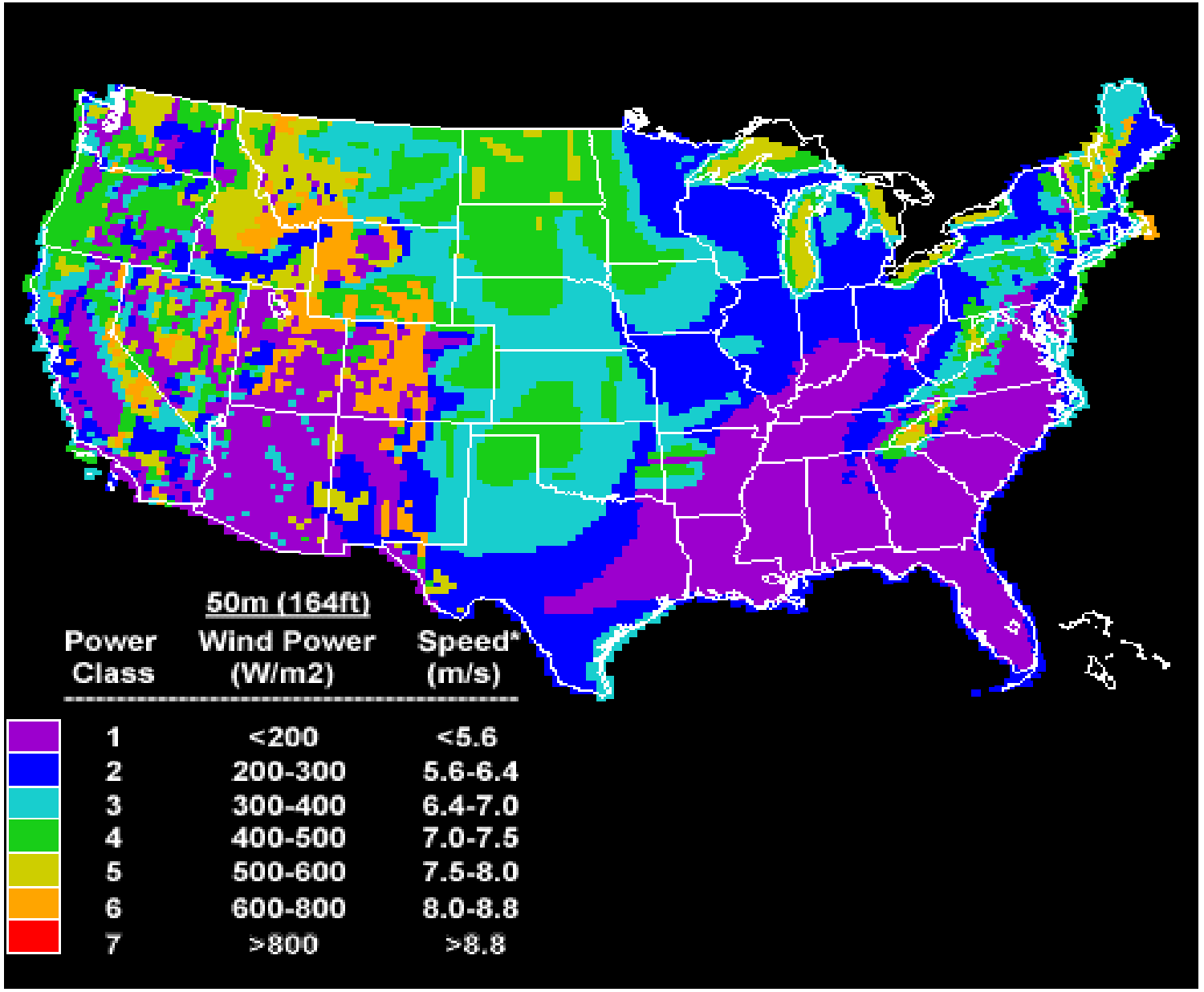


U.S. Wind Energy Use

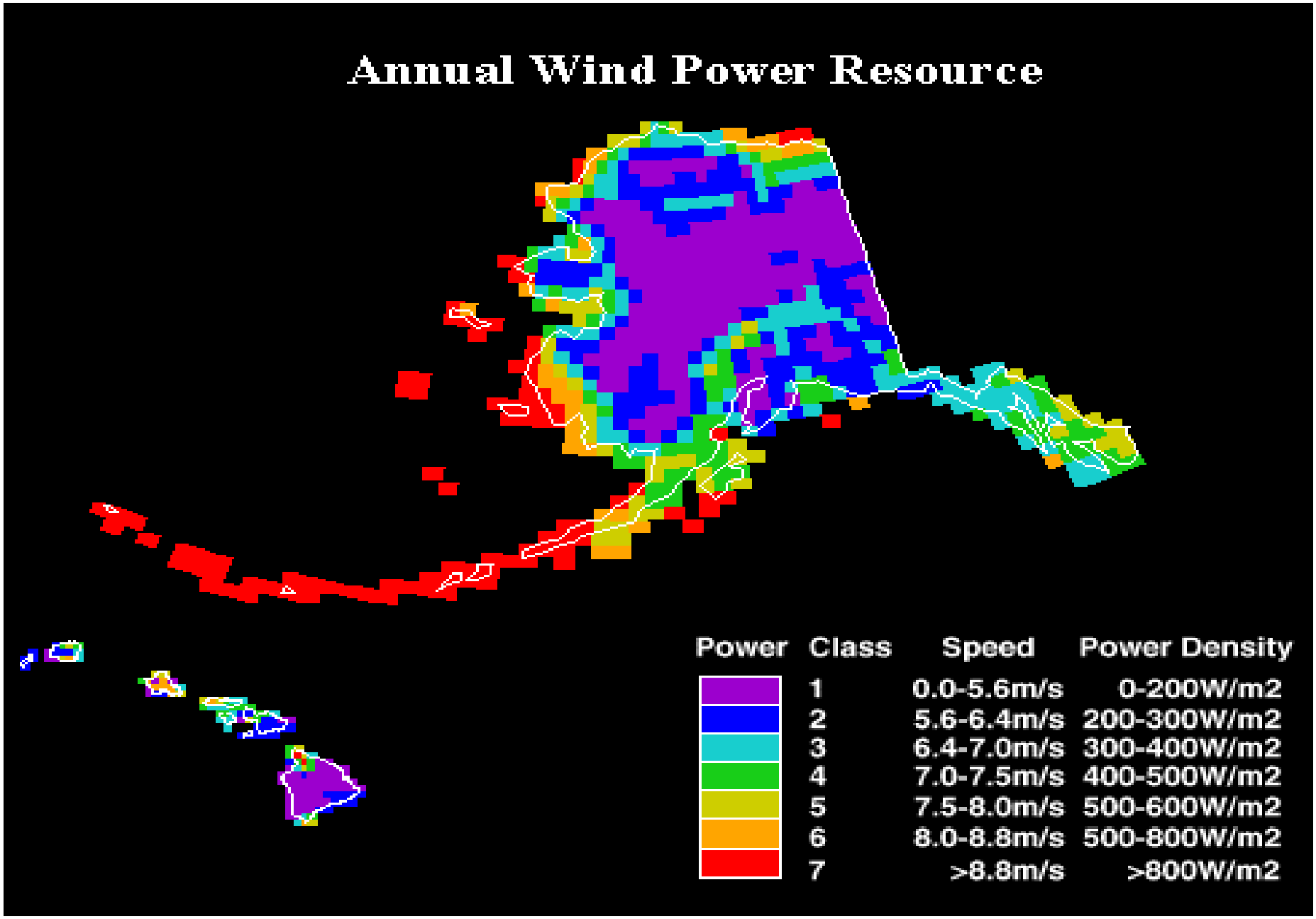
- The U.S. has more than 1,600 MW of installed capacity and produces about *3 billion KWh of electricity each year.*

- More than *90 percent* of this power is produced by three wind farms in California (Altamont Pass, Tehachapi and Palm Springs).

