wind energy

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Contents

History of Wind Energy

Ancient wind energy system

- **Harvesting** wind power is not a new idea
- Ancient civilisation used wind power for **sailing, wind mill and wind pump** – 1st recorded wind mill in 7th Century in Persia

- **1,000 years old Vertical-axis windmills** in Iran
- Sails connected to a **vertical shaft** connected to a grinding stone
- Used for **milling** grain for flour

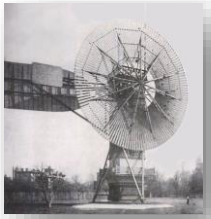
Middle ages wind energy system

- **Horizontal-Axis Wind-Mill:** sails connected to a horizontal shaft on a tower encasing gears and axles for translating horizontal into rotational motion

Evolution of wind energy technology

7th century Persian windmills

Middle ages windmill in Europe



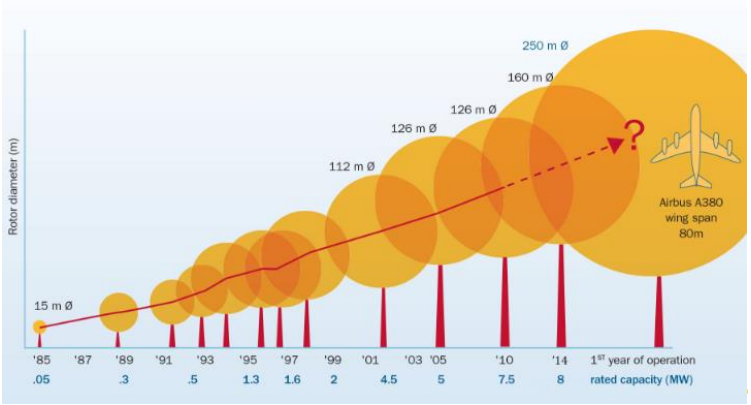
1888 – wind turbine to produce electricity, 12 kW (USA)

7.5 MW

Off shore wind farm

Vertical axis wind turbine

Modern era wind energy technology

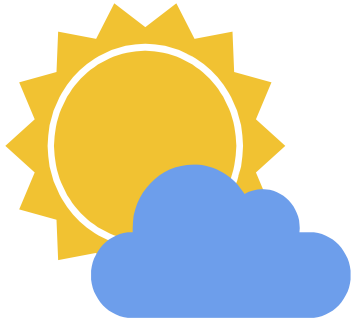


- **Modern era** wind energy technology
  - *Scale increase*
  - *Commercialization*
  - *Grid integration*
  - *Economics*
  - *Environmental benefits*

Wind power fundamental

Origin of Wind

Wind – atmospheric air **in motion**



Energy source

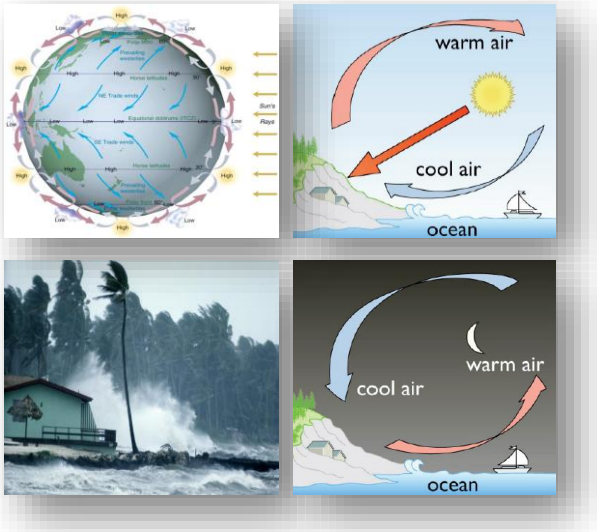
Solar radiation differentially absorbed by earth surface converted through convective processes due to temperature differences to air motion

Approximately 1%-2% of the incident solar irradiation is converted into wind

Types of wind

Geostrophic wind
direction and speed are determined by a balance of the pressure-gradient force and the force due to the **earth's rotation**.

Extreme wind
storm
tornadoes
thyphoon
hurricane



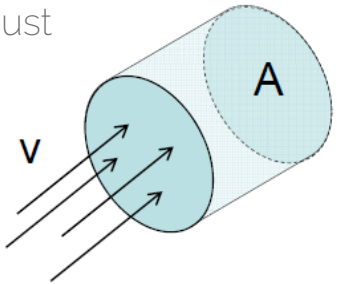
Regional/Local wind
the prevailing pattern of easterly surface **winds** found in the tropics towards the Earth's equator

Mountain wind
a breeze of diurnal period depending on the **unevenness of land surfaces** and blowing down the slope by night

Fundamental Equation

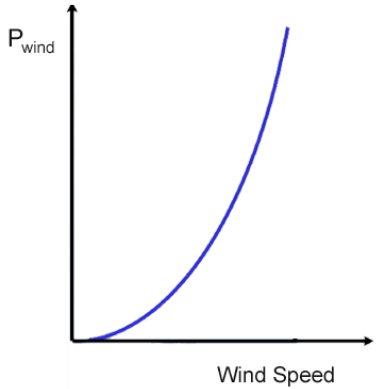
Wind variation with time

- **Inter annual -** > 1 year variation
- **Annual** – seasonal or monthly
- **Diurnal** – daily
- **Short term** – turbulance & gust



