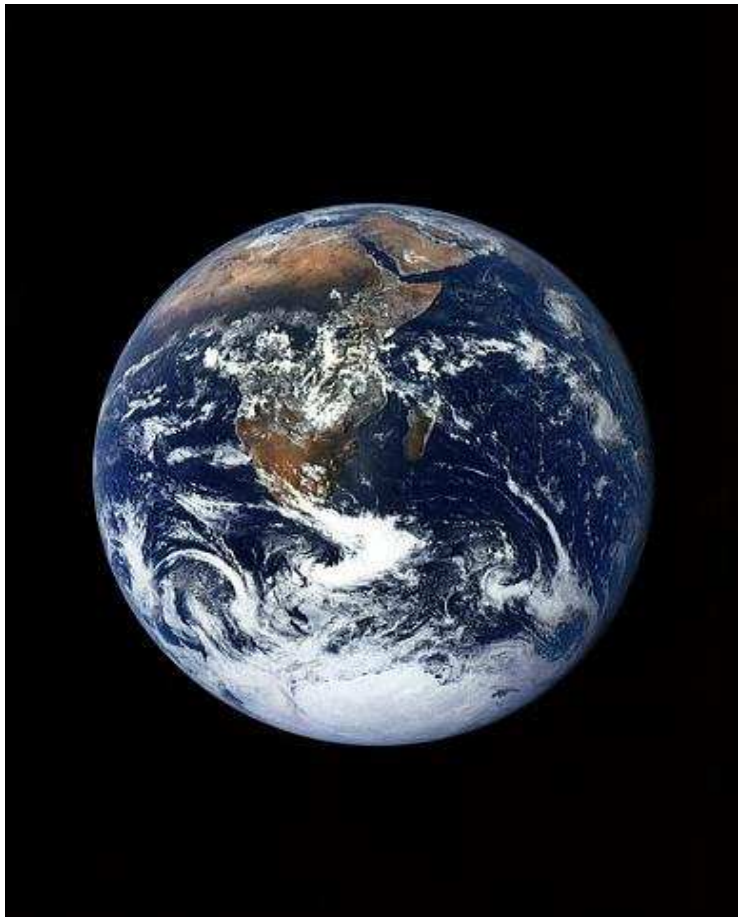
EEE124 - Lecture Content - DAS

- Wind power Lecture:
  - Introduction
  - Physics of Wind Power
  - Generator Topologies
  - Location Issues
  - Power Availability



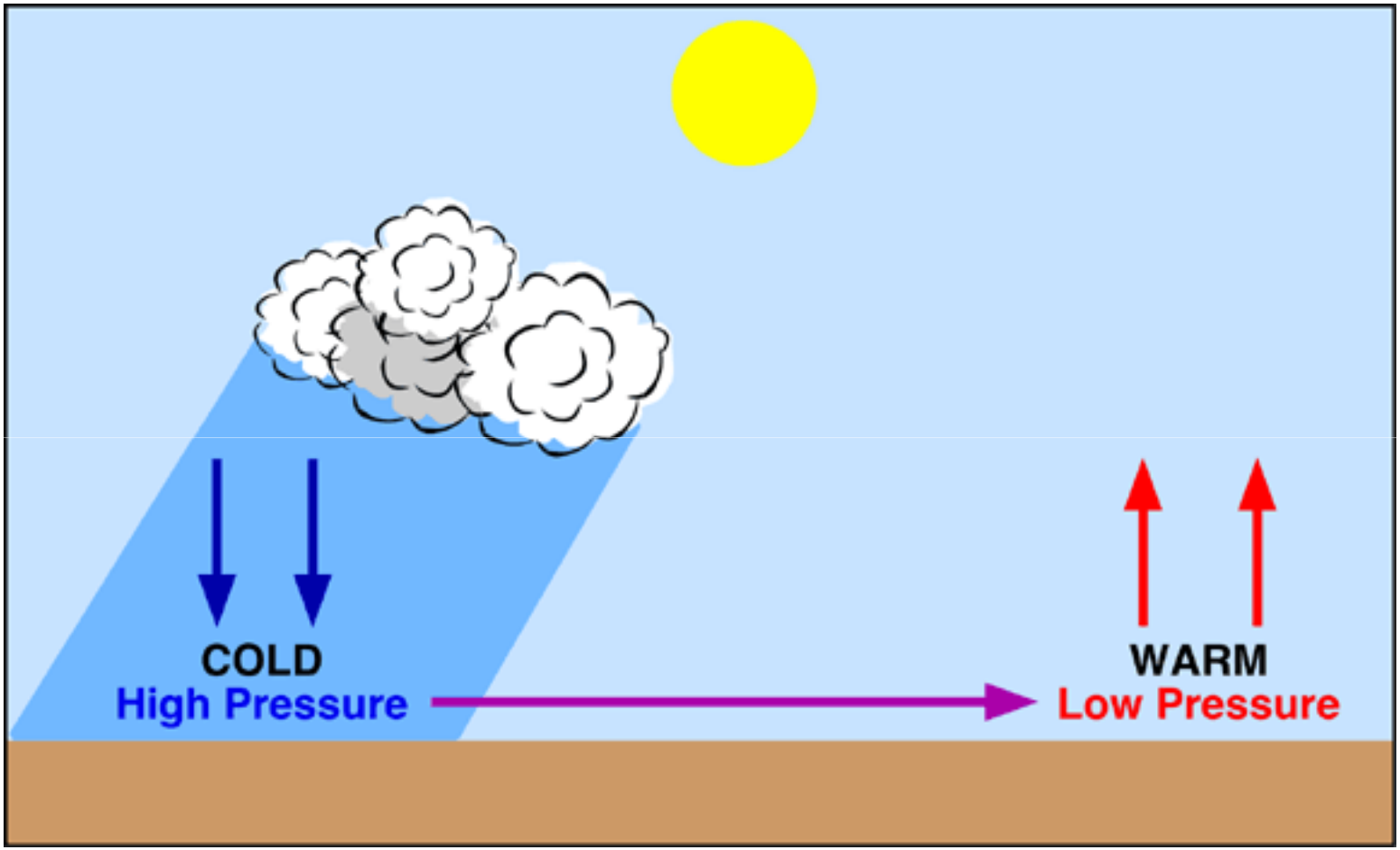
Electricity!

Electricity is energy transported by the motion of electrons

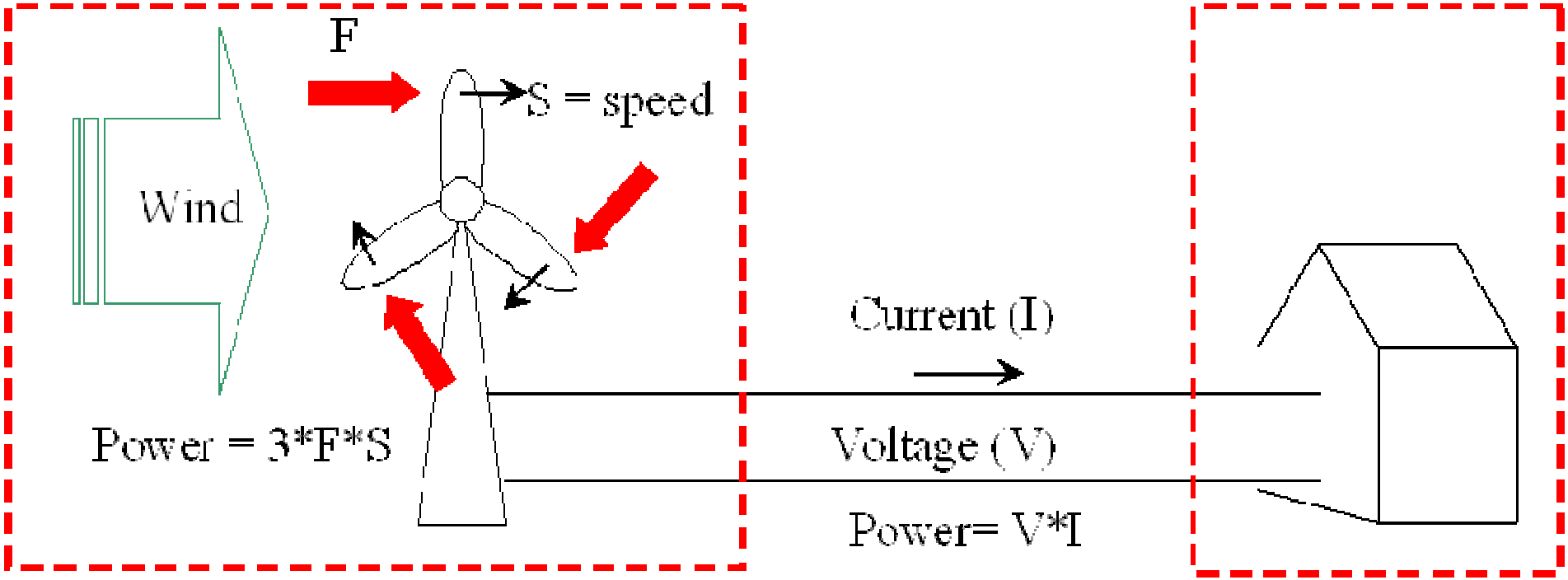
Energy cannot be created or destroyed, therefore we do not make electricity, we CONVERT other energy sources into electrical energy