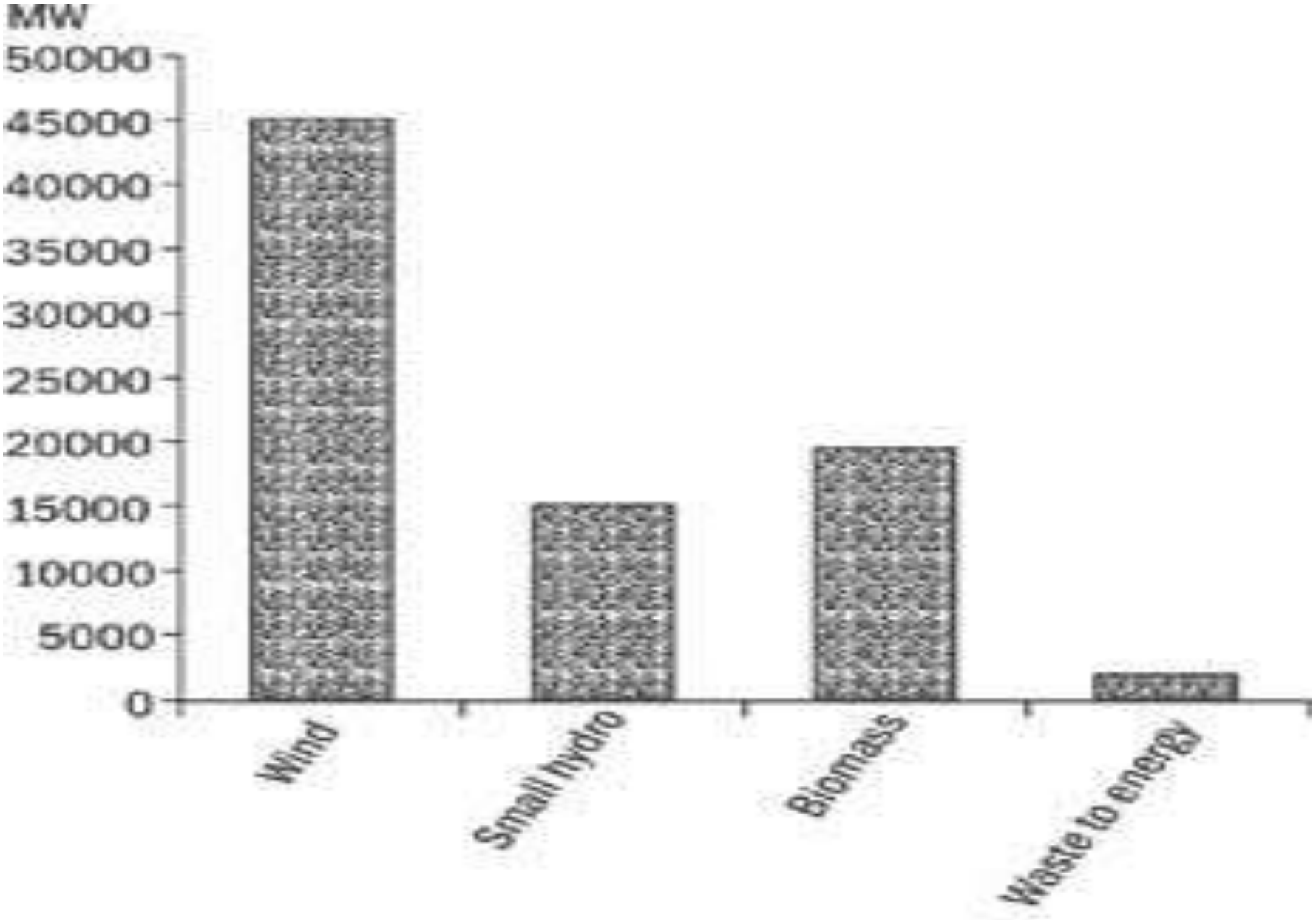
Annual Wind Power Resource - US Mainland



