

ENERGY



Dr Philip Holden

Types of Energy



Mechanical
Energy



Thermal
Energy



Nuclear
Energy



Chemical
Energy



Electromagnetic
Energy



Sonic
Energy



Gravitational
Energy



Kinetic
Energy



Potential
Energy



Ionization
Energy

Units of Energy

Joule (J) is the SI unit of energy

calorie (cal) is the amount of energy needed to raise one gram of water by 1°C

Please, note:

kcal = energy needed to raise **1000 g** of water 1°C

food Calories = kcals

Energy Conversion Factors

$$1 \text{ calorie (cal)} = 4.184 \text{ joules (J) (exact)}$$

$$1 \text{ Calorie (Cal)} = 1000 \text{ calories (cal)}$$

$$1 \text{ kilowatt-hour (kWh)} = 3.60 \times 10^6 \text{ joules (J)}$$

James Prescott Joule

James Prescott Joule

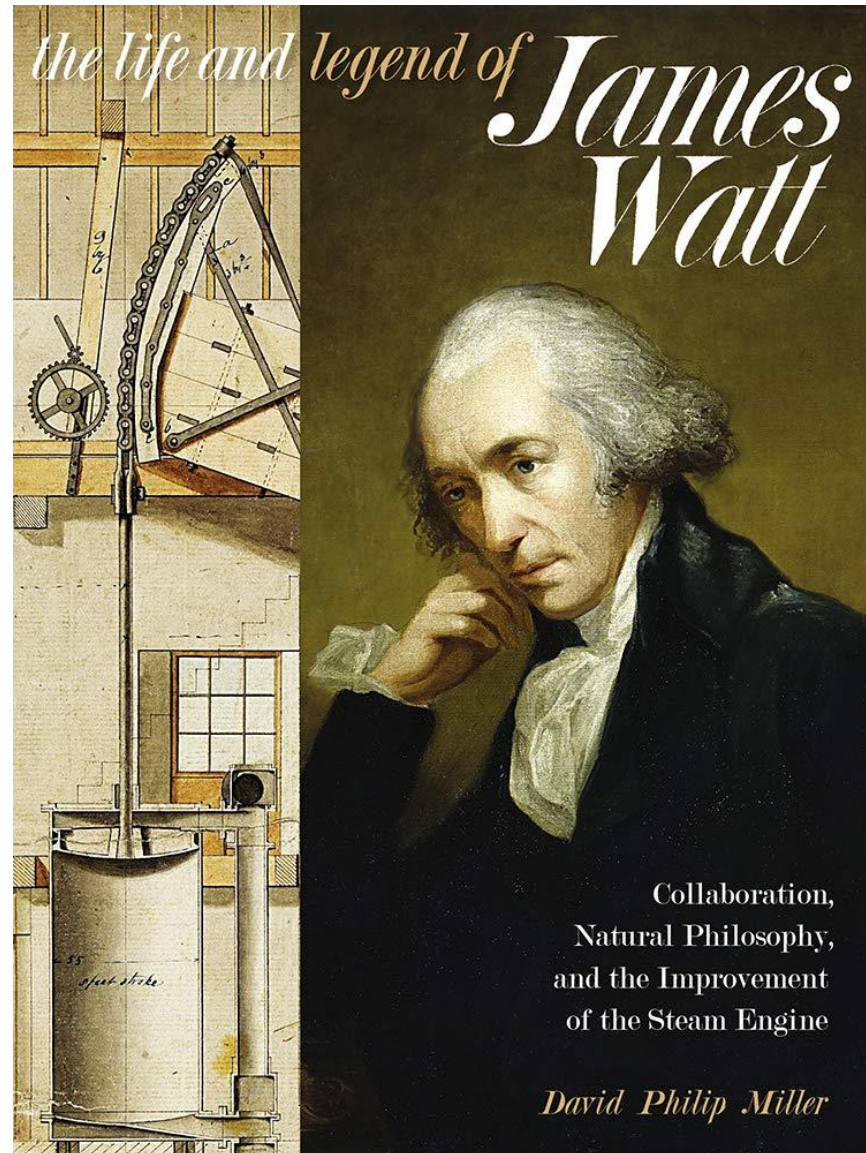
James Prescott Joule was born on December 24, 1818 in Salford. He was an English physicist. Joule studied the nature of heat, and discovered its relationship to mechanical work in each state of matter. His name is now the unit for heat. He was awarded a Copley Medal and a Royal Medal. He died on October 11, 1889.



SI Units of Energy and Power

- The SI unit of energy is a **Joule**: $1 \text{ kg} \cdot \text{m}^2/\text{s}^2 = 1 \text{ Newton} \cdot \text{m}$ (Newton is the unit of Force)
 - mass * velocity ²
 - mass * g * height (on earth, $g = 9.81 \text{ m/s}^2$)
 - for an ideal gas = $c_v k_B T$ ($c_v = 3/2$ for a monatomic gas)
- **Power** is energy per time: $1 \text{ Watt} = 1 \text{ Joule/s} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^3$
 - most commonly used in electricity, but also for vehicles in horsepower (acceleration time)

James Watt



Kinetic and Potential Energy

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

m = mass of object (kg)

v = velocity (speed) of
object (m/s)

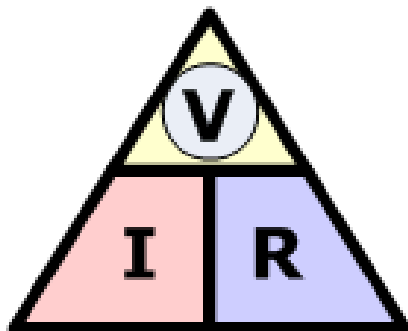
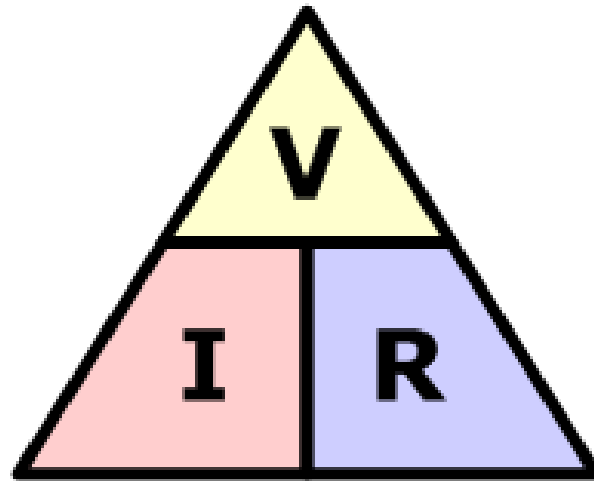
$$\text{Gravitational P.E.} = mgh$$

m = mass of object (kg)

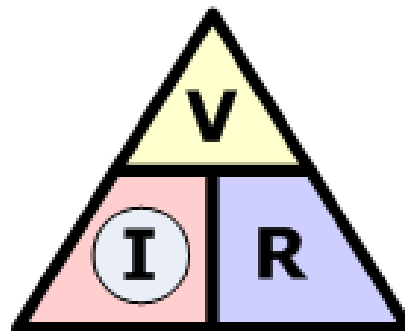
g = gravitational acceleration, on Earth = 9.8 m/s²

h = height of object from sea level (defined as 0 m)