Conversion is the name of the game

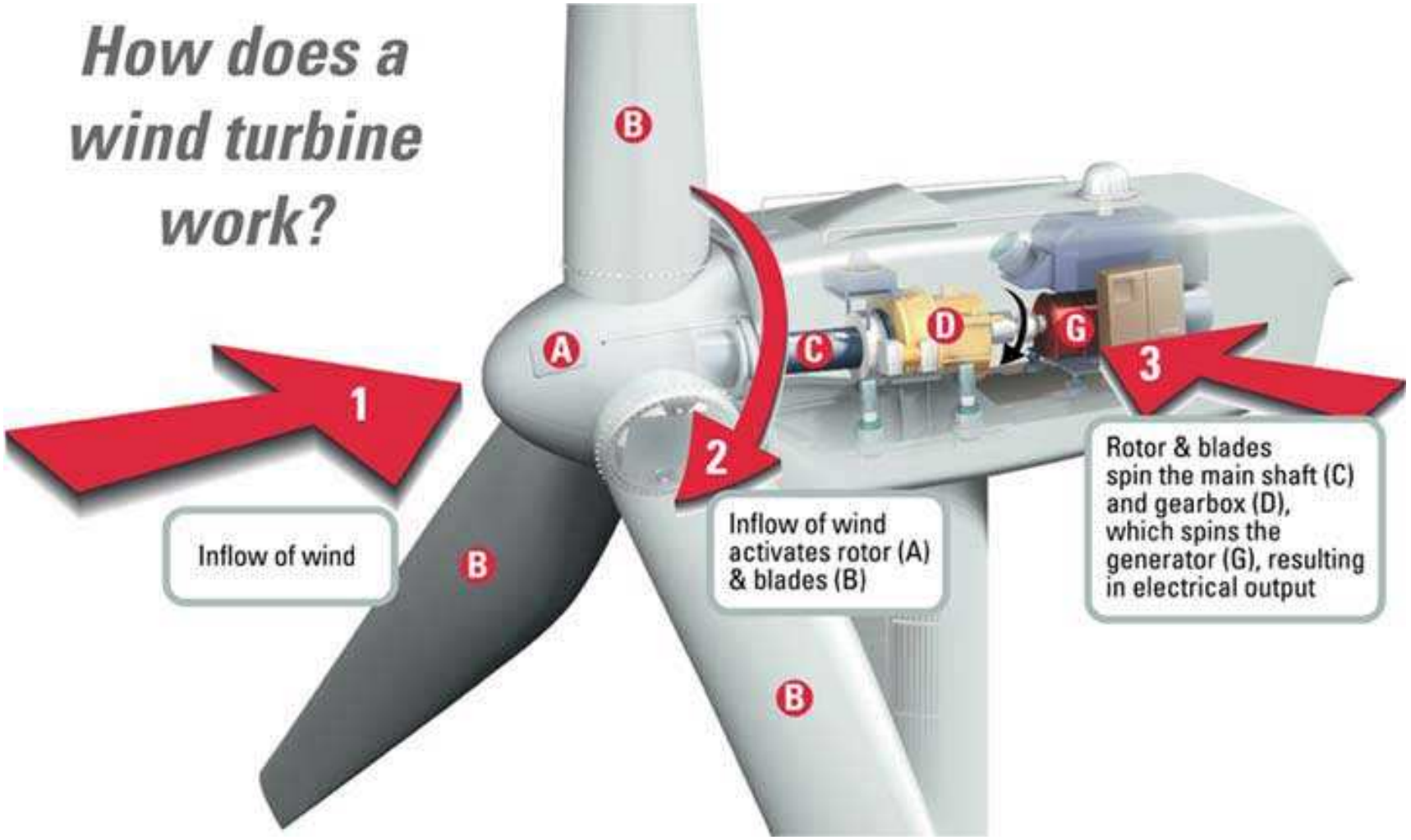
Solar power!



Wind Power to Electricity



How does it work?



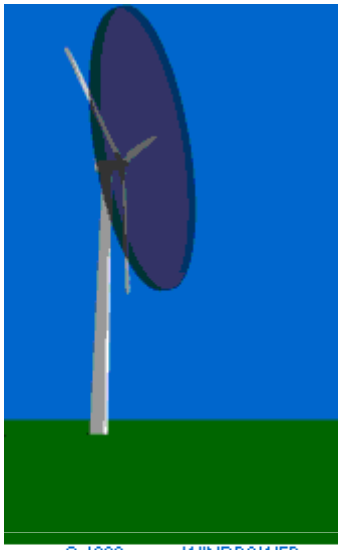
Wind Power – Energy Available

Kinetic Energy = Work = ½mV^2

Where:

M= mass of moving object

V = velocity of moving object



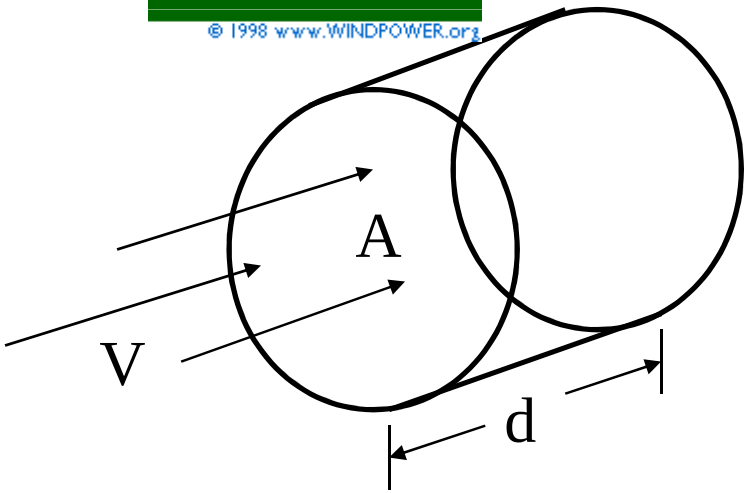
What is the mass of moving air?

= density (ρ) x volume (Area x distance)

= ρ x A x d

= (kg/m^3) (m^2) (m)

= kg



Wind Power – Energy Extraction

Power in the wind

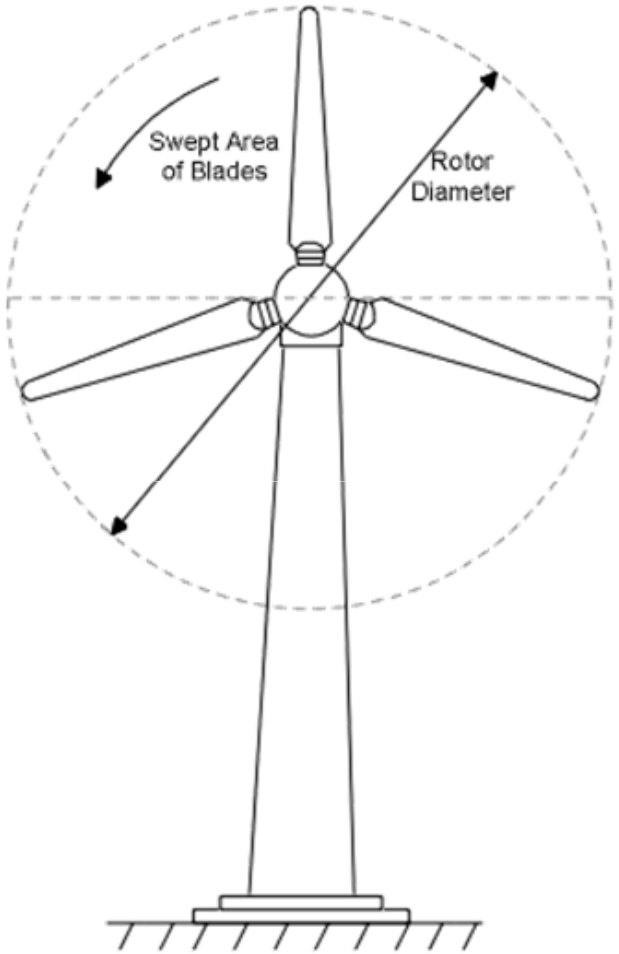
$$= \tfrac{1}{2} \rho A V^3$$

Effect of air density, ρ

Effect of swept area, A

Effect of wind speed, V

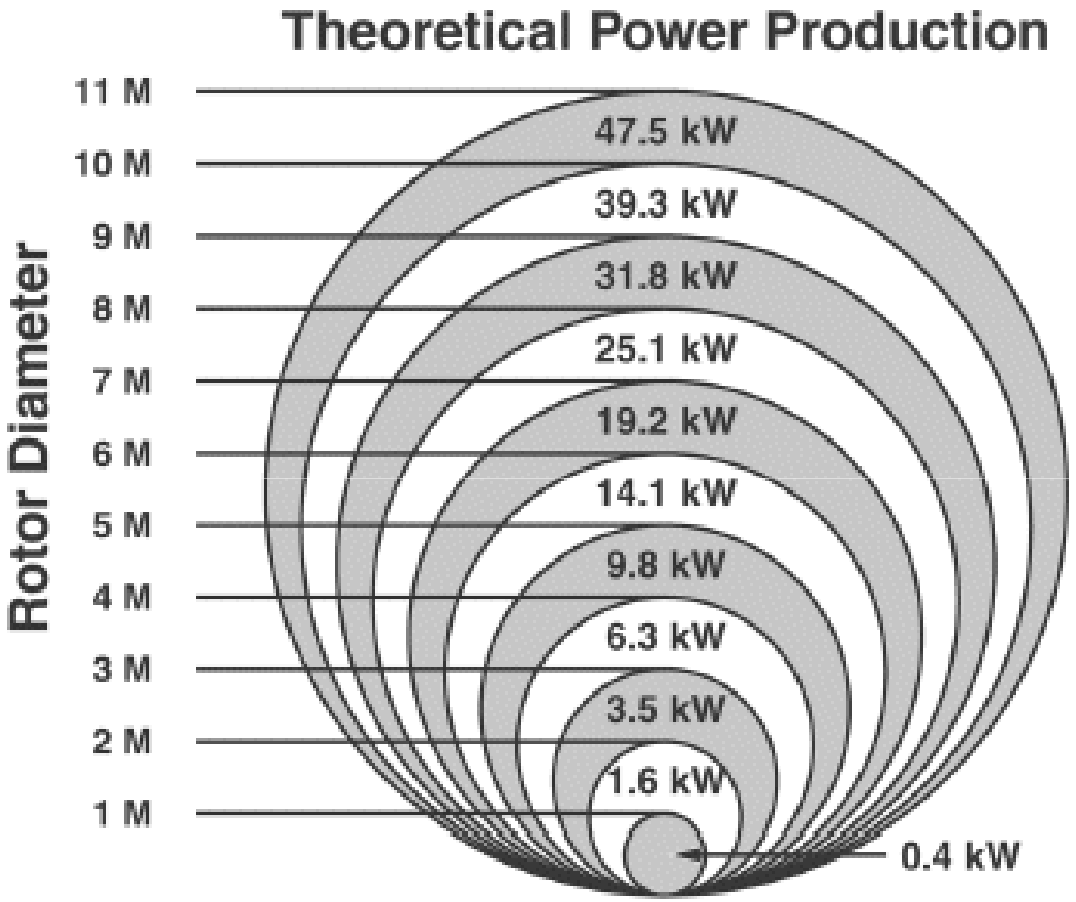
Swept Area: $A = \pi R^2$
Area of the circle swept by the rotor (m^2).



Wind Power – Size Matters!