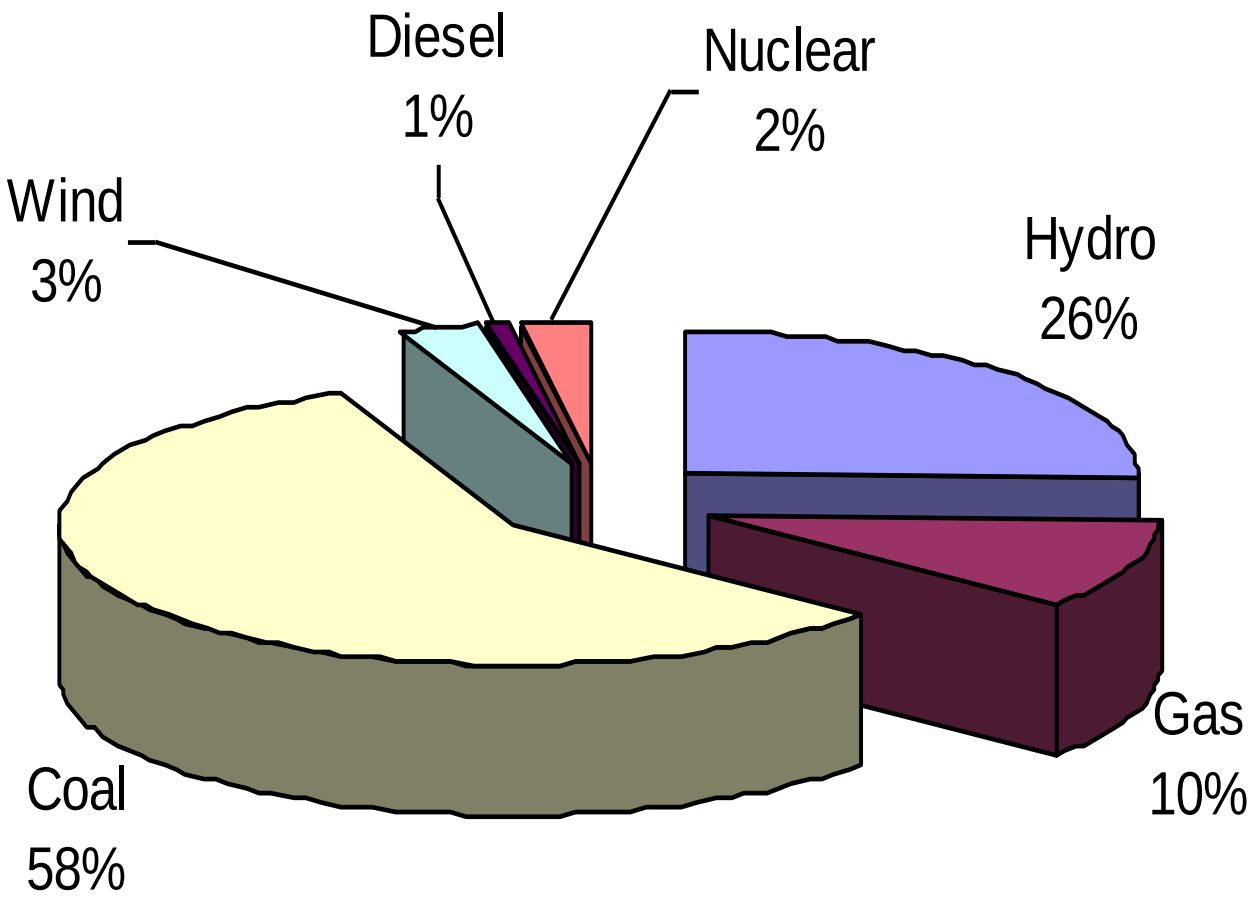
Annual Wind Power Resource - Alaska and Hawaii