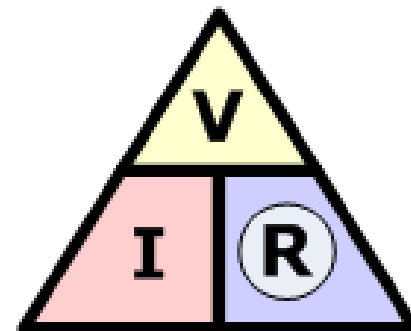
Ohms Law Triangle



$$\textcircled{\mathbf{V}} = I \times R$$

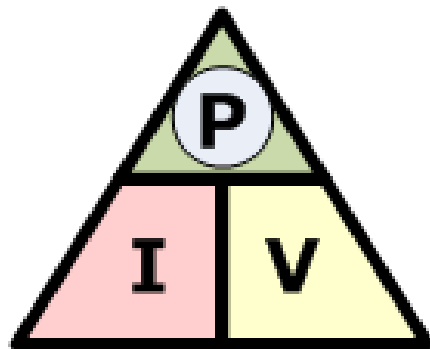
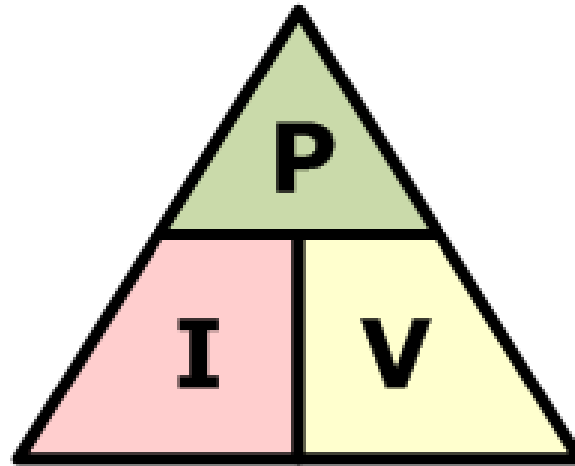


$$\textcircled{\mathbf{I}} = \frac{V}{R}$$

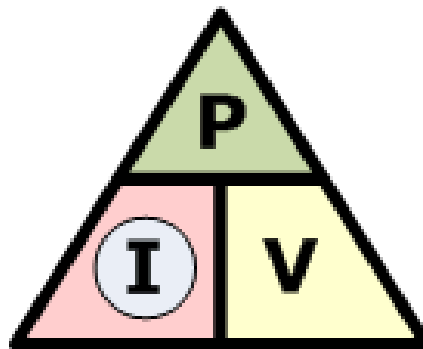


$$\textcircled{\mathbf{R}} = \frac{V}{I}$$

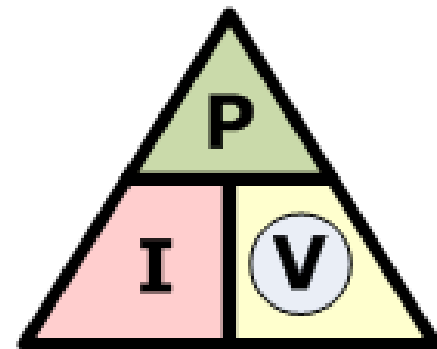
The Power Triangle



$$\textcircled{P} = I \times V$$



$$\textcircled{I} = \frac{P}{V}$$



$$\textcircled{V} = \frac{P}{I}$$

Georg Simon Ohm

Ohm's Law

$$I = V / R$$



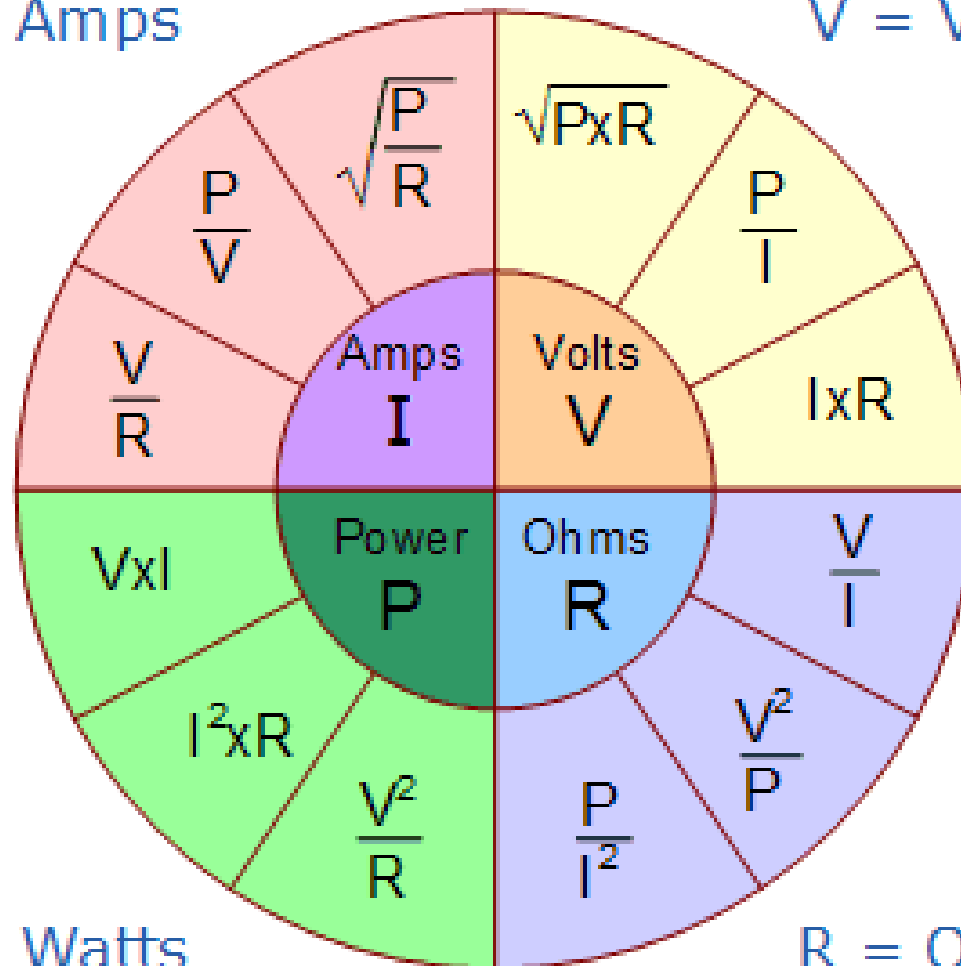
Georg Simon **Ohm** (1787-1854)

- I = Current (Amperes) (amps)
- V = Voltage (Volts)
- R = Resistance (ohms)