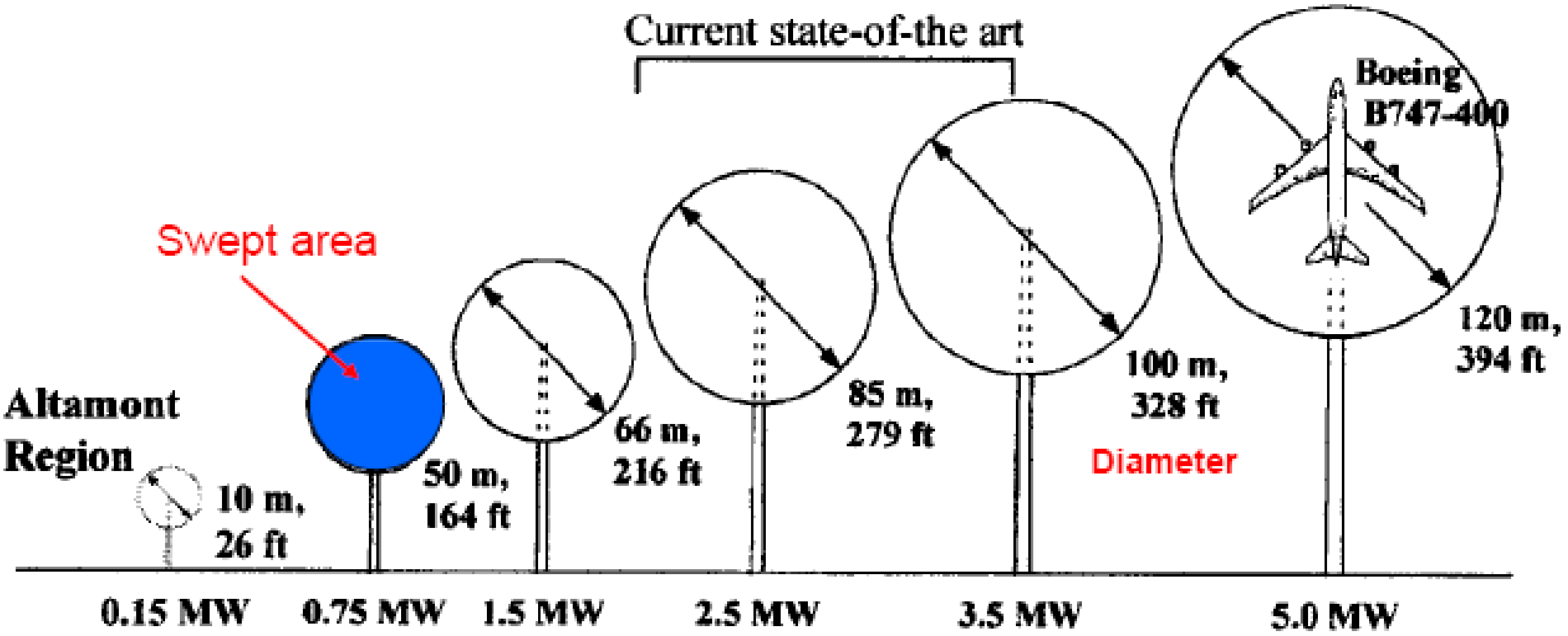
Swept are is proportional to square of the rotor diameter

- 20% increase in rotor diameter increases area by 44%
- Doubling diameter increases area 4 times

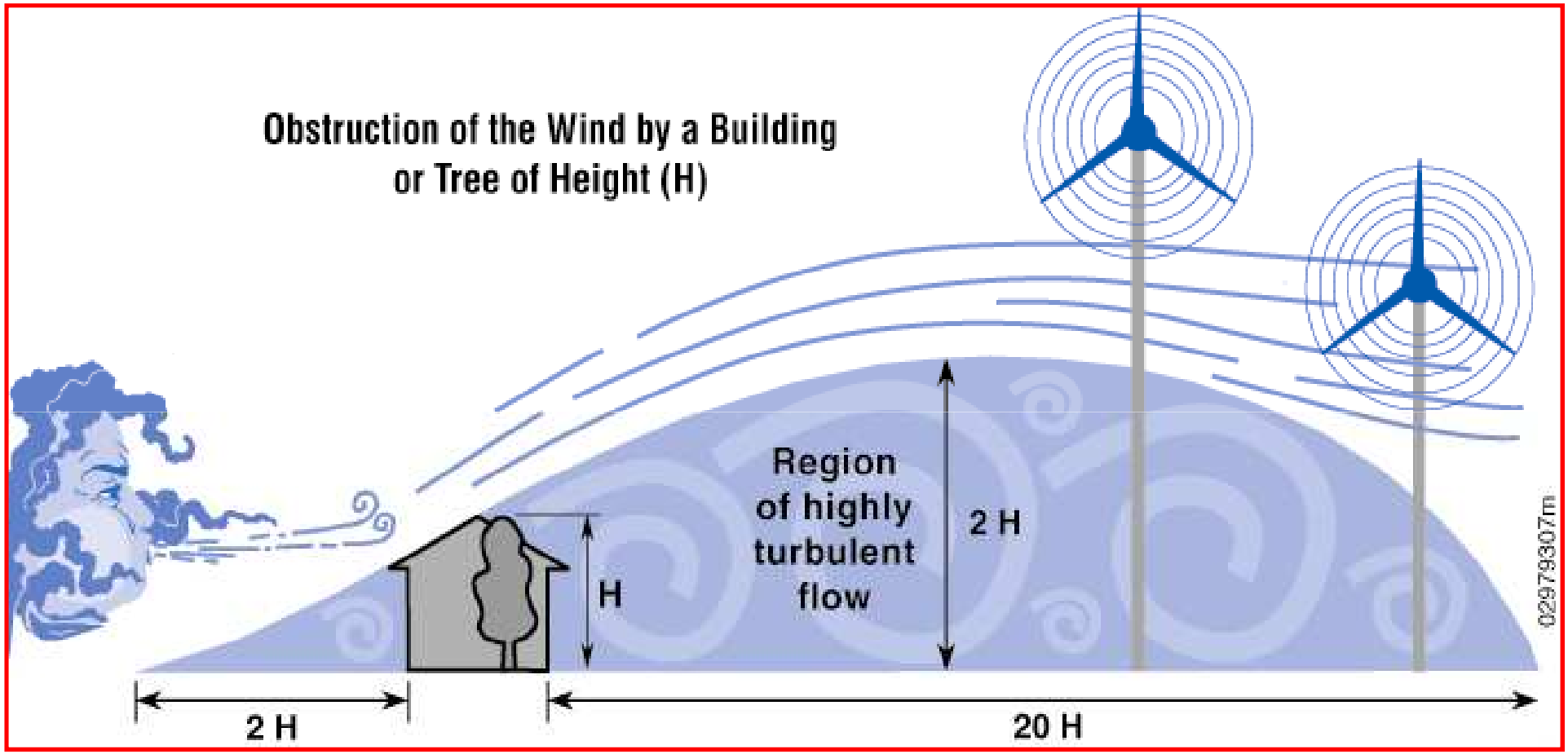


Generator Scale

Generator Scale – Moving Forward



Local Turbulence – Siting the turbine



Examples of Wind Power

Terminology

- Wind Machine
  - Kinetic device used to capture the wind and put it to work
- Wind System
  - Wind machine, tower, and all ancillary equipment
- Windmill
  - Wind machine that generates mechanical motion (ie. water pumping, grain grinding, etc.)
- Wind Turbine
  - A device that produces **electricity** from the kinetic energy of wind

Early Technology c1900's

Birth of Modern Wind Power

1940’s

1980’s

Modern Examples

Small (<10kW)

- Homes & Farms
- Off-Grid Applications
- £2k-£15k
- 60cm – 6m Diameter

Medium (10-250kW)

- Village Power / Factories
- Hybrid Systems
- Distributed Power
- £40k - £250k
- 5m -50m Diameter

Large (250 kW – 5 MW)

- Wind Farms
- £500k - £2M (per turbine)
- 50m – 100m Diameter

Generator Scale

Generator Topologies

Turbines can be categorized into two overarching classes based on the orientation of the rotor

Vertical Axis

Horizontal Axis

VAWT's

Lift Device

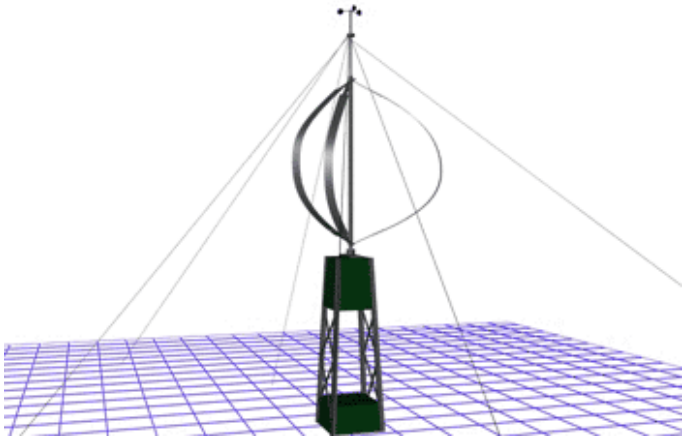
"*Darrieus*"

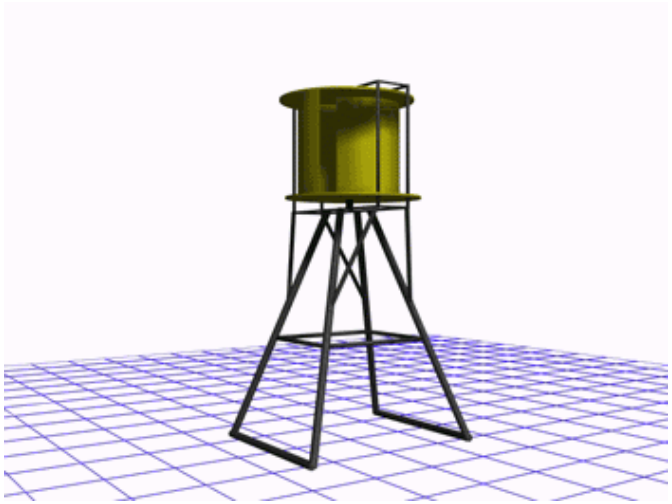
- Low solidity, aerofoil blades
- More efficient than drag device

Drag Device

"*Savonius*"

- High solidity, cup shapes are pushed by the wind
- At best can capture only 15% of wind energy