Wind power depends on:

- Amount of air **(volume)**
- Speed of air **(velocity)**
- Mass of air and
- Air density
- Wind direction



Wind power equation

Kinetic Energy

$$KE = \frac{1}{2}mv^2$$

Wind Power

$$P = \frac{1}{2}\rho A v^3$$

where;

m *is the air mass* (kg)

v *is the air velocity* (m/s)

A *is the rotor swept area* (m^2)

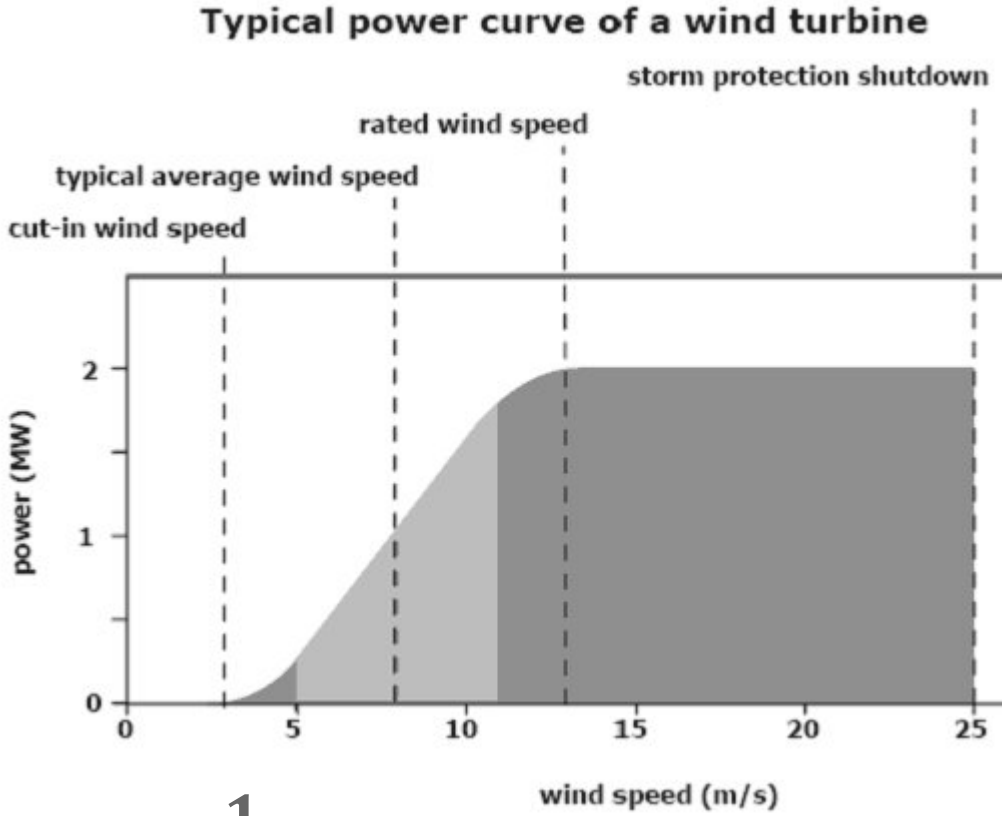
ρ *is air density* (kg/m^3)

Power coefficient of a Wind Turbine

Power Coefficient, **Cp**, is the ratio of power extracted by the turbine (P_T) to the total contained in the wind resource (P_W)