Ohms Law Pie Chart

I = Amps

V = Volts



P = Watts

R = Ohms

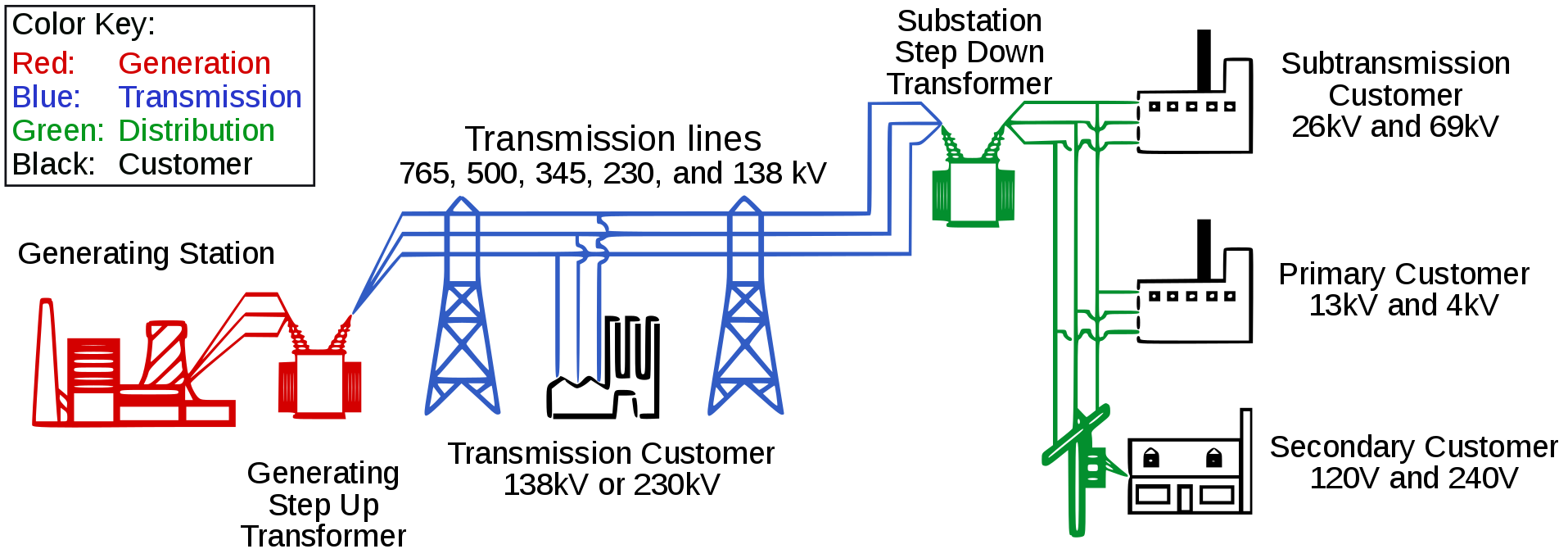
Ohms Law Matrix Table

Ohms Law Formulas				
Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I \times R$	$P = I^2 \times R$
Voltage & Current	$R = \frac{V}{I}$	---	---	$P = V \times I$
Power & Current	$R = \frac{P}{I^2}$	---	$V = \frac{P}{I}$	---
Voltage & Resistance	---	$I = \frac{V}{R}$	---	$P = \frac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{P \times R}$	---
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	---	---

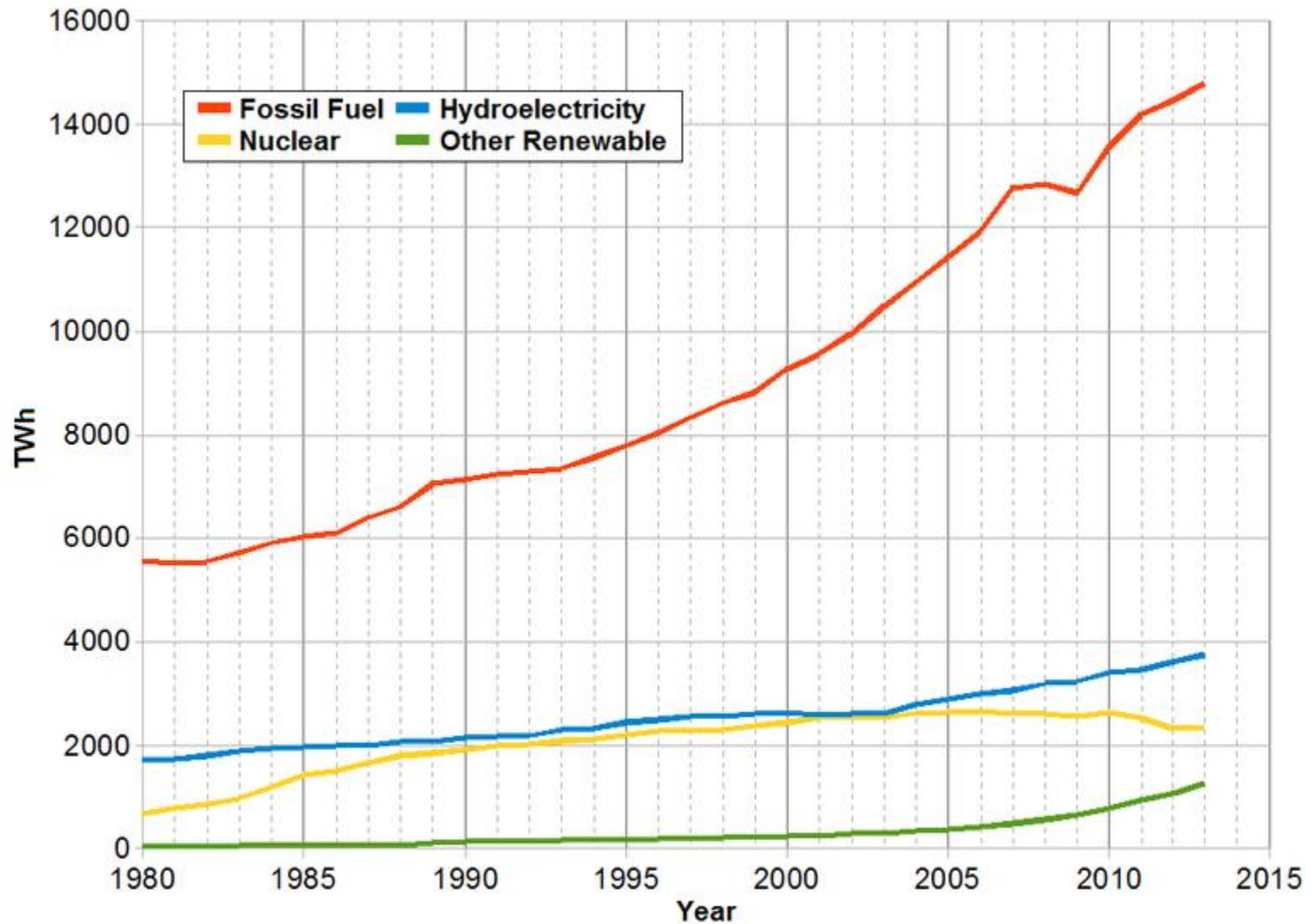
Common Energy Units

Energy conversion			
Unit	Quantity	to	Note
1 calorie =	4.1868000	Joule	
1 kiloWatt hour = kWh =	3600000	Joule	A power of 1 kW for a duration of 1 hour.
1 British Thermal Unit = btu	1055.06	Joule	It is a is a unit of energy used in North America.
1 ton oil equivalent = 1 toe	4.19E+010	Joule	It is the rounded-off amount of energy that would be produced by burning one metric ton of crude oil .
1 ton coal equivalent	2.93E+10	Joule	
1 ton oil equivalent = 1 toe	1 / 7.33	Barrel of oil	or 1 / 7.1 or 1 / 7.4 ...
1 cubic meter of natural gas	3.70E+07	Joule	or roughly 1000 btu/ft ³
1000 Watts for one year	3.16E+010	Joule	for the 2000 Watt society
1000 Watts for one year	8.77E+006	kWh	for the 2000 Watt society
1 horsepower	7.46E+002	Watts	