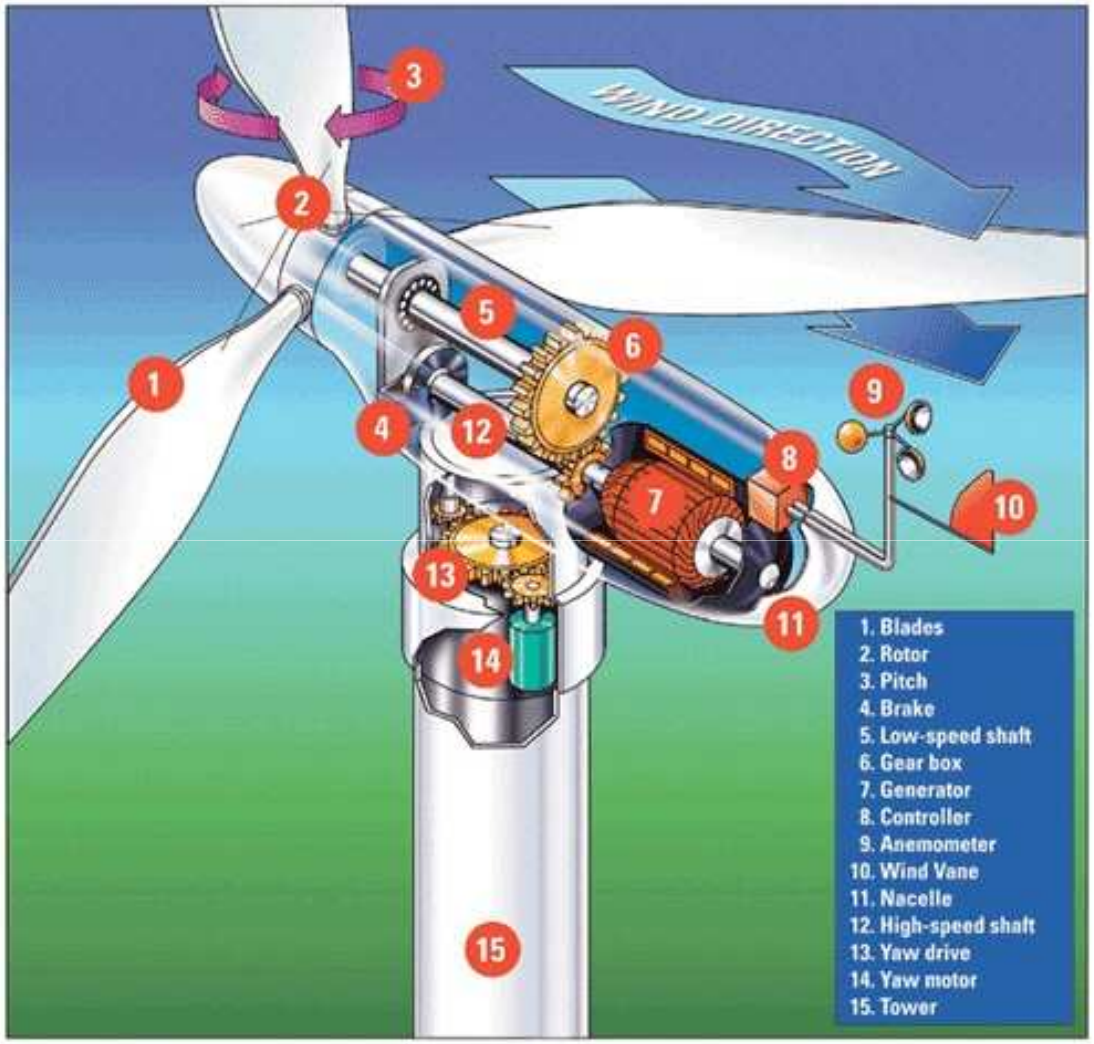


HAWT's

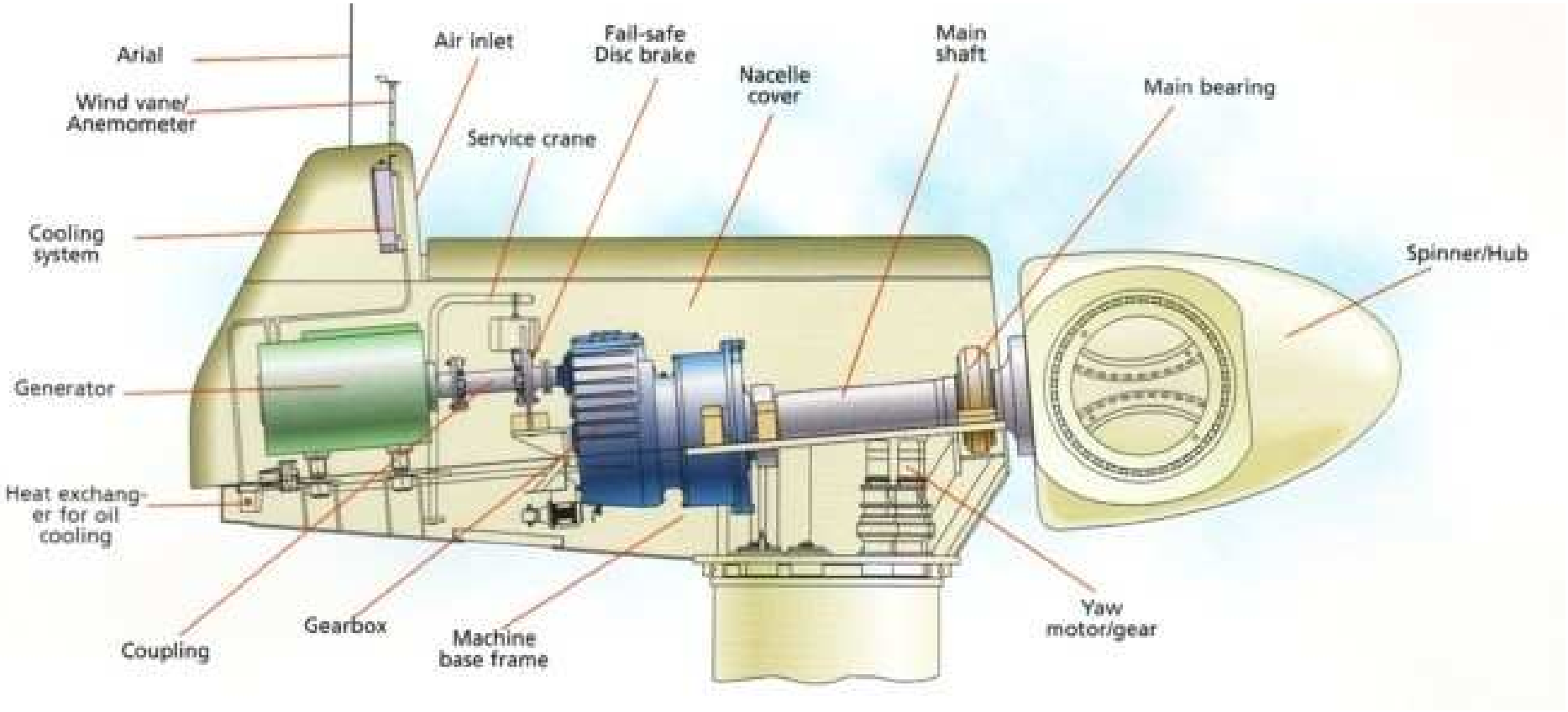
- Rotors are usually Up-wind of tower
- Some machines have down-wind rotors, but only commercially available ones are small turbines

Large HAWT Components

- Significant moving parts
- Low speed of the blades use gears to drive turbine
- Brake system
- Motor turns blades into wind



Inside the HAWT



Generator Maintenance

Onshore wind farm sites UK

Wind Farm Potential

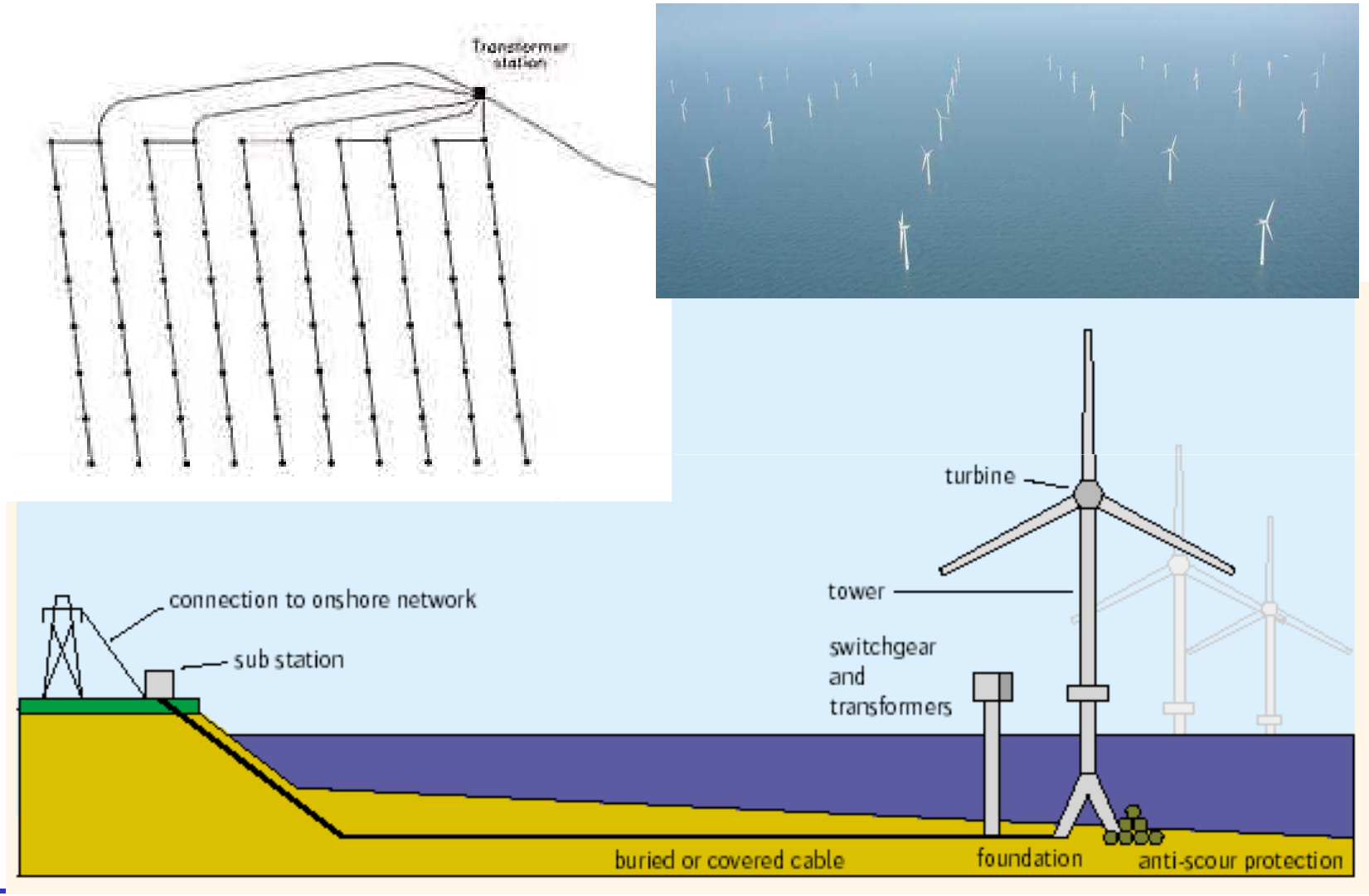
- Each wind turbine can produce between 1/4 and 2 MW of electrical power.
- Wind farm needs to be located where there is a relatively high average wind speed.
- Assume 24 wind turbines each generating 0.25 MW for 70% of time.
- In a year this amounts to 3.66×10^7 kwhr.
- If this figure is divided by average amount of electricity used by a consumer ie 10,607 kwhr in a year,
- Answer is 3600 consumers.
- But 166 of these small wind farms = 1000Mw power station!
- Is the power available when you want it?