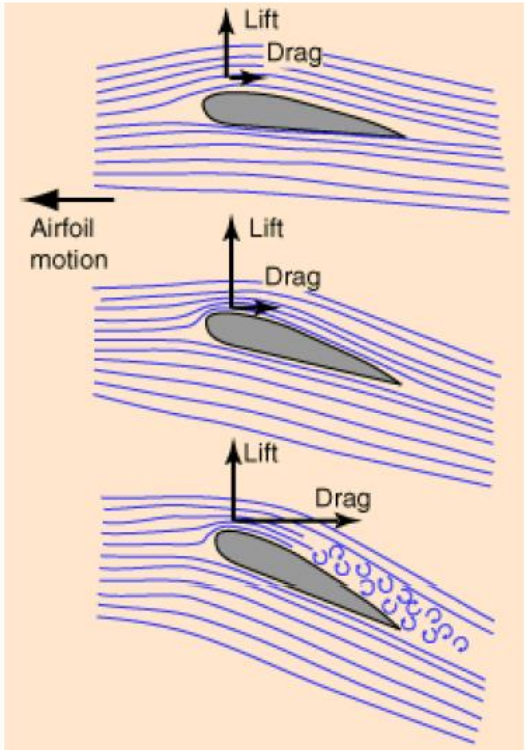
$$C_p = \frac{P_T}{P_W}$$

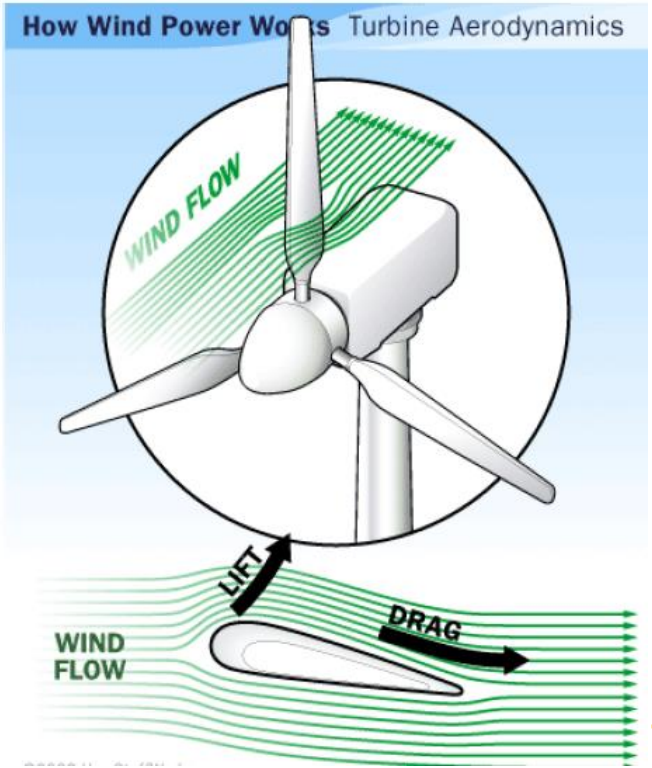
C_P of a Wind turbine is called **Betz Limit** at **0.59**