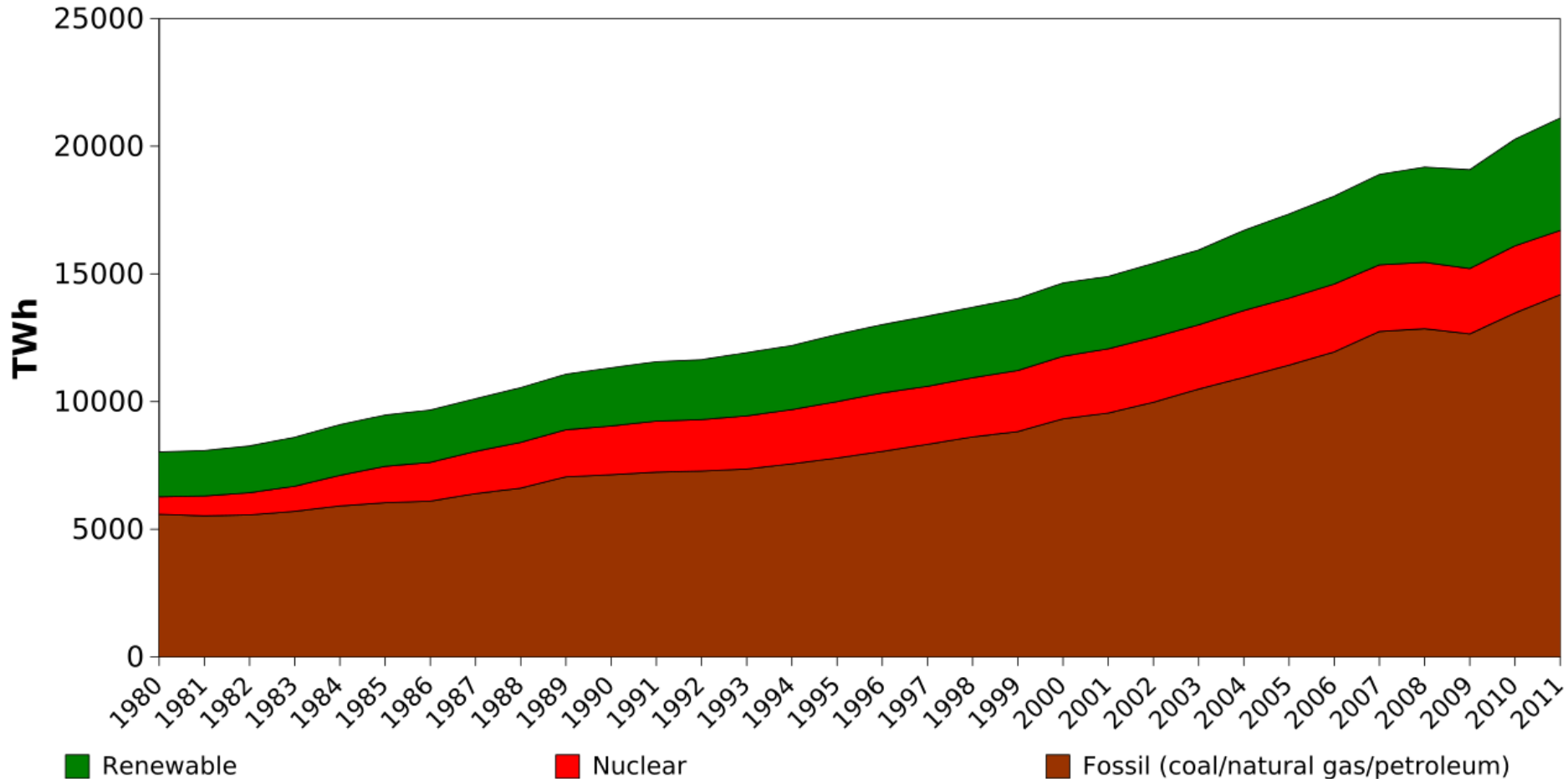
ELECTRICITY GENERATION



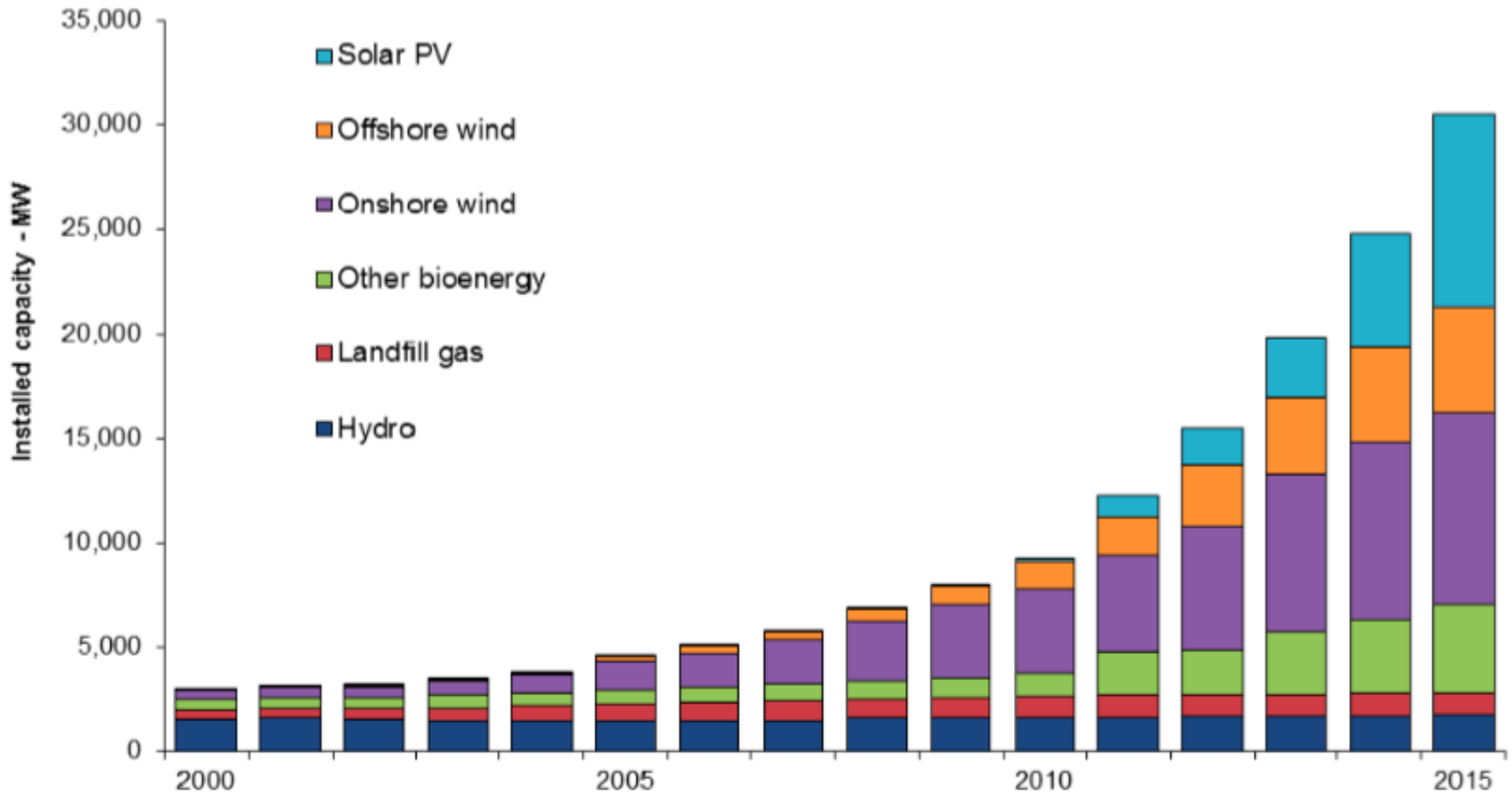
World Electricity Generation



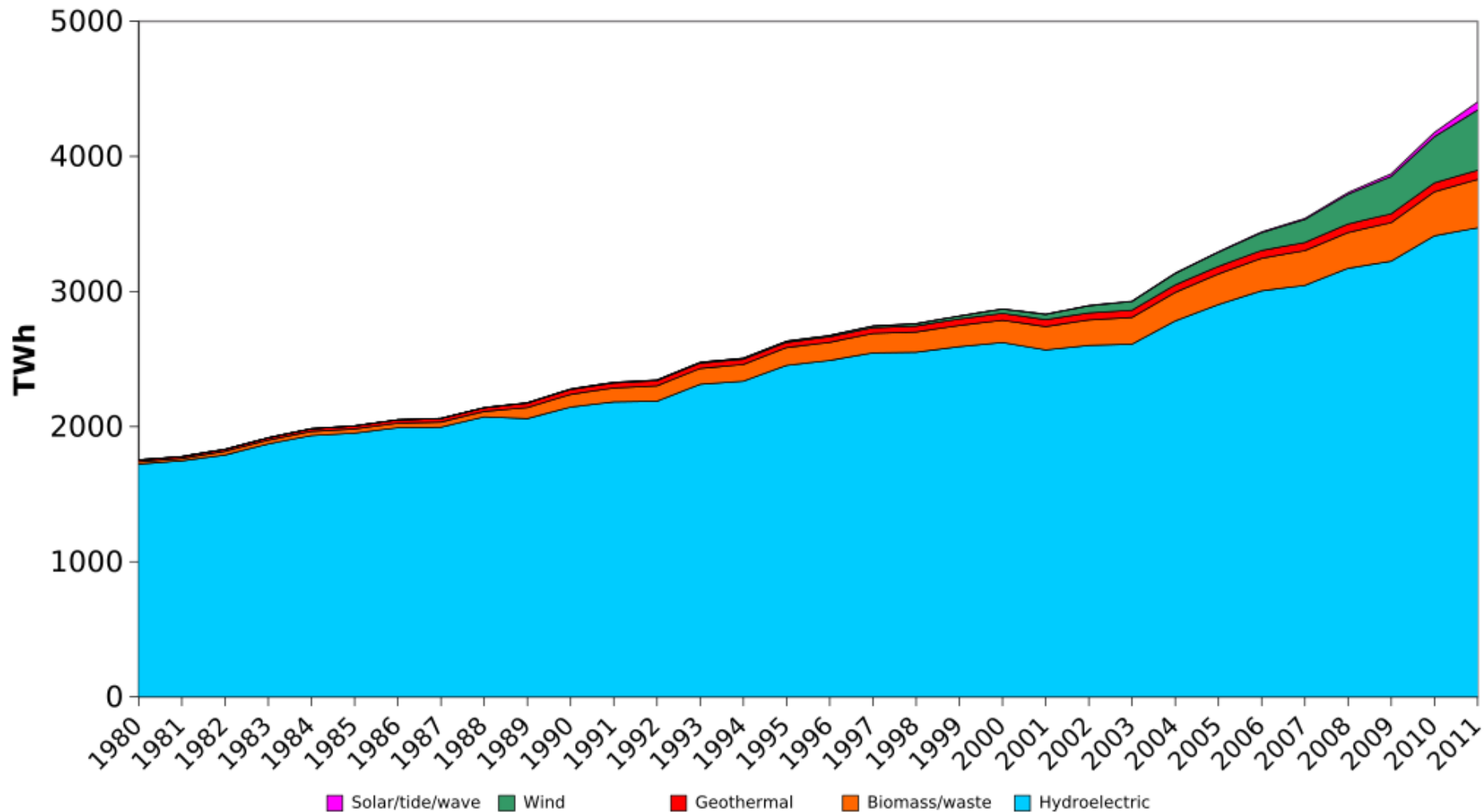
Annual World Net Electricity Generation



Renewables World Electricity Generation

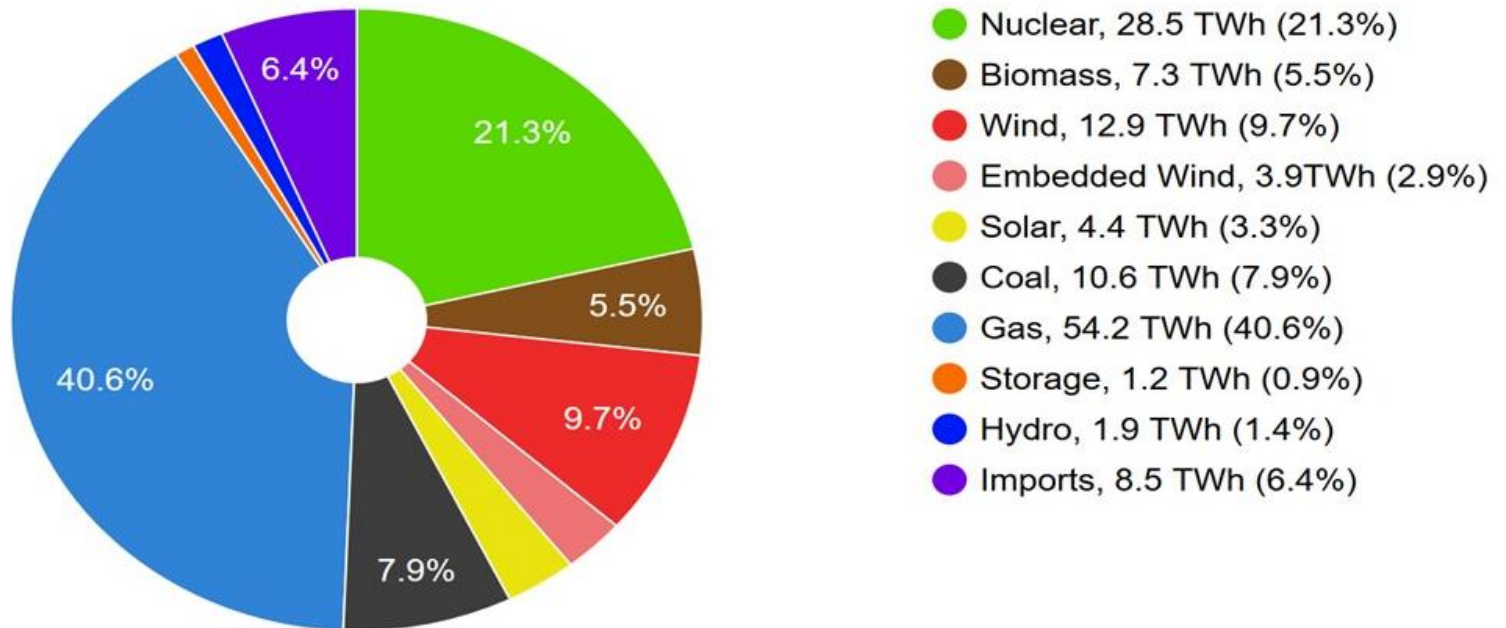