Offshore Wind Turbines

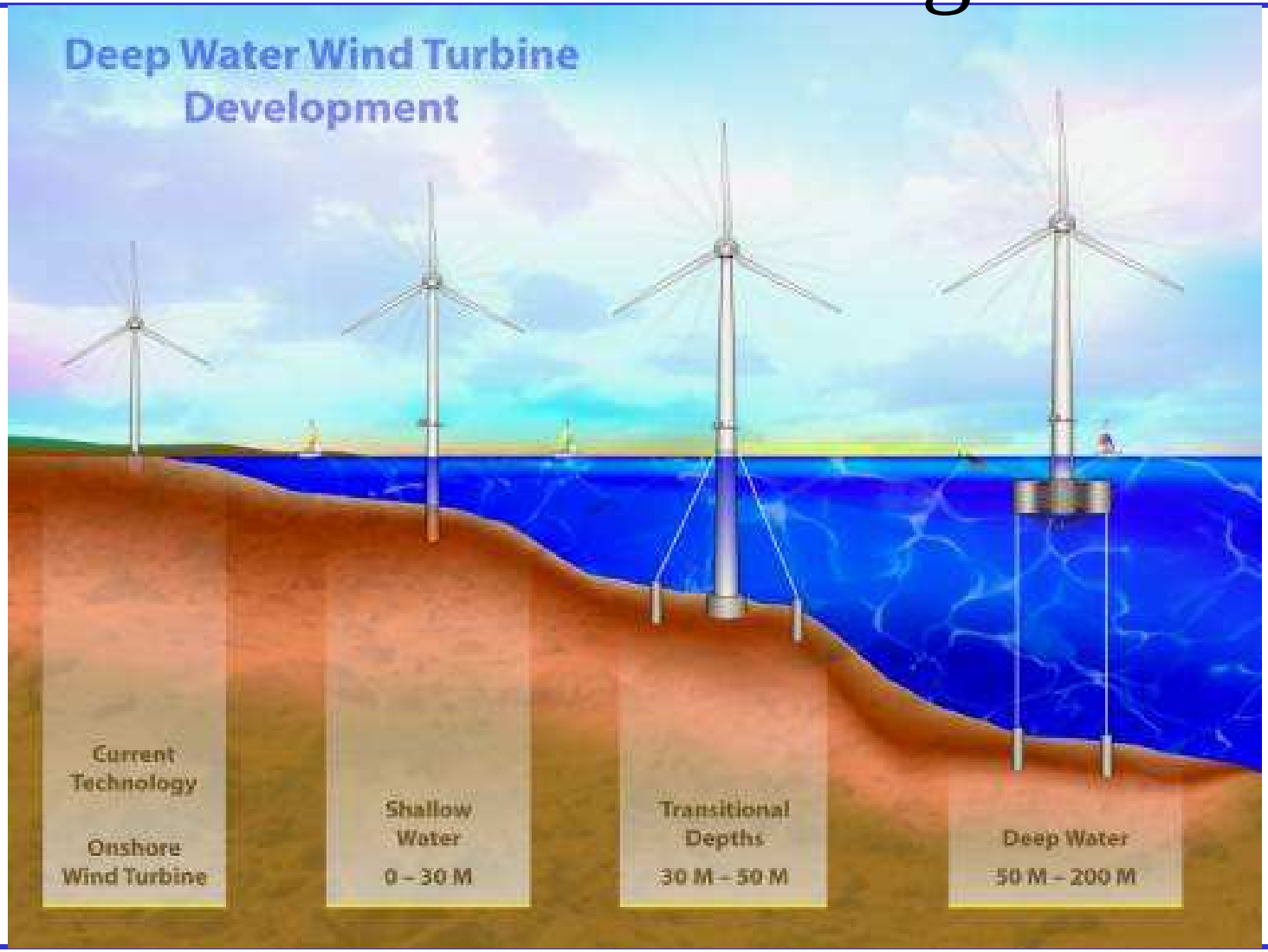
Offshore Wind Cluster Features

- Larger average wind speed than onshore
- Easier planning consent
- Technical expertise exists from oil rig experience
- Suitable locations