$$P_T = \frac{1}{2}\rho A v^3 C_P$$

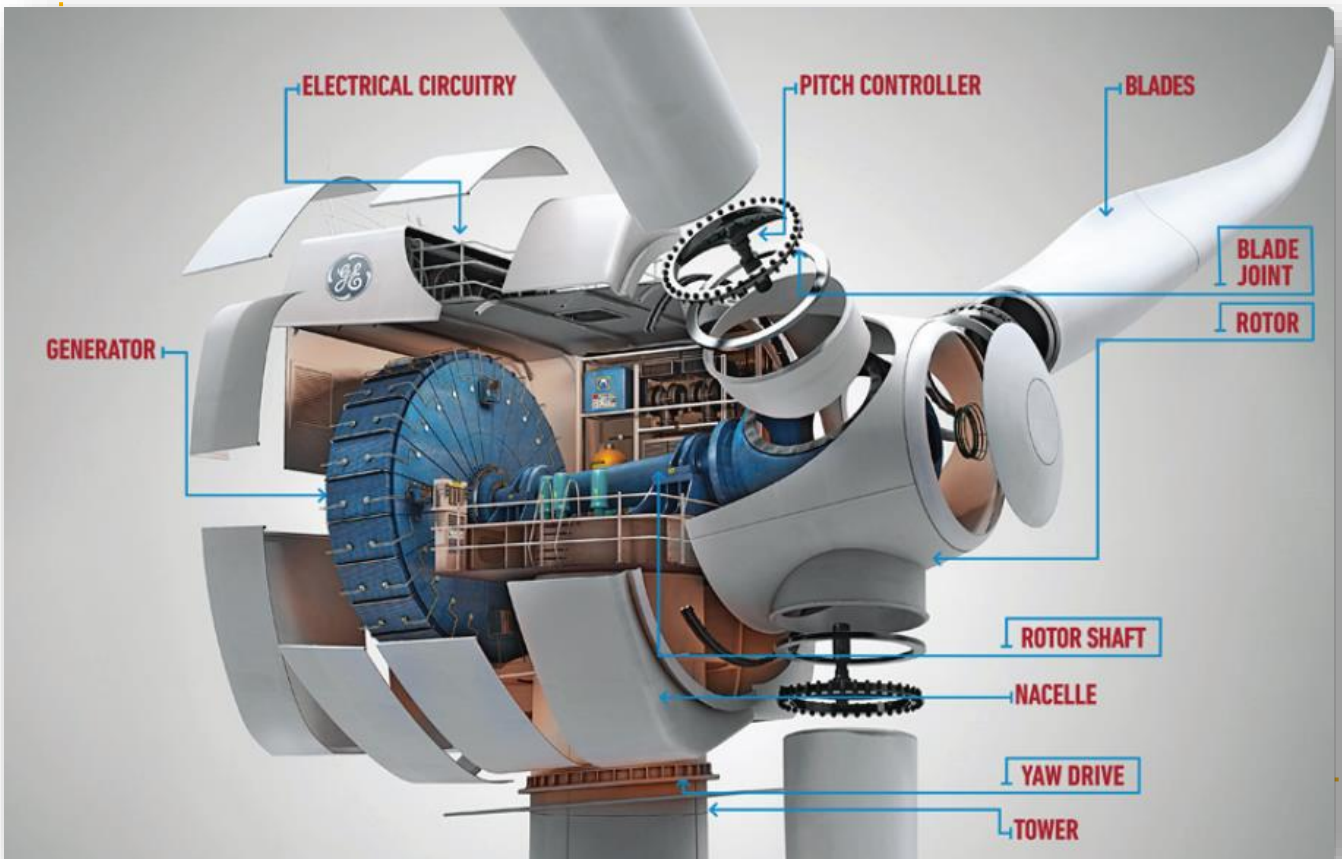
Lift & Drag forces





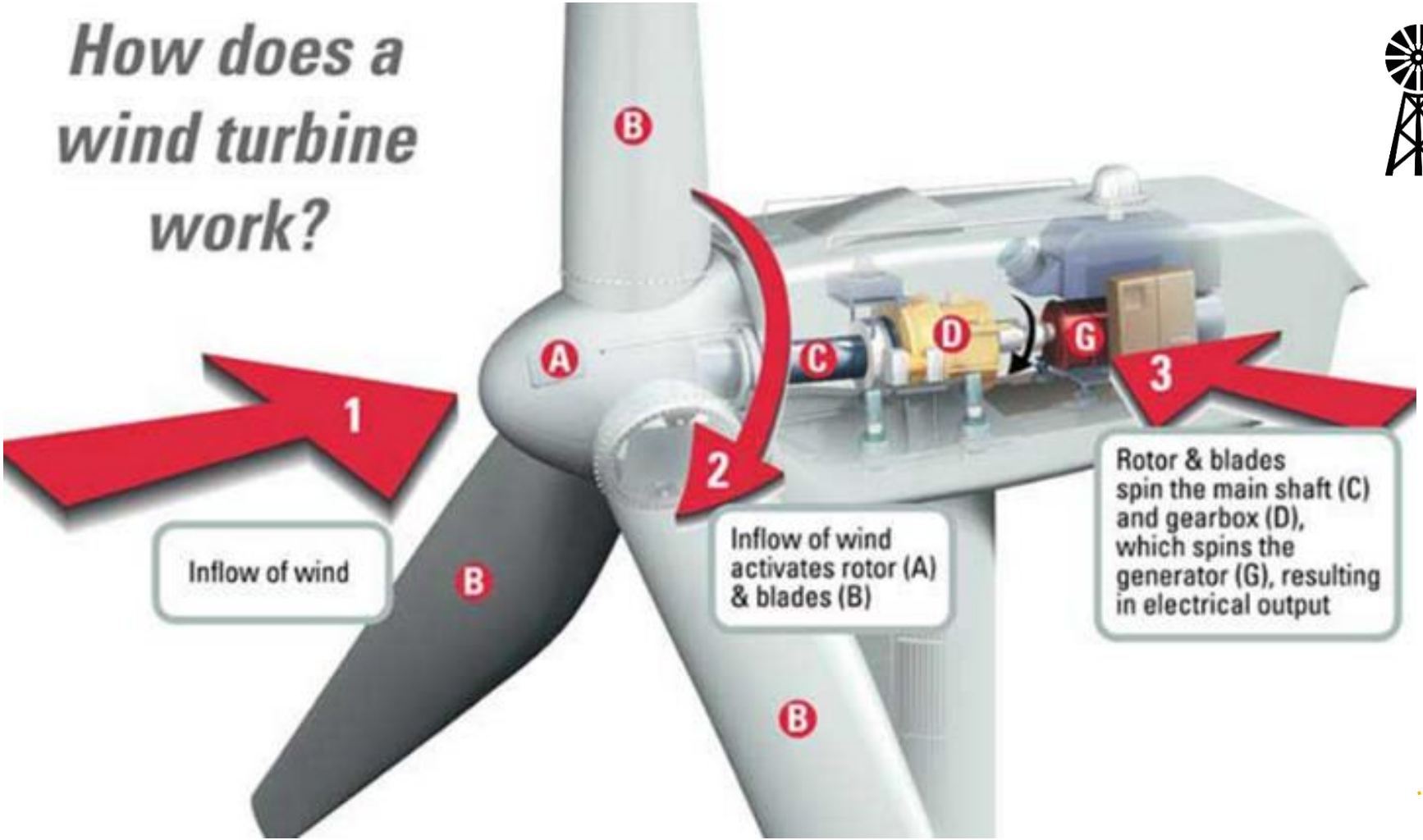
Wind energy conversion technology