Renewables Annual Net World Electricity Generation



British Electricity Mix

British electricity Mix, 1 Jan 2017 – 09 Jun 2017



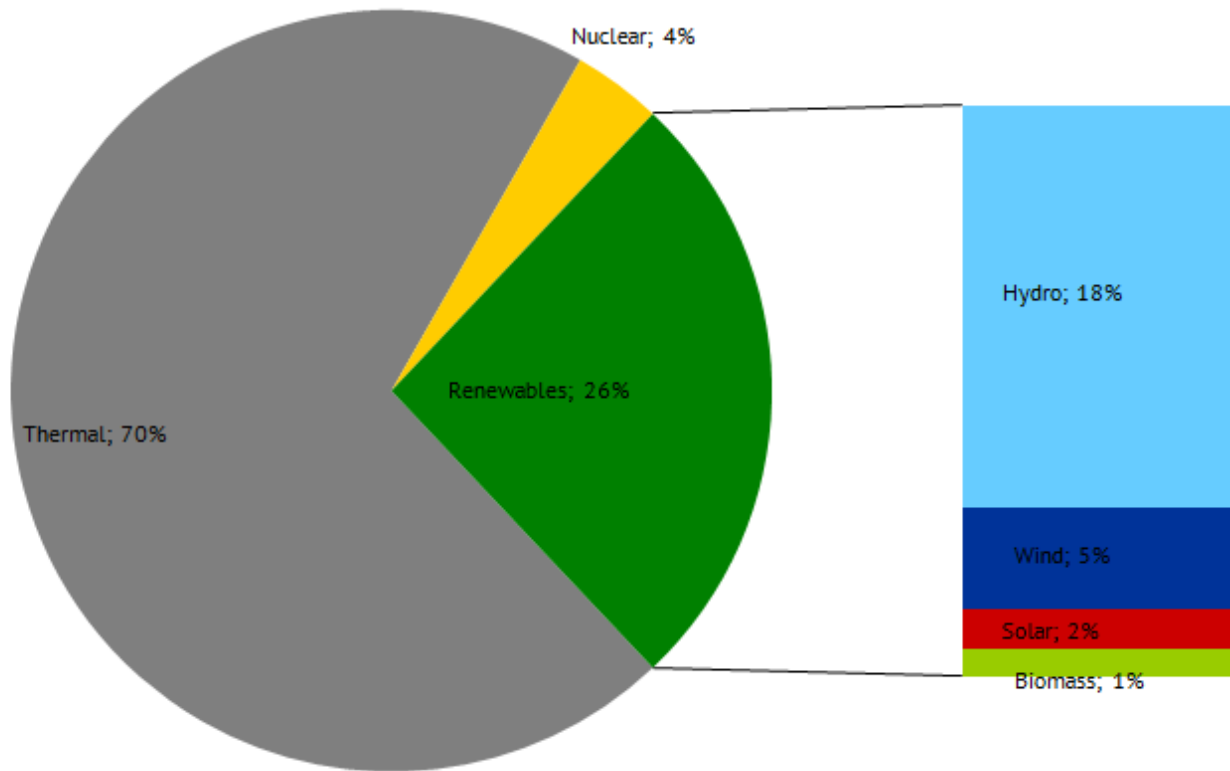
*Embedded wind is turbines and wind farms which are not connected directly to the grid but to the local network. These are not metered so I provide estimated values.