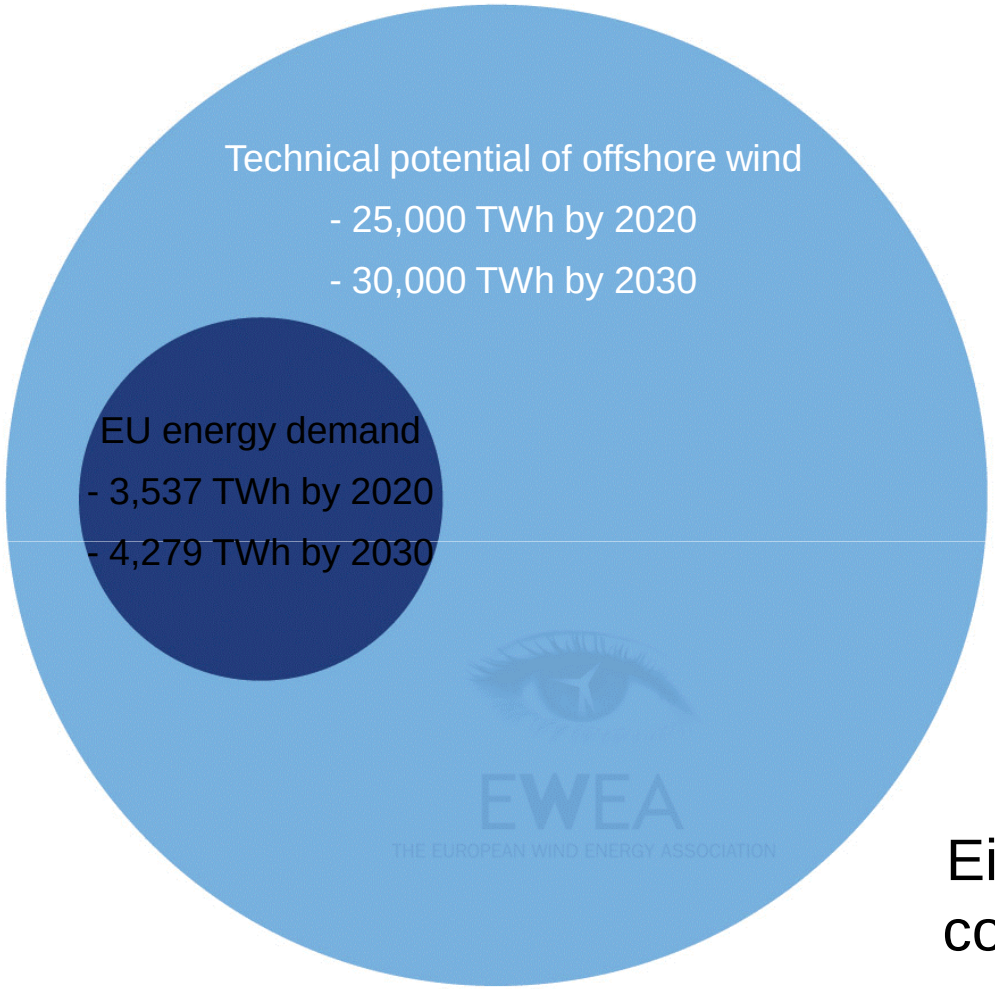
Offshore Wind Farm Topology

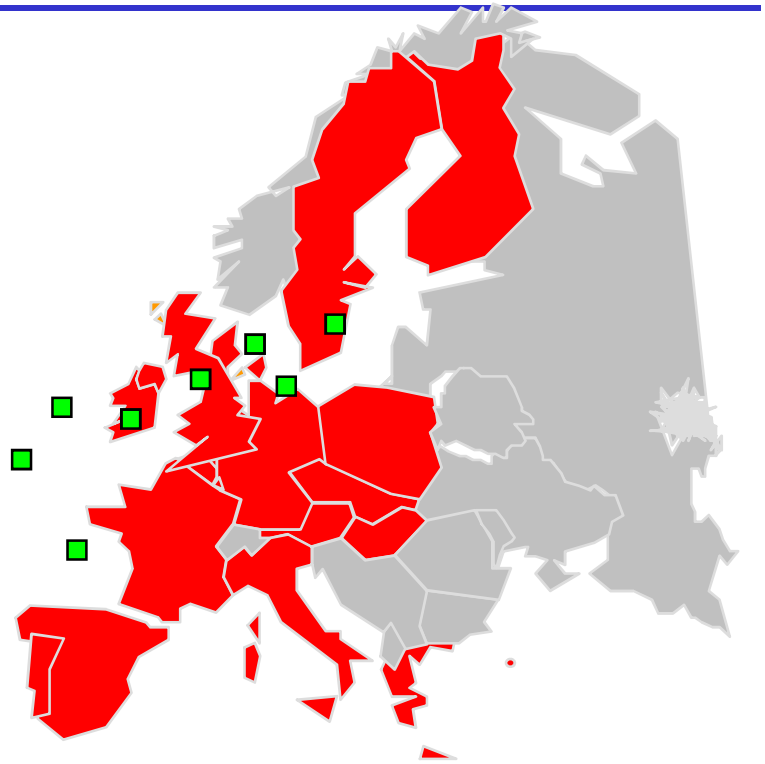


Turbine Mounting



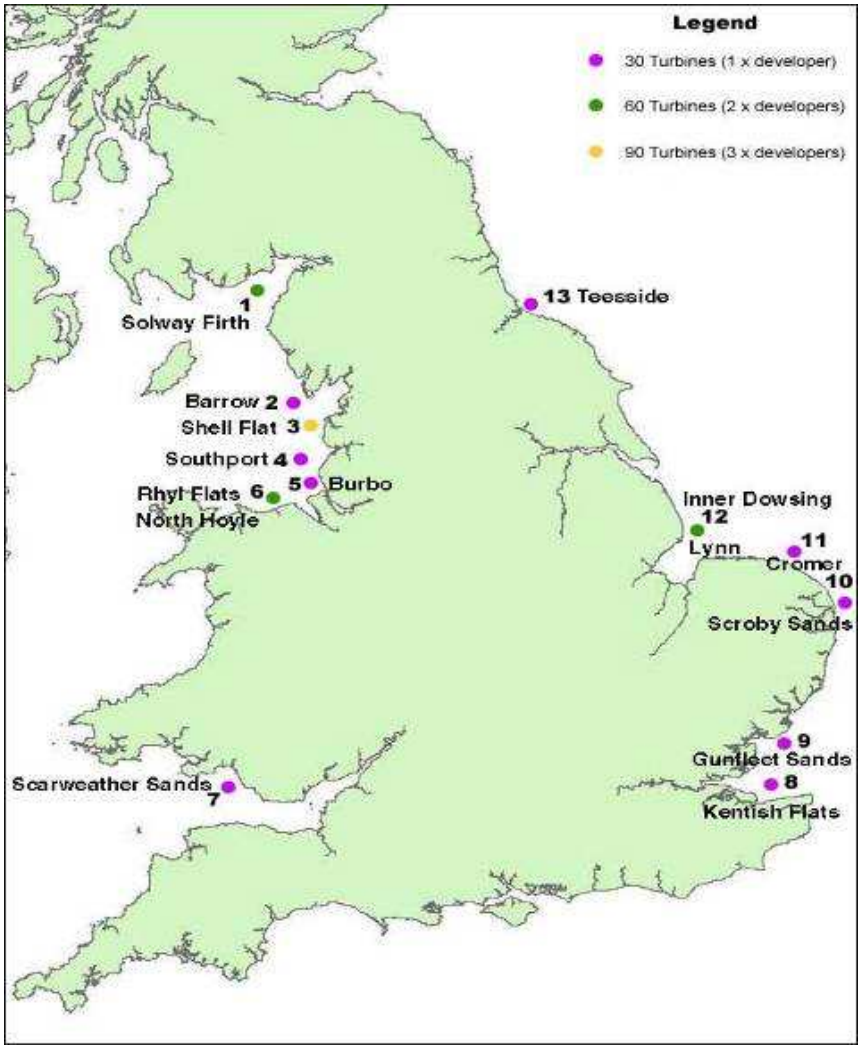
Offshore Wind Potential



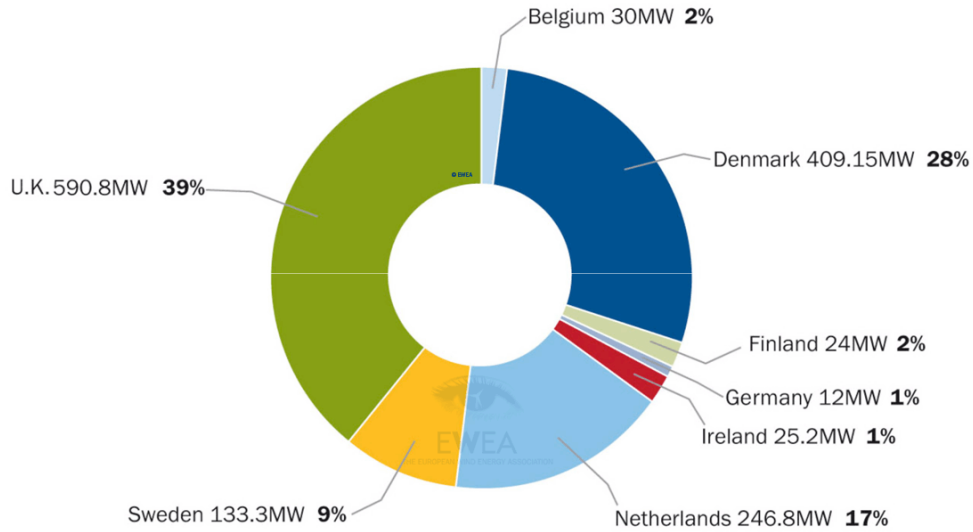


Eight 100x100 km offshore wind farms could produce 3,000 TWh – equivalent to EU power demand

Offshore Wind Farm Sites

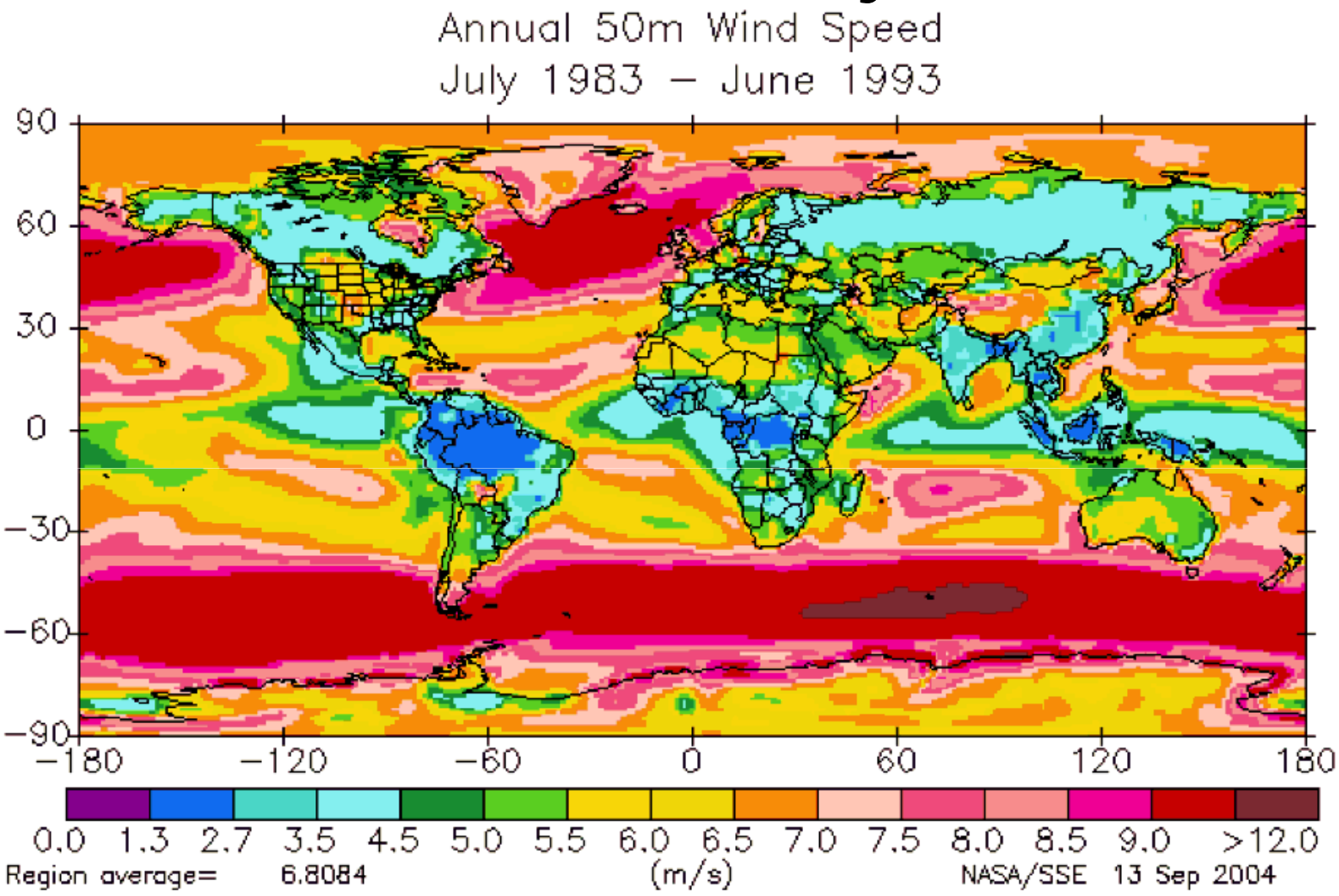


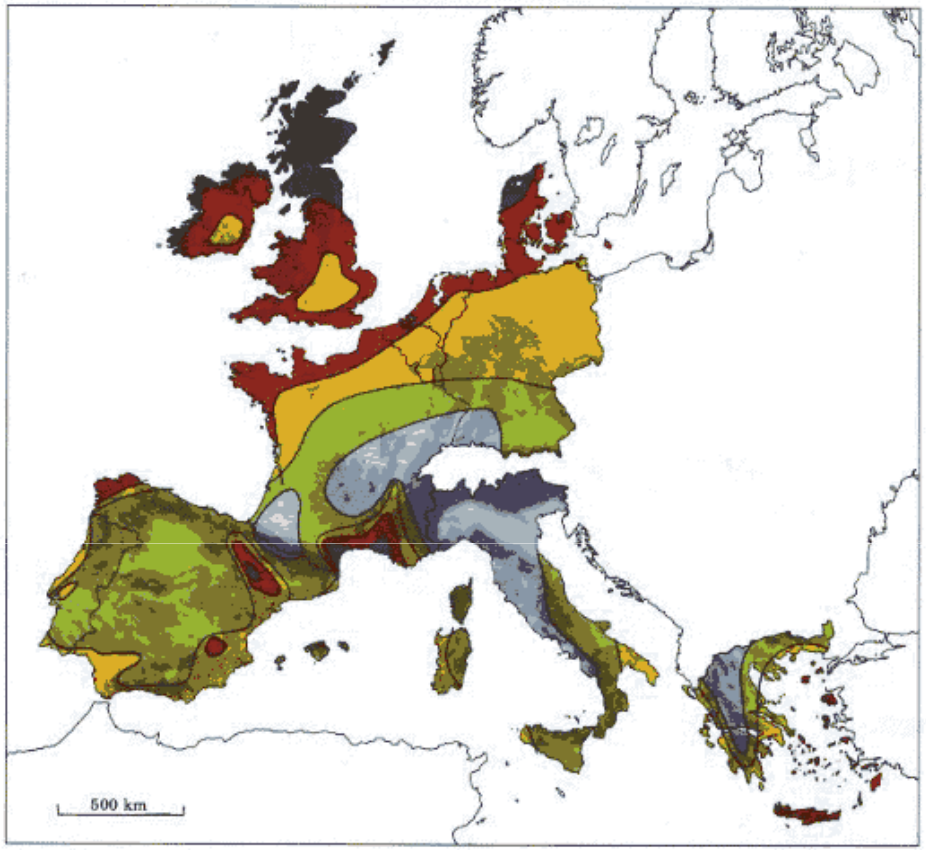
End 2008: 1.5 GW offshore – 8 EU countries