Components

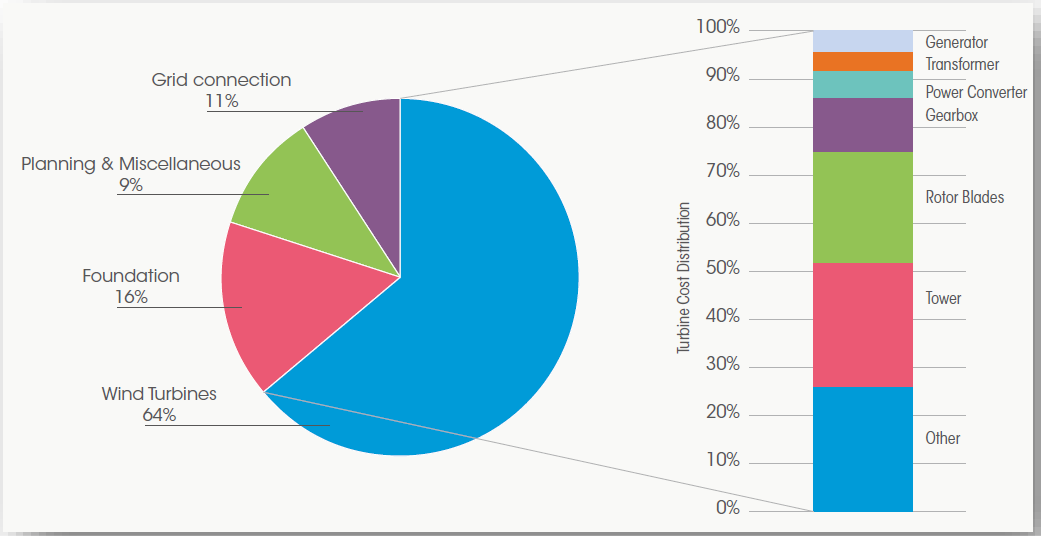


Anemometer & wind vane

How does a wind turbine work?



Economy



Investment cost (RM/kW)