Source: www.MyGridGB.co.uk, Elexon Portal, Sheffield University

<http://www.mygridgb.co.uk/2016-vs-2017/>

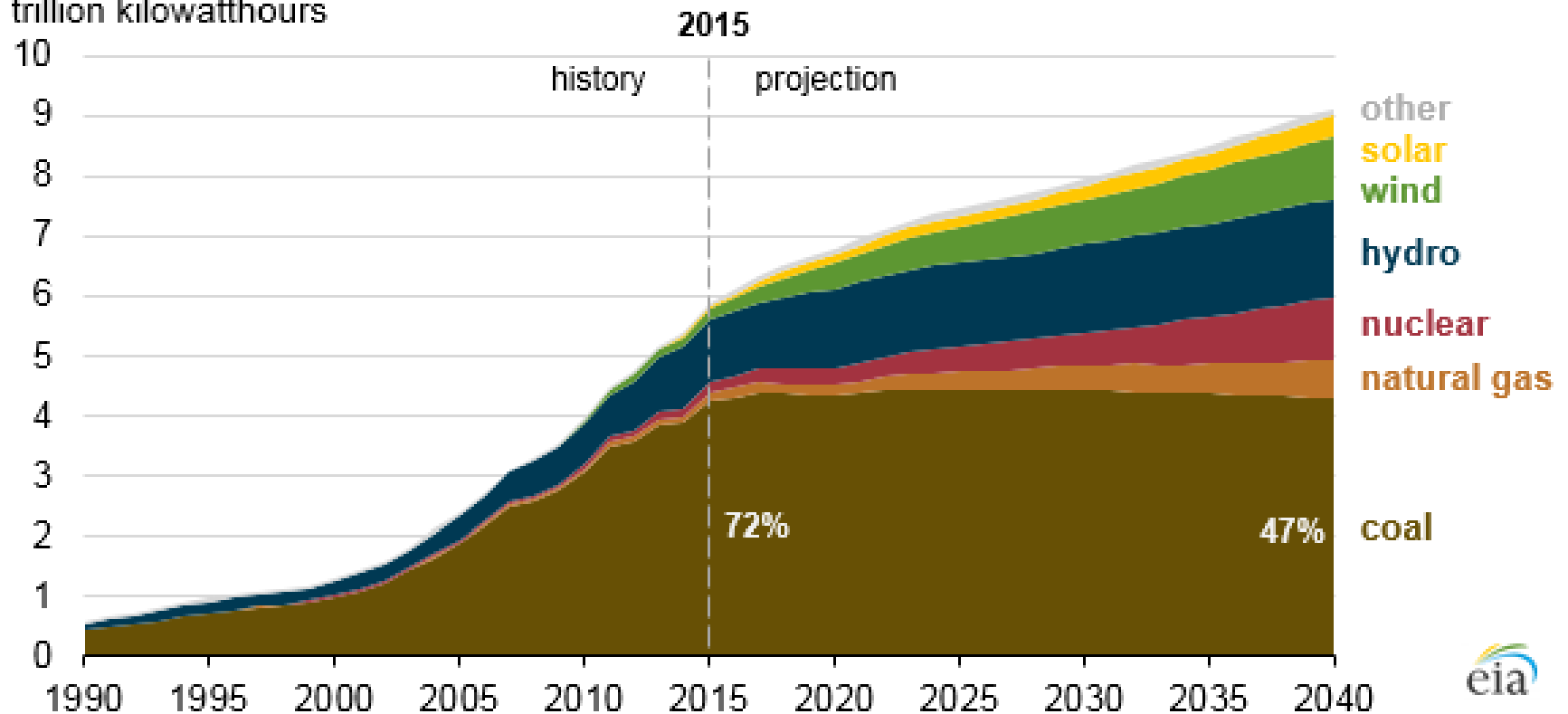
Chinese Electricity Mix

Generation in 2017:
6558 TWh

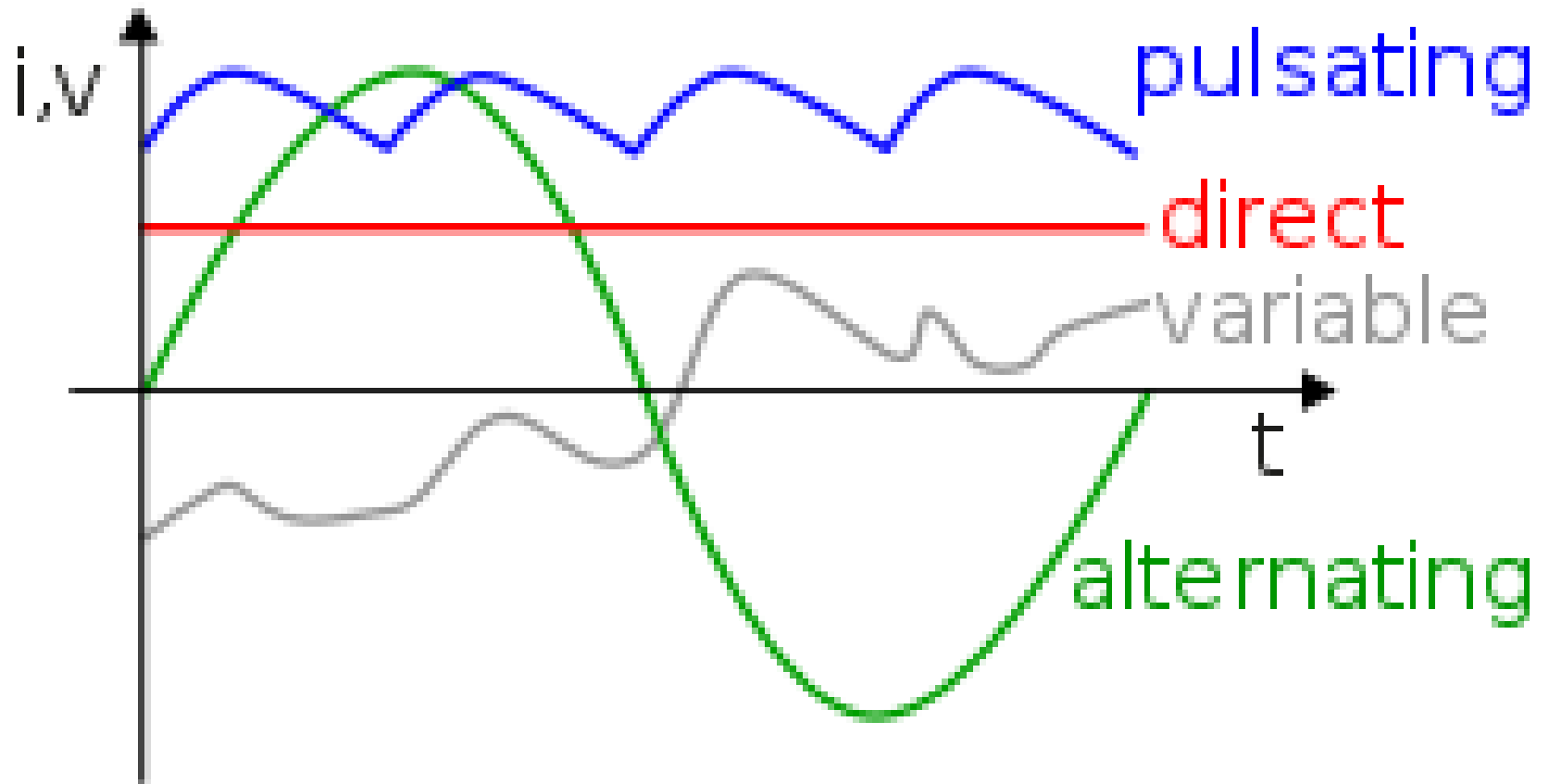


Chinese Electricity Mix (projected)