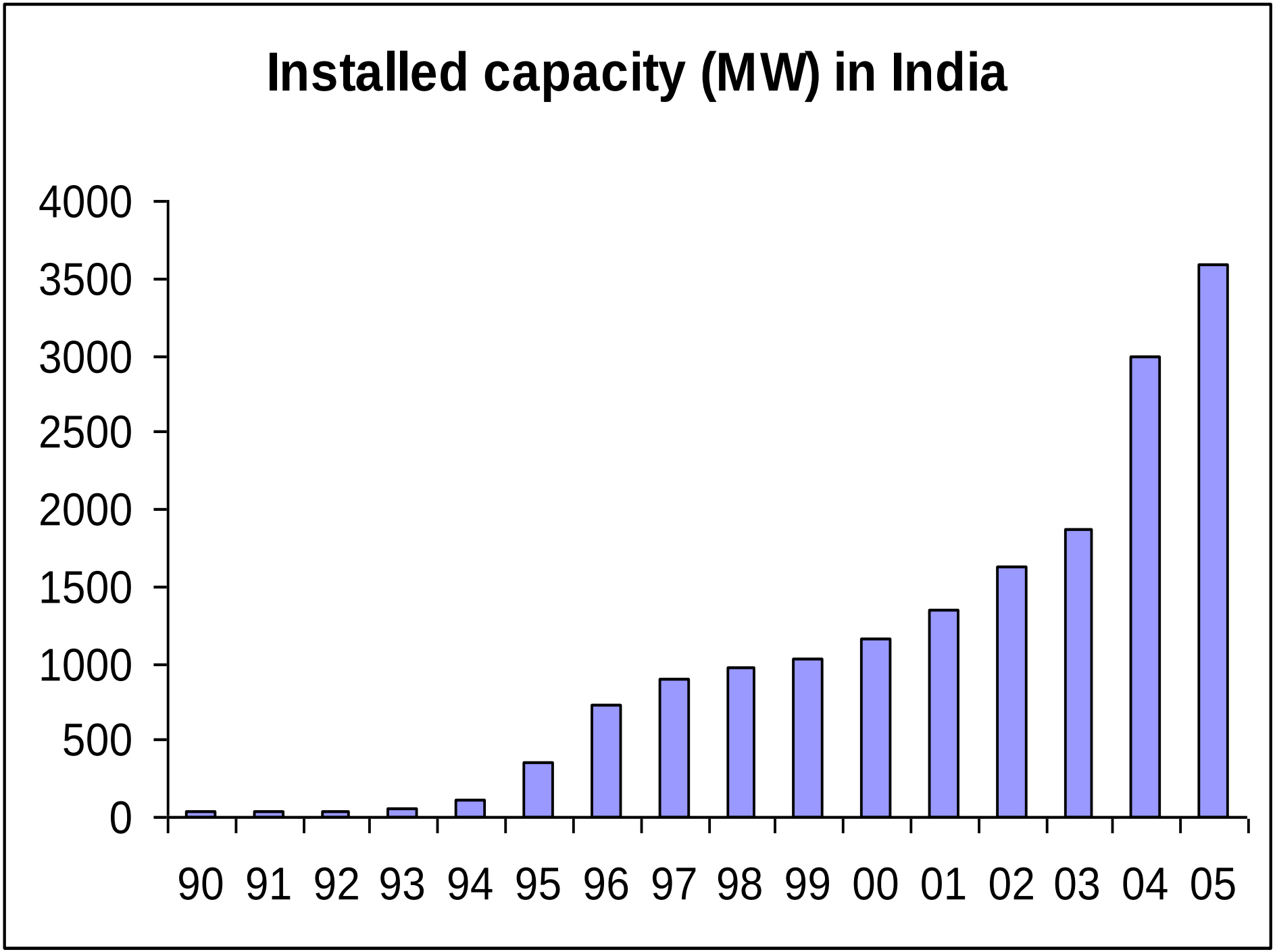


Available potential in India



All India Fuel wise Installed Capacity, 2004




Installed capacity (MW) in India
4000
3500
3000
2500
2000
1500
1000
500
0
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05