Total: 1,471.33 MW

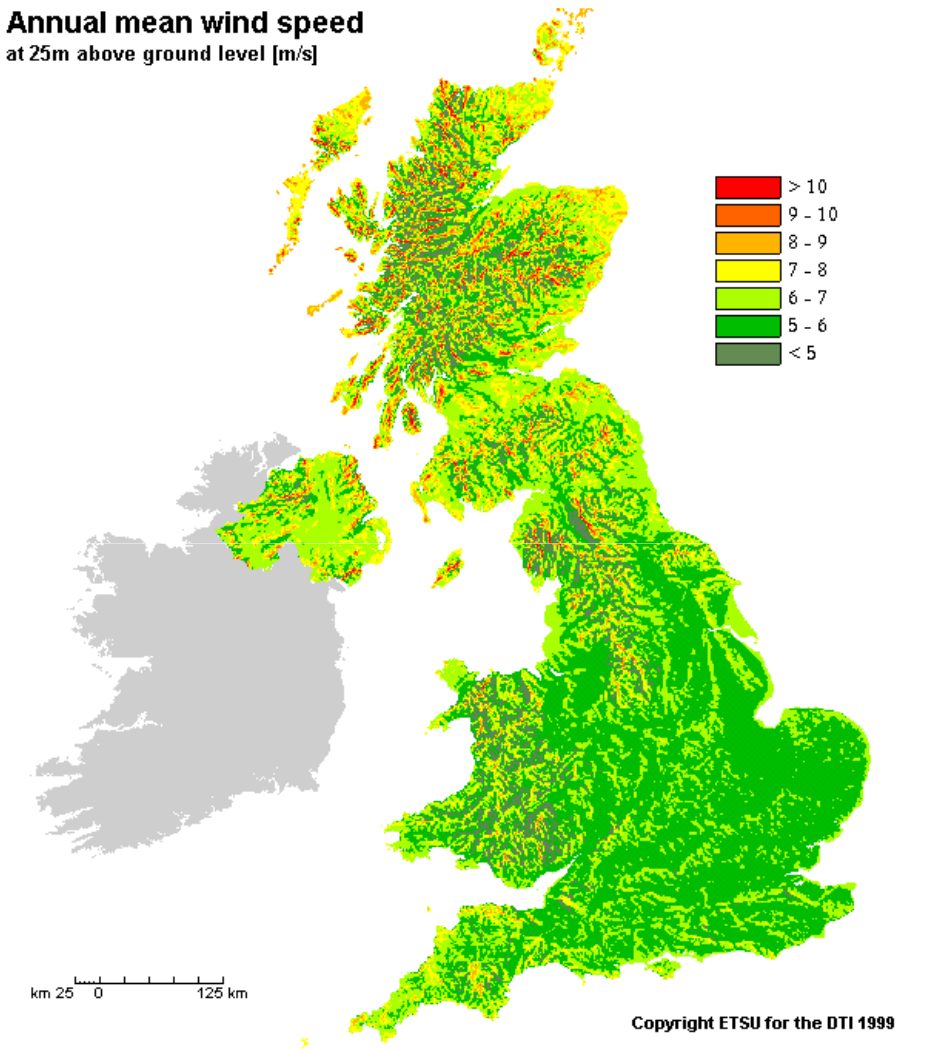
Where's Windy!



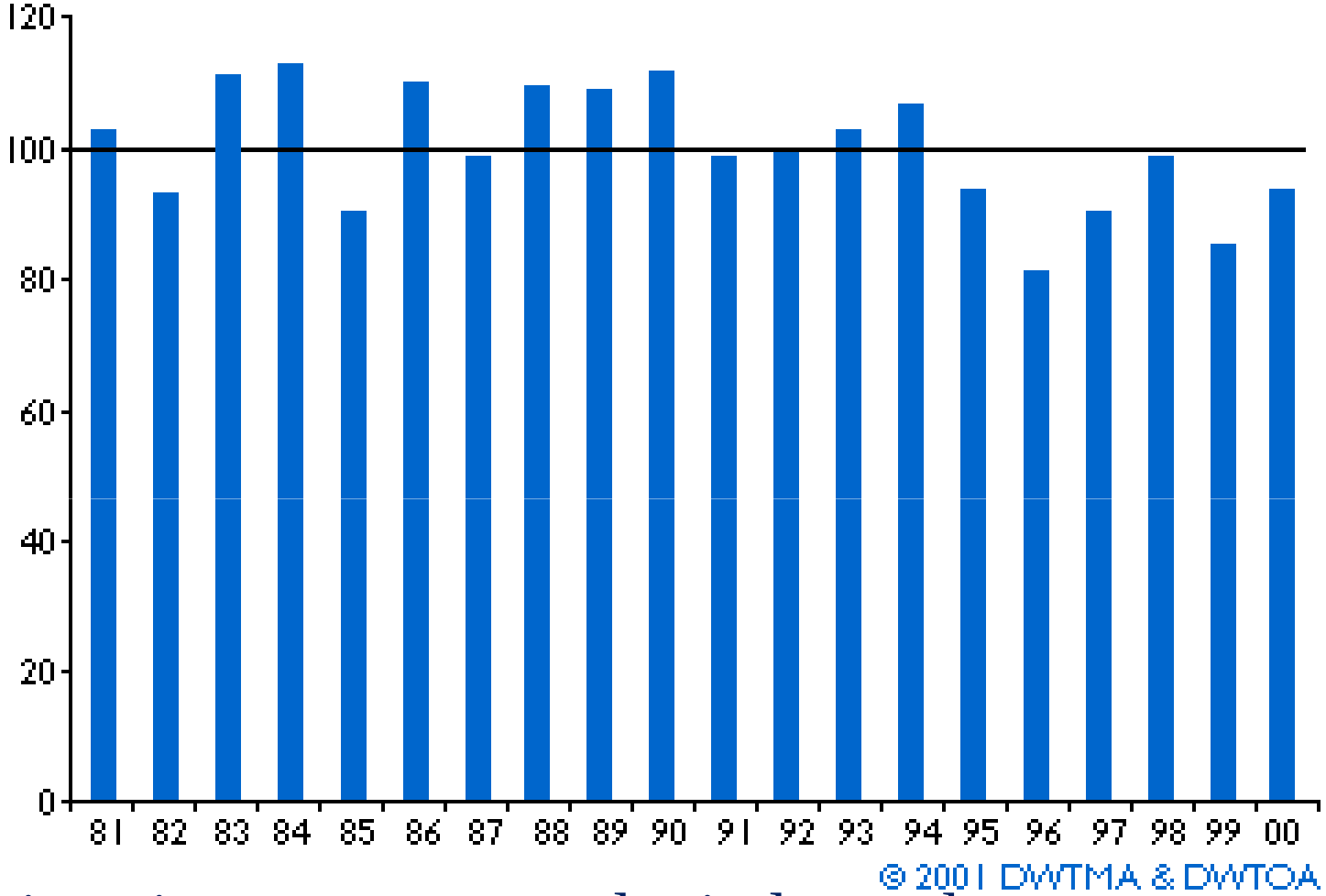


Wind resources[1] at 50 metres above ground level for five different topographic conditions

	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	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
	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
	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
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