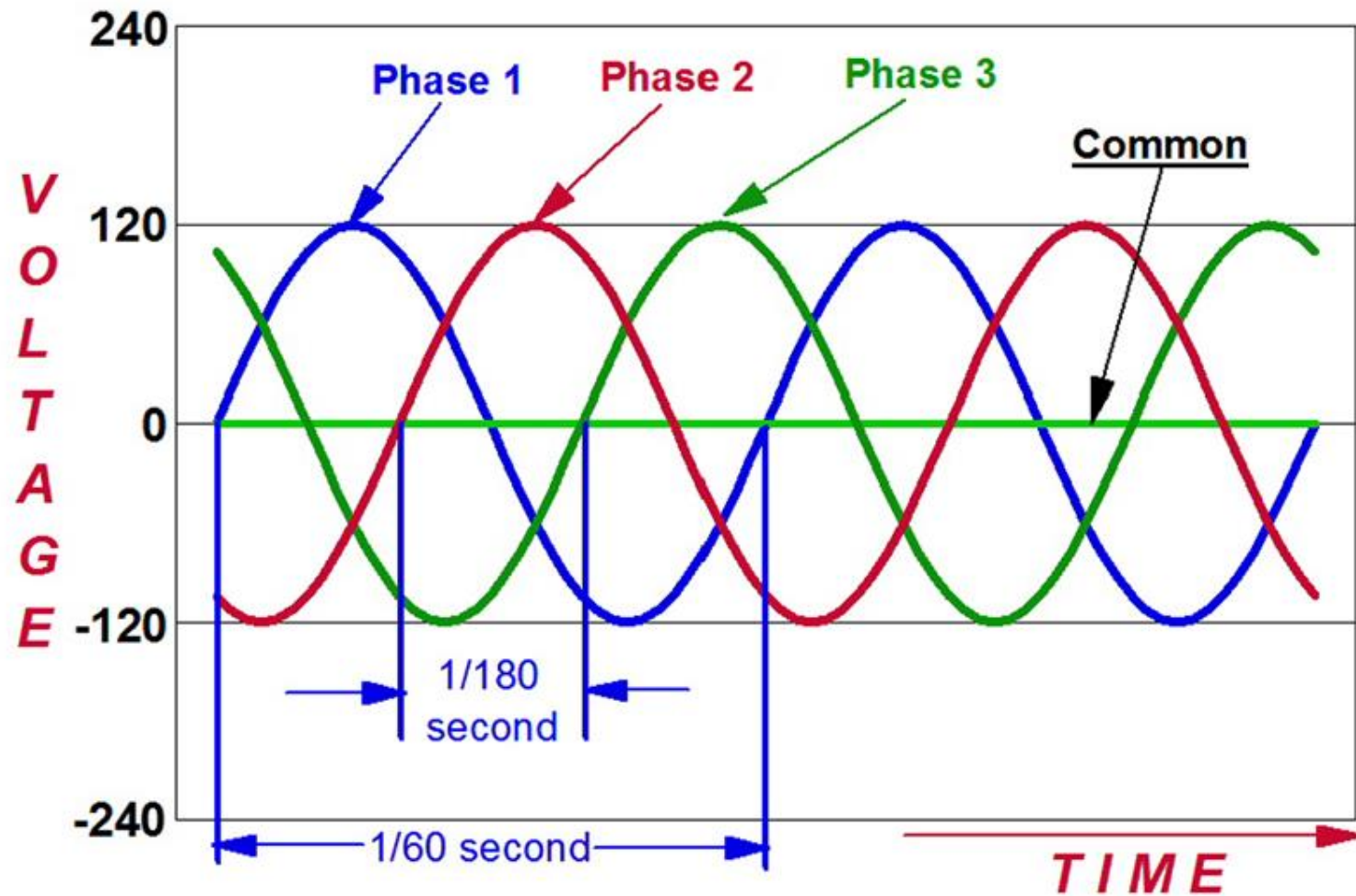
Annual electricity generation in China, IEO2017 Reference case (2005-2040)
trillion kilowatthours



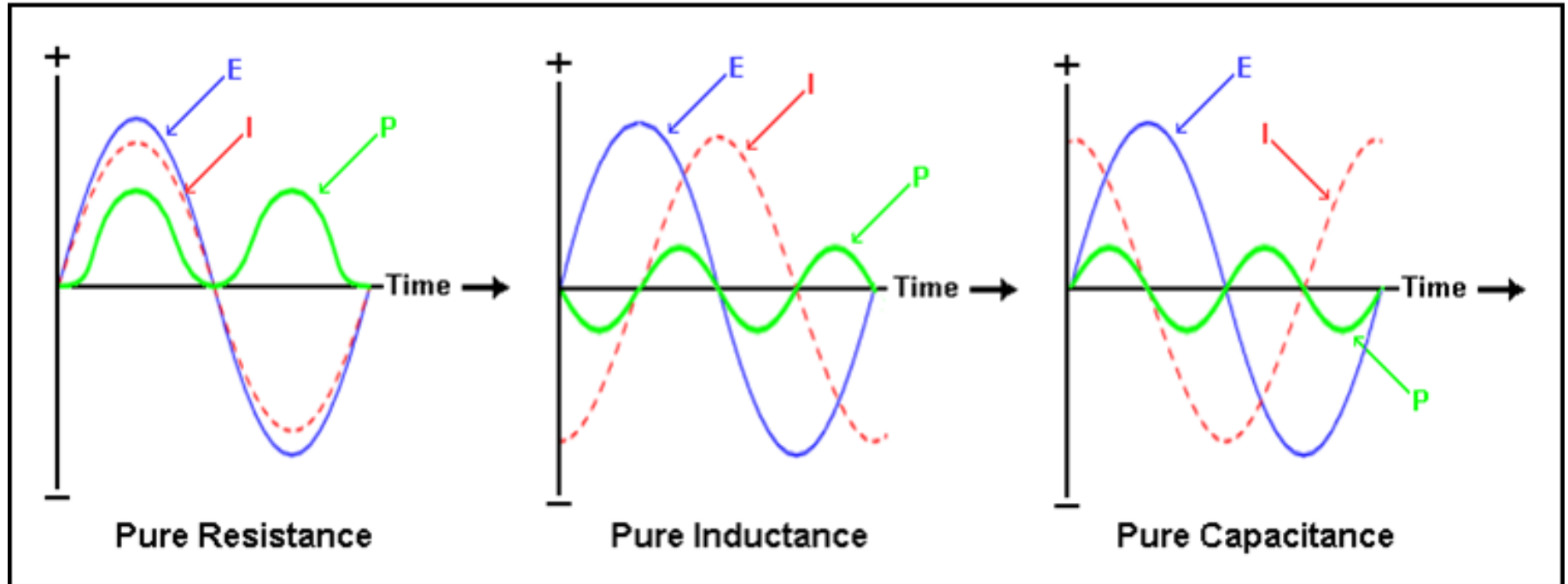
Current Types (AC,DC etc)