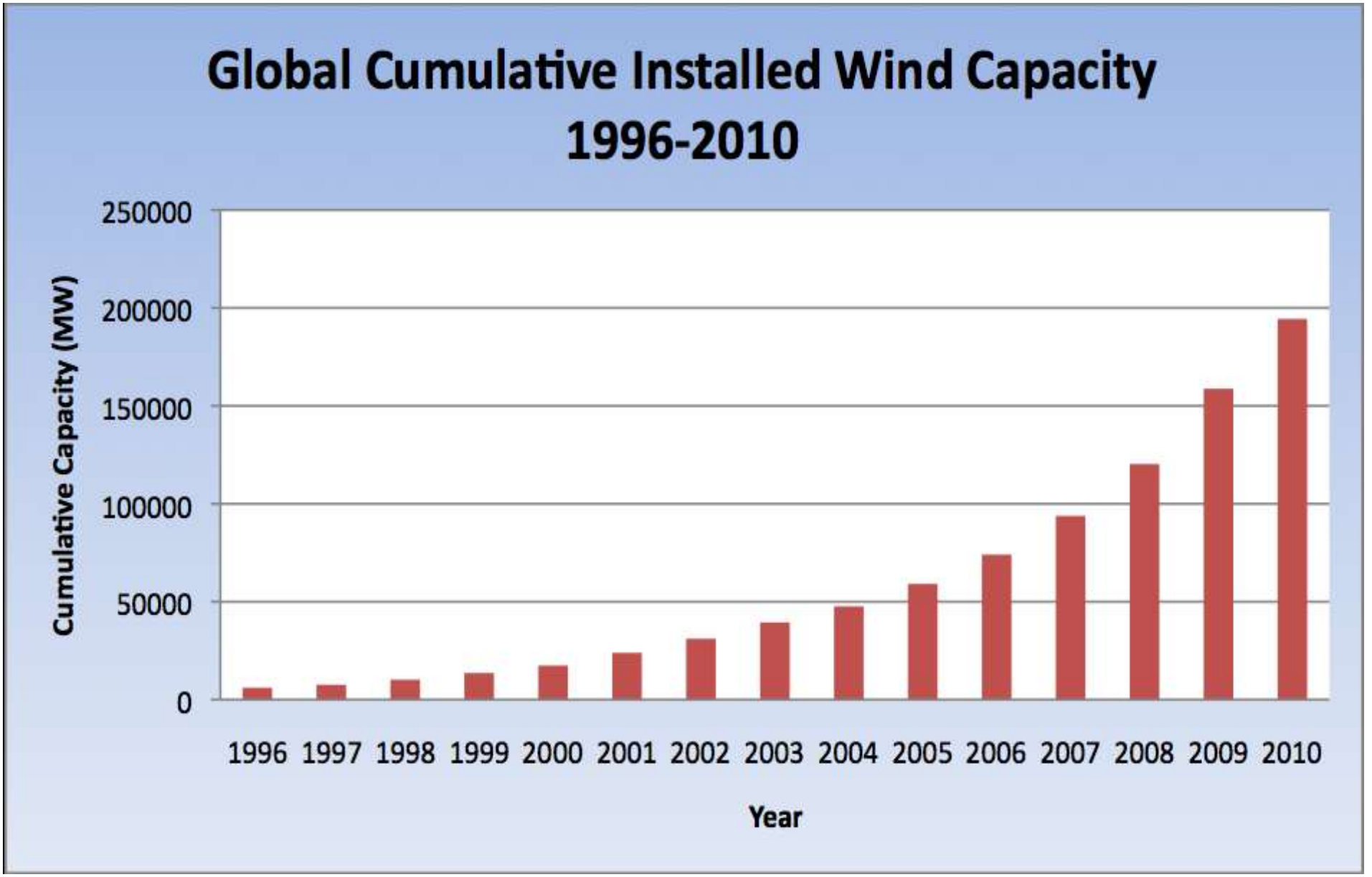
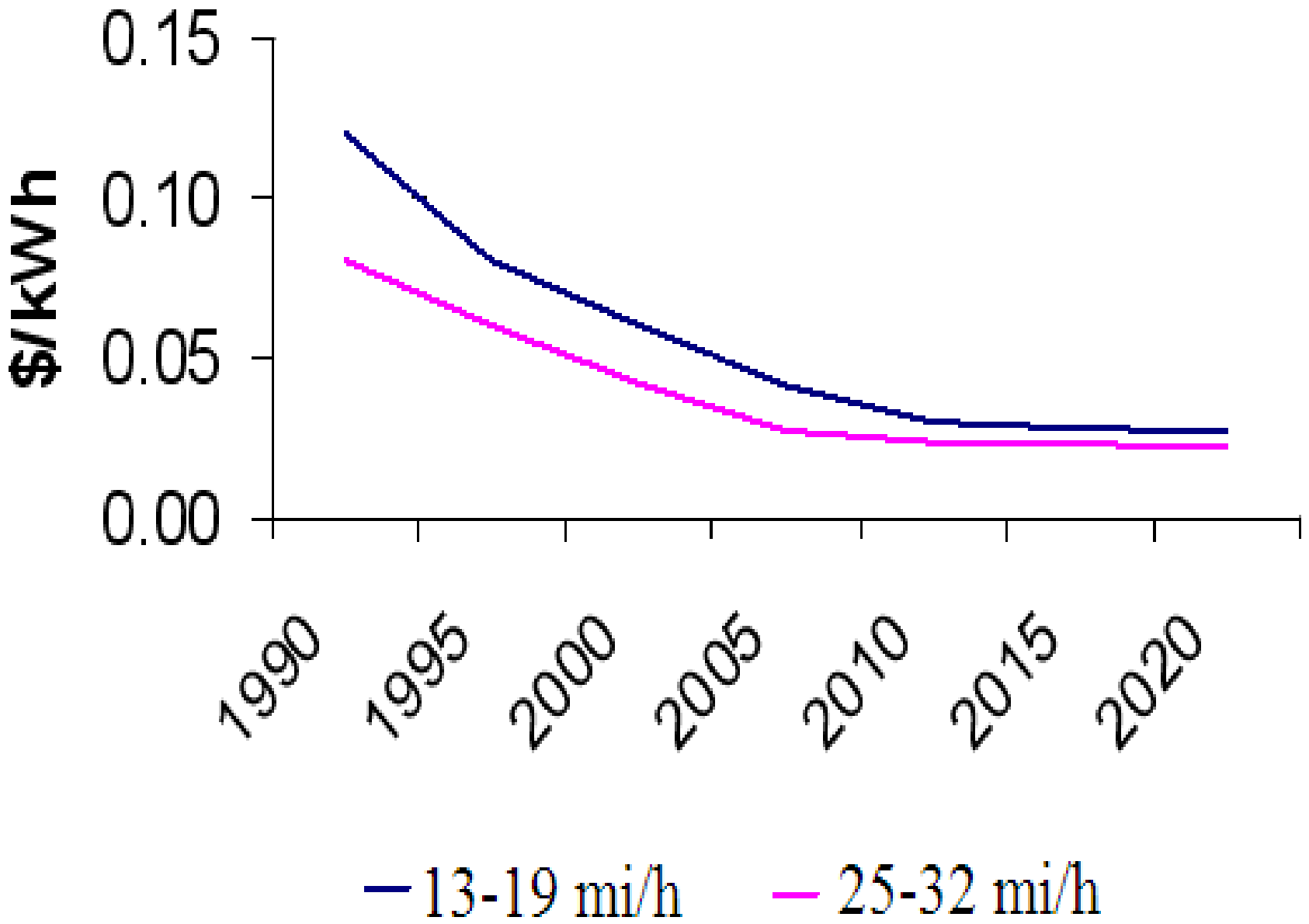