Onshore

- RM6,500– 9,500/kW

Offshore

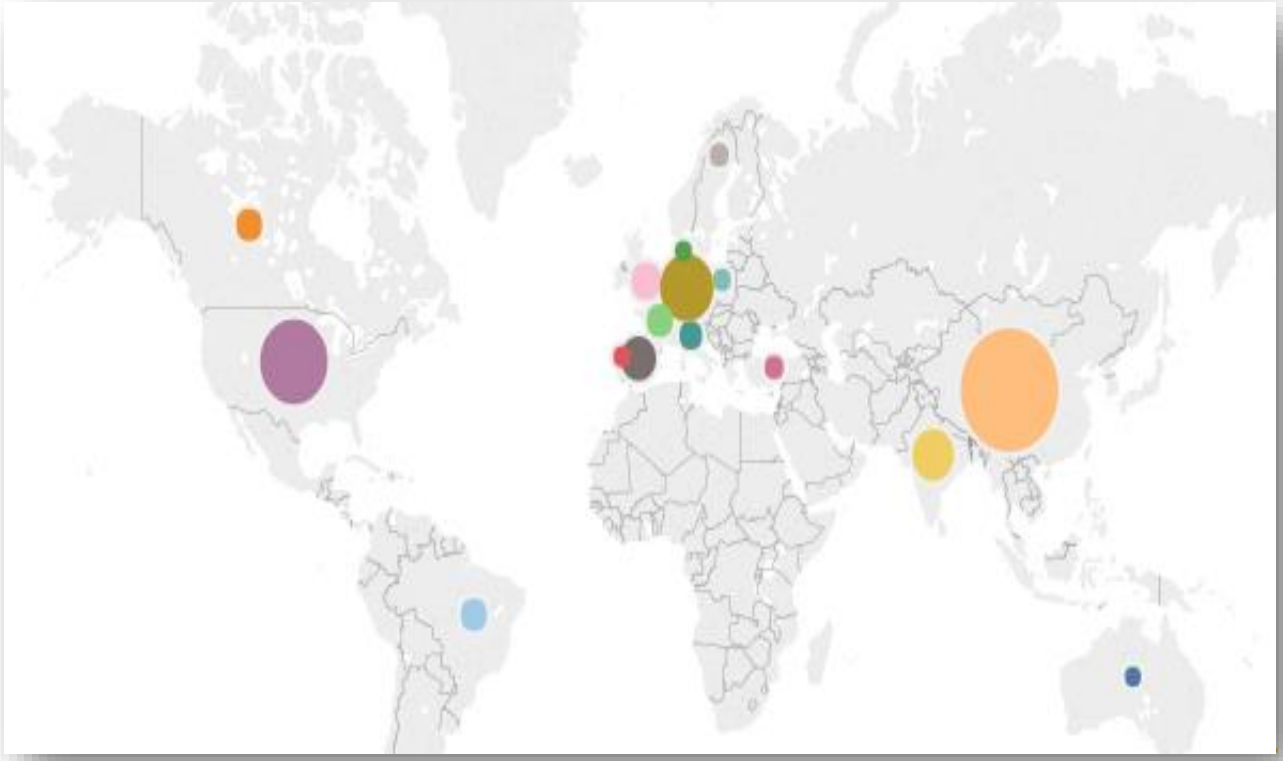
- RM12,500– 19,000/kW

Solar PV Grid connected

- RM5,000 /kWp

Source : IRENA, 2012 & NREL, 2015

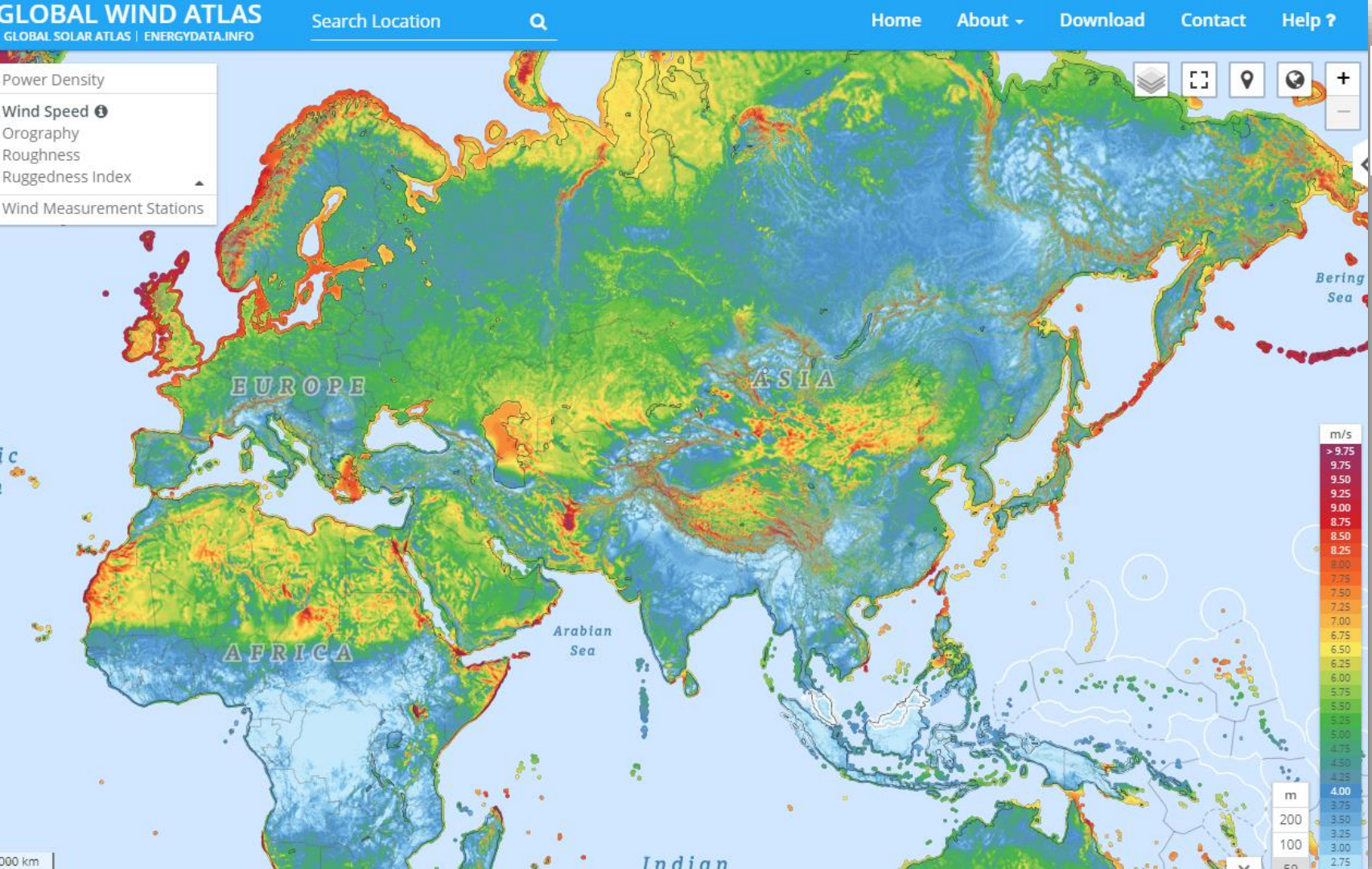
Global wind power installation



Country	Installed capacity (GW)
China	176.7
USA	84.3
Germany	52.9
India	32
Spain	23
United Kingdom	16.2
Canada	12.1
France	12.6
Denmark	5.3
Brazil	12.3
Italy	9.4
Sweden	6.5
Poland	5.8
Australia	4.7
Turkey	6.5
Portugal	5.3