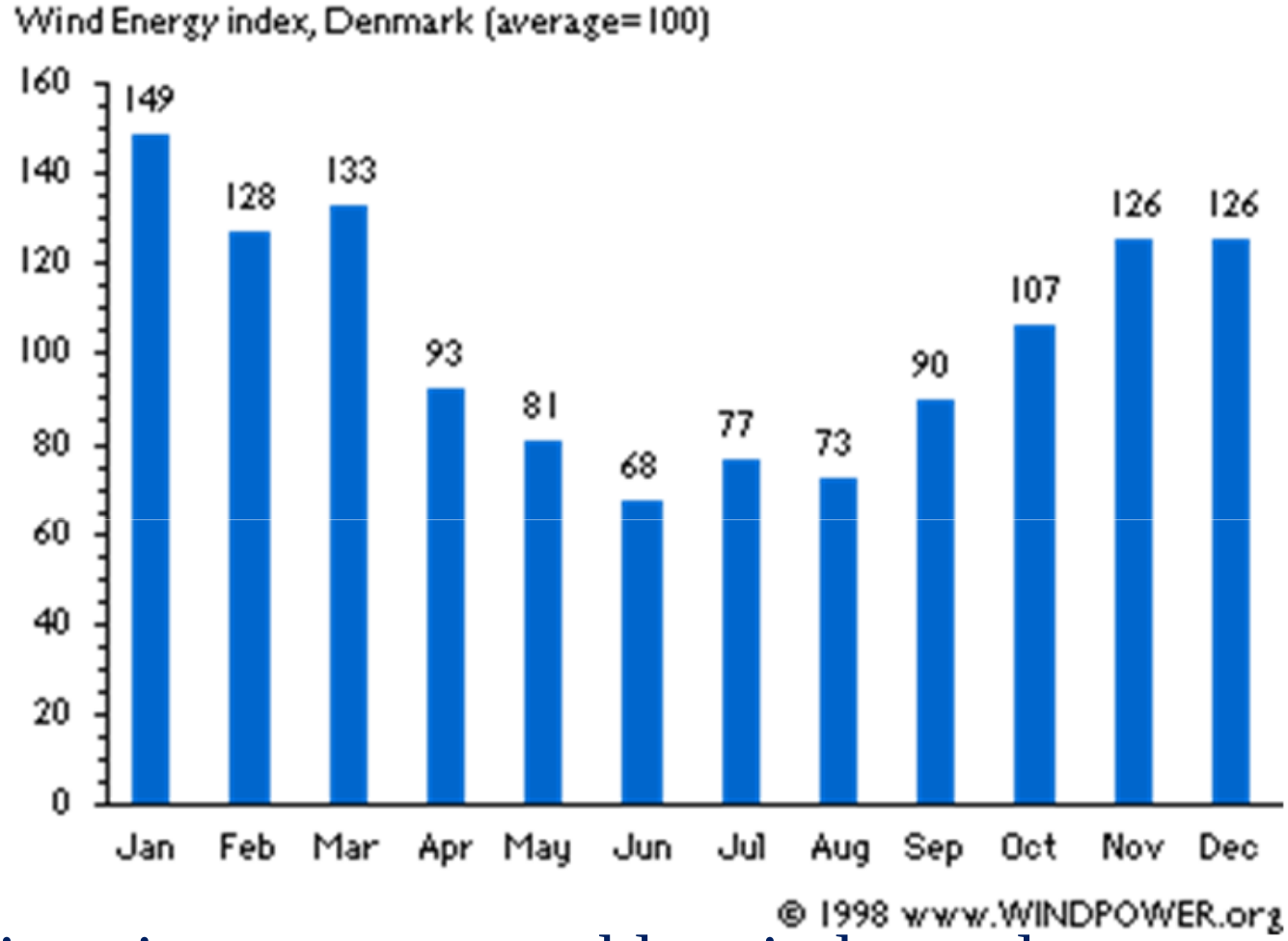


Variations



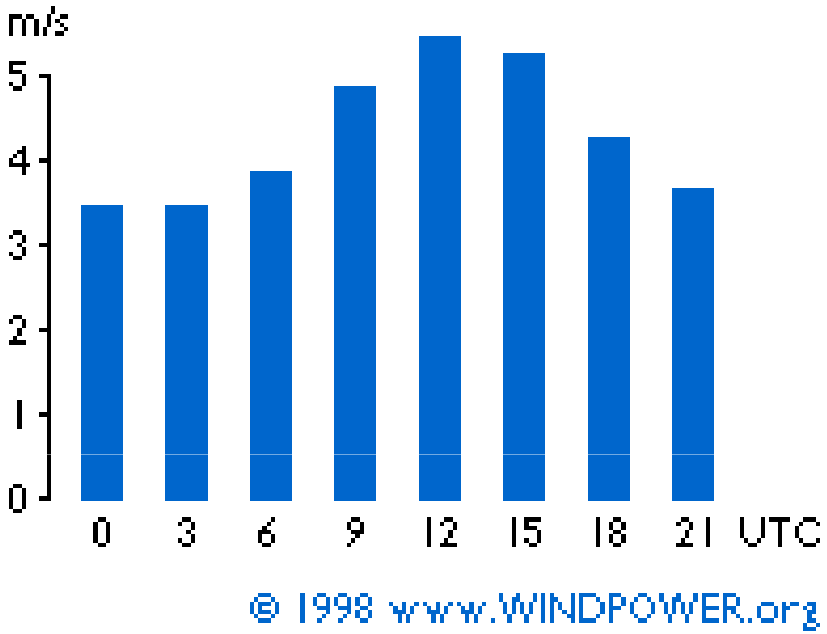
- Variations in average annual wind speeds

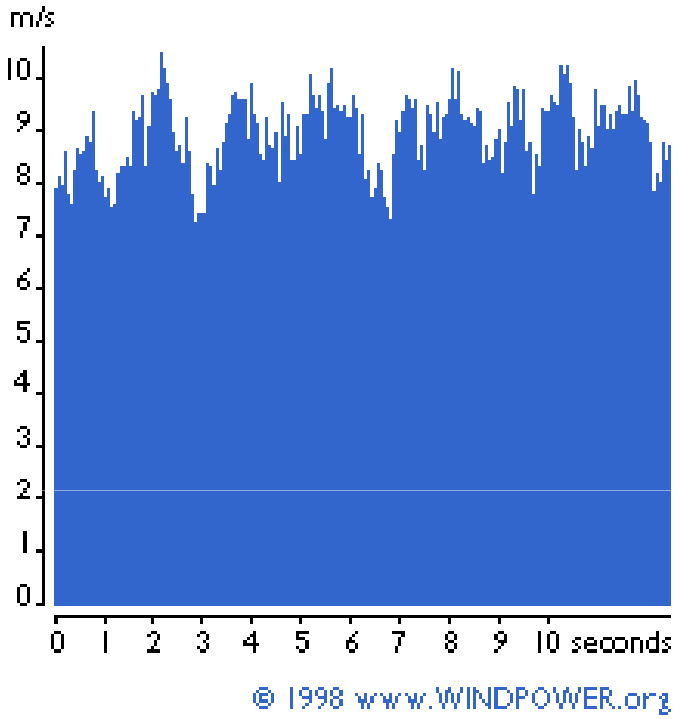
Variations



- Variations in average monthly wind speed

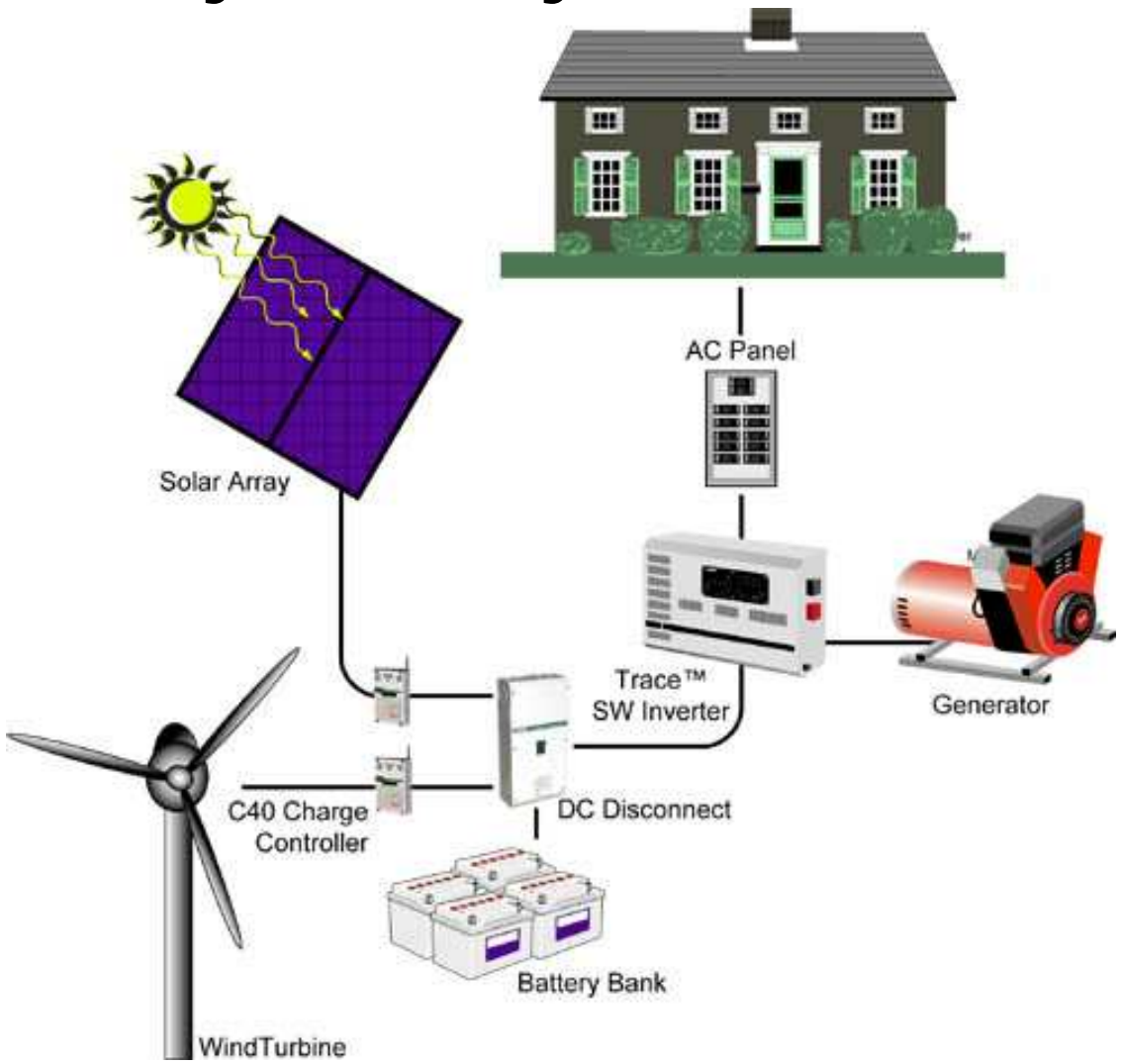
Variations



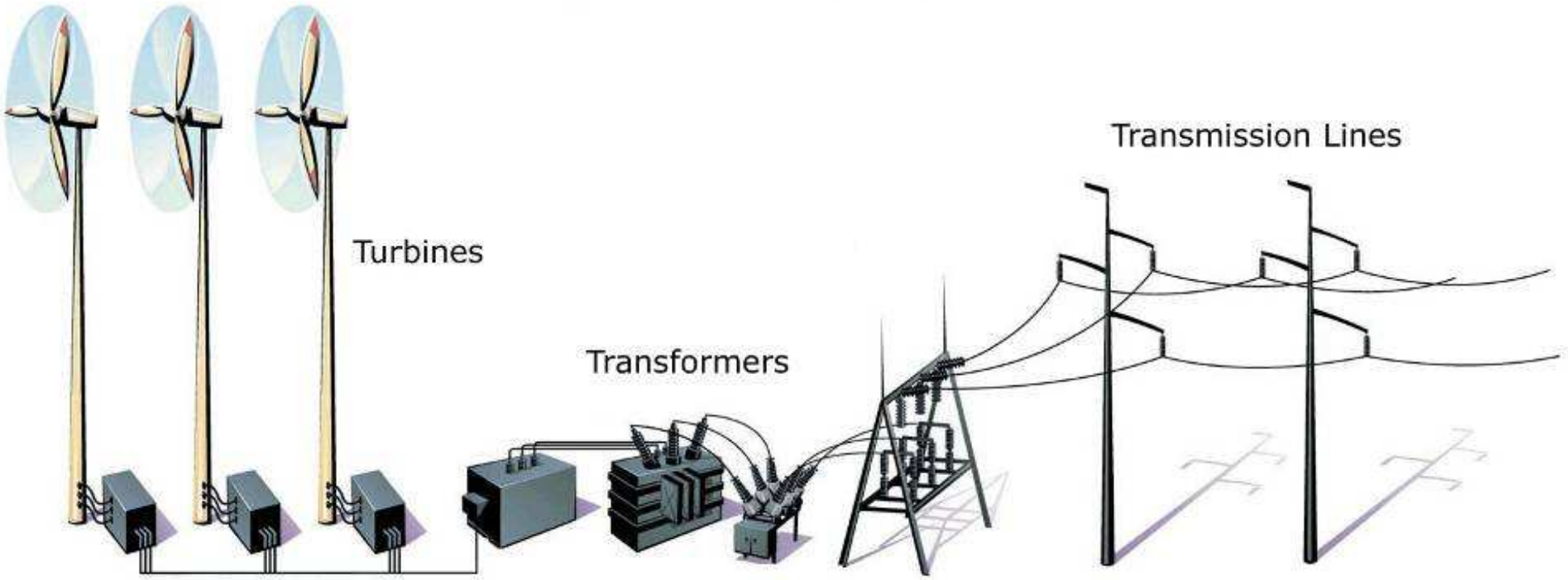


- Variations in average wind speed throughout the day, and instantaneously.

Hybrid Systems



Commercial Generation



Exceptional Conditions

Which do you prefer?

- 15- 20MW

- 300MW Oil Fired

Summary

Wind Power Isn't Perfect

- Wind Power output varies over time
- Wind Power can only meet part of your load
- Wind Power is location-dependent
- Wind Power is transmission-dependent
- Wind Power has environmental impacts

. . . But Wind Power could have a Great Future!

References

- http://learn.kidwind.org/
- www.windpower.org