Figure 6: Global Cumulative Installed Wind Capacity 1996-2010
Information from (GWEC, 2010, p.14)

Cost of Wind Energy



Energy Cost Trend

1979: 40 cents/kWh

2000:
4 - 6 cents/kWh

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements

2004:
3 – 4.5 cents/kWh

- **A typical 600 kW turbine costs about $450,000.**
- **Installation costs are typically $125,000.**
- **Therefore, the total costs will be about $575,000.**

- **The average price for large, modern wind farms is around $1,000 per kilowatt electrical power installed.**

- **Modern wind turbines are designed to work for some 120,000 hours of operation throughout their design lifetime of 20 years. (13.7 years non-stop)**

- **Maintenance costs are about 1.5-2.0 percent of the original cost, per year.**

Offshore turbines

- More wind speeds
- Less noise pollution
- Less visual impact
- Difficult to install and maintain
- Energy losses due long distance transport

Benefits of Wind Power

- **Environmental benefits**
  - **No emissions**
  - **No fuel needed**
  - **Remote locations**

Limitations of Wind Power

- Power density is very low.
  - Needs a very large number of wind mills to produce modest amounts of power.
- Cost.
- Environmental costs.
  - material and maintenance costs.
  - Noise, birds and appearance.
- Cannot meet large scale and transportation energy needs.

Thank you