Wind energy potential in Malaysia

PULAU PERHENTIAN, TERENGGANU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Orography
Roughness
Ruggedness Index
Wind Measurement Stations
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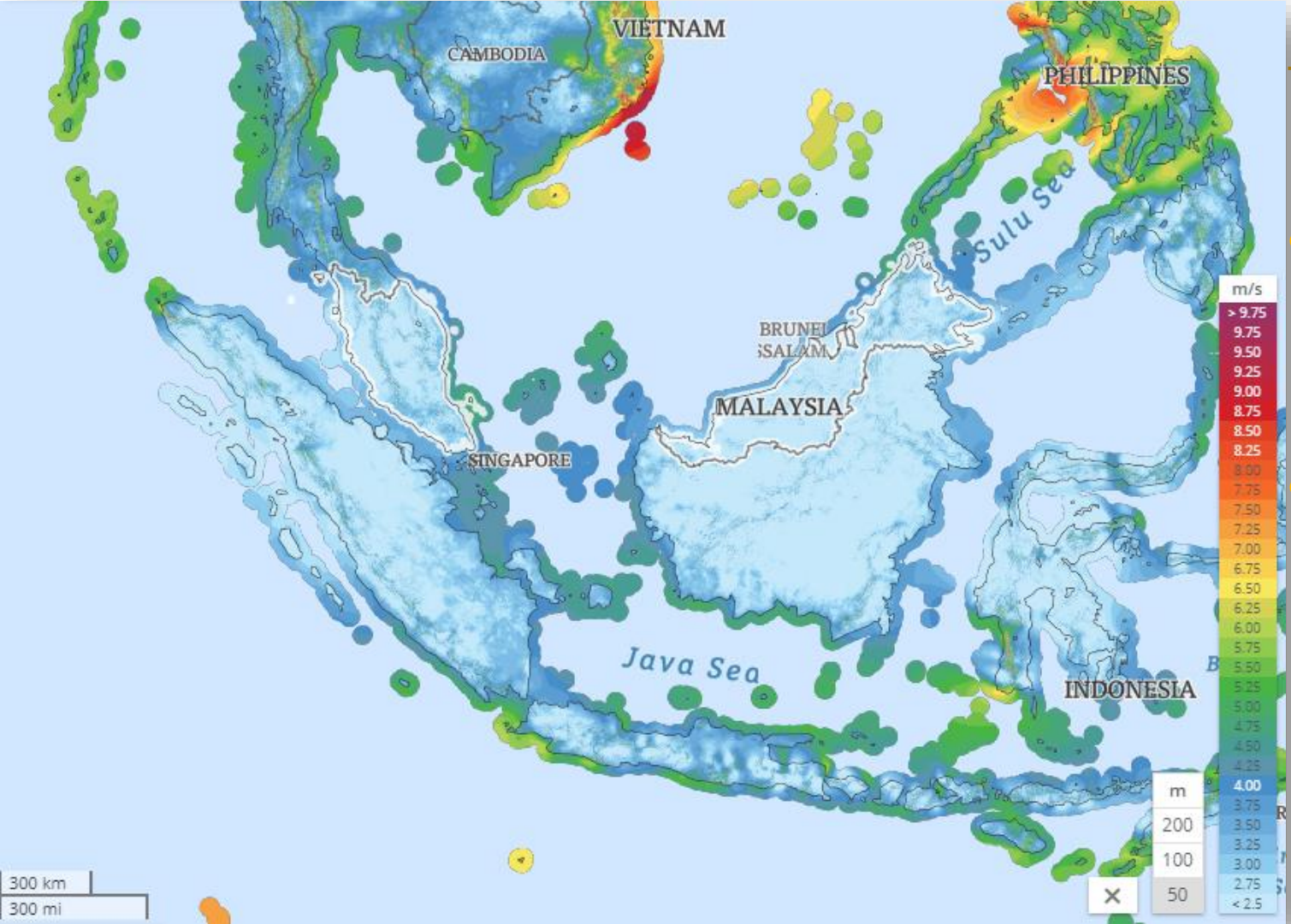
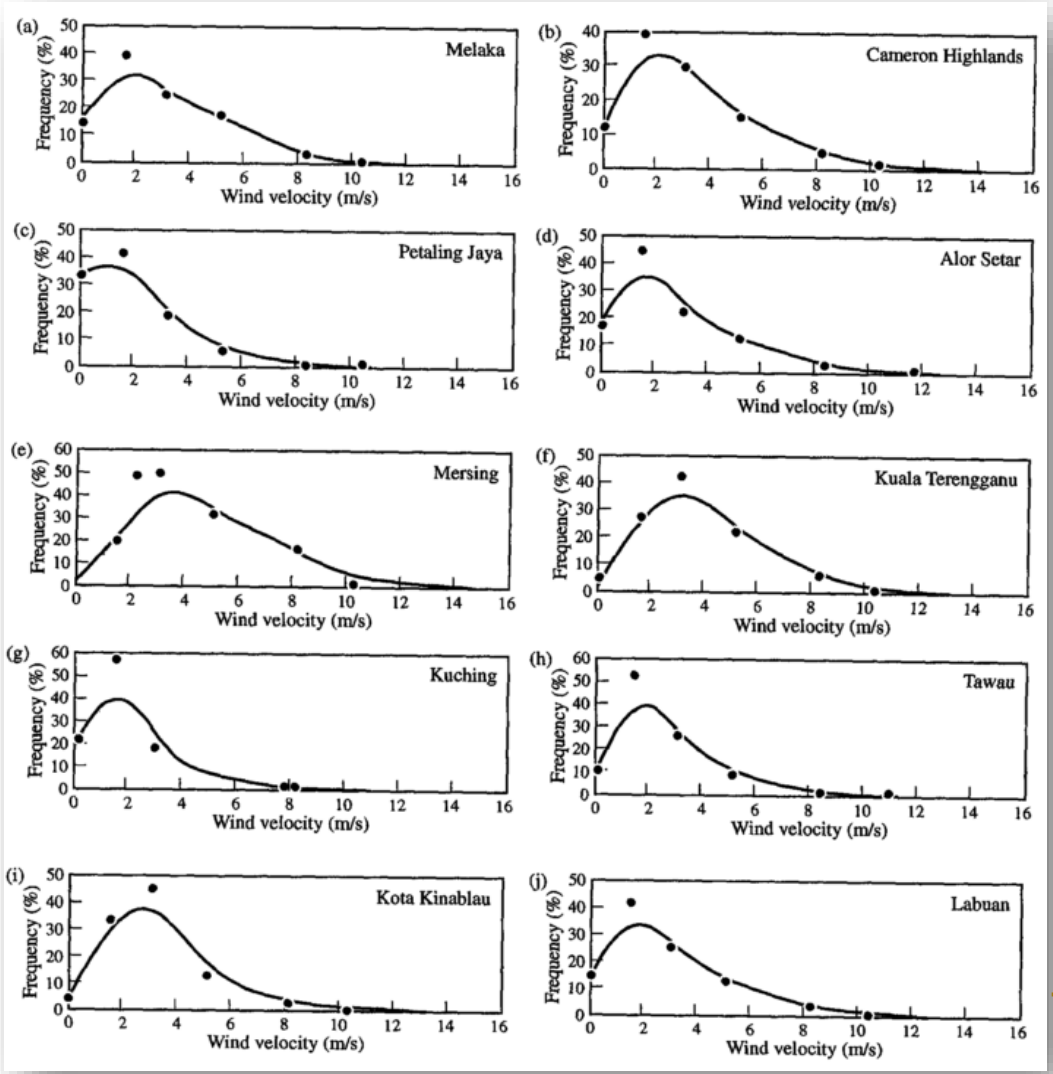


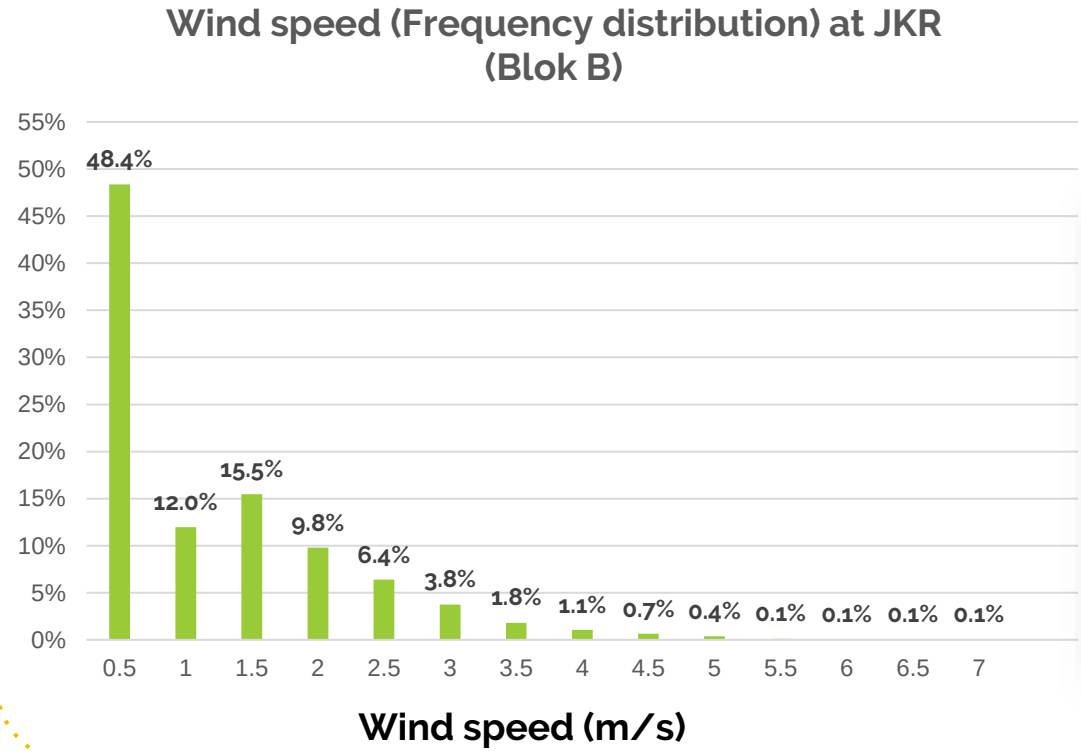
- Malaysia is located at mean **low wind speed** region
- Area in **Kudat, Sabah** shows some potential and mean wind speed can reach **slightly above 5 m/s**



Wind energy assessment

- A study was conducted at **10 meteorological stations.** Data was recorded for **10 years (1998 – 2008)**
- Requires further studies on **low wind speed turbine**

Wind power potential at JKR



Anemometer

Wind turbine system in Malaysia

		System Capacity	Current Status
Pulau Layang layang, Sabah (2003)		**Wind : 150 kW Data on other components not available**	**Not function**
Teluk Melano, Sarawak Bario, Sarawak Ranau, Sabah (2008)		**Wind : 4 x 2.5 kW PV : 1.8 kWp Genset : 15 kVA**	**Not function**
Pulau Perhentian, Terengganu (2007)		**Wind : 2 x 100 kW PV : 100 kWp Genset : 200 kW**	**Only PV & genset function**

Wind vs Solar PV

	Wind energy technology	Solar PV technology
 Resources	Low wind speed < 4 m/s Varies with location	Abundant Sunlight available all year
 Potential	107 W/m² @ 50 meter 118 W/m² @ 100 meter (UK : 928 W/m² @ 100meter) Potential to intergrate with other source	± 4,000 Wh/m² 1,200 kWh/kW/year Temperature effect Requires space ~ 1 kW = 10 m²
 Cost	Grid connected: RM6,500 – RM19,000/ kW	Grid connected: < RM5,000/kWp


THANK YOU