Three Phase Supply



Power Factors

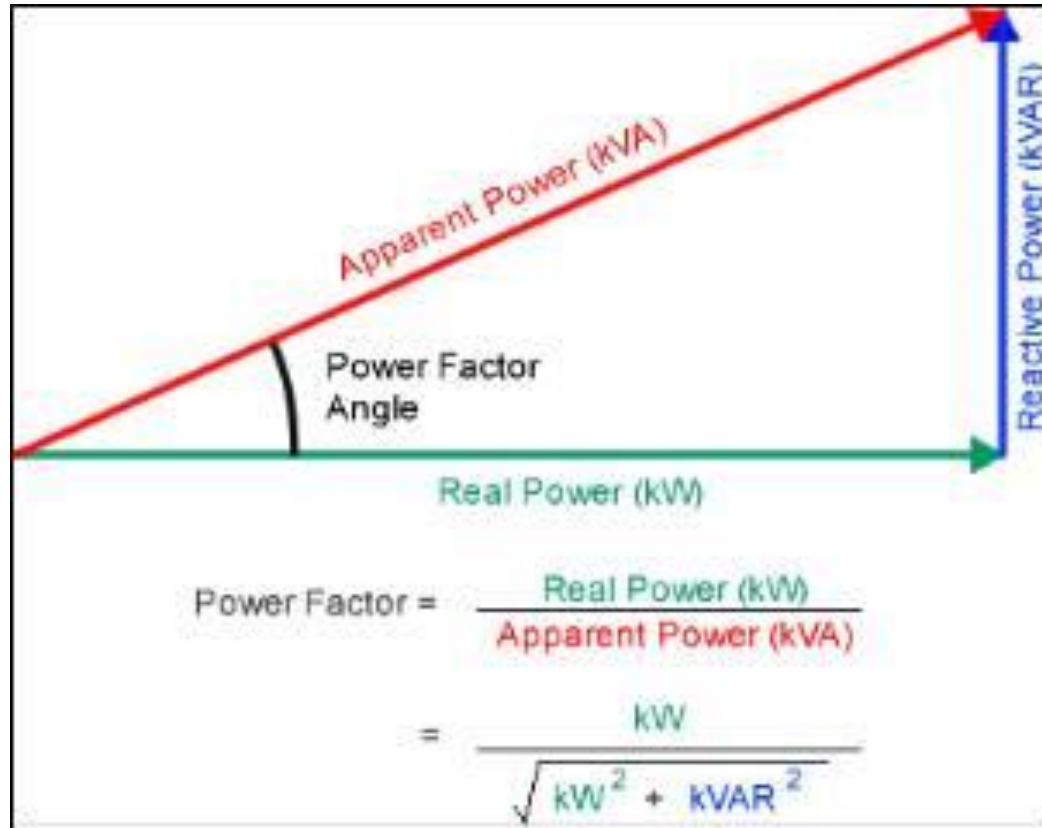


E = Voltage

I = Current

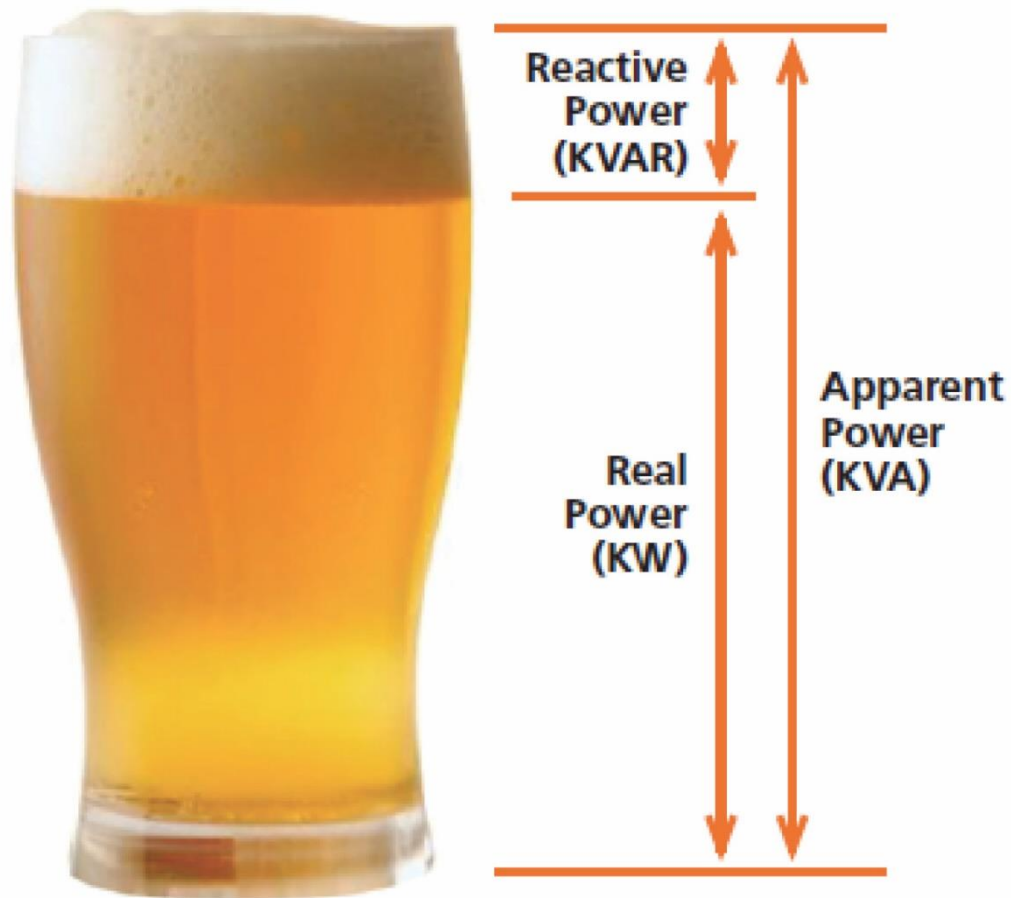
P = Power

Power Factor Calculation

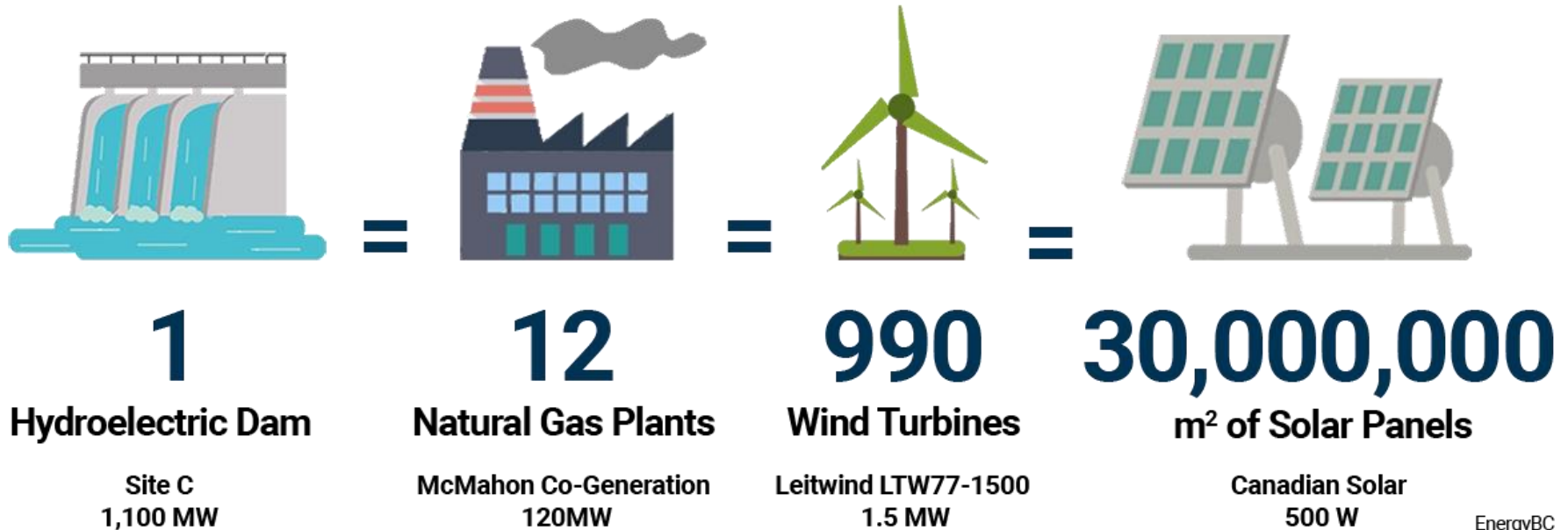


Therefore $\cos \phi = \text{adjacent/hypotenuse} = \text{Real power/apparent power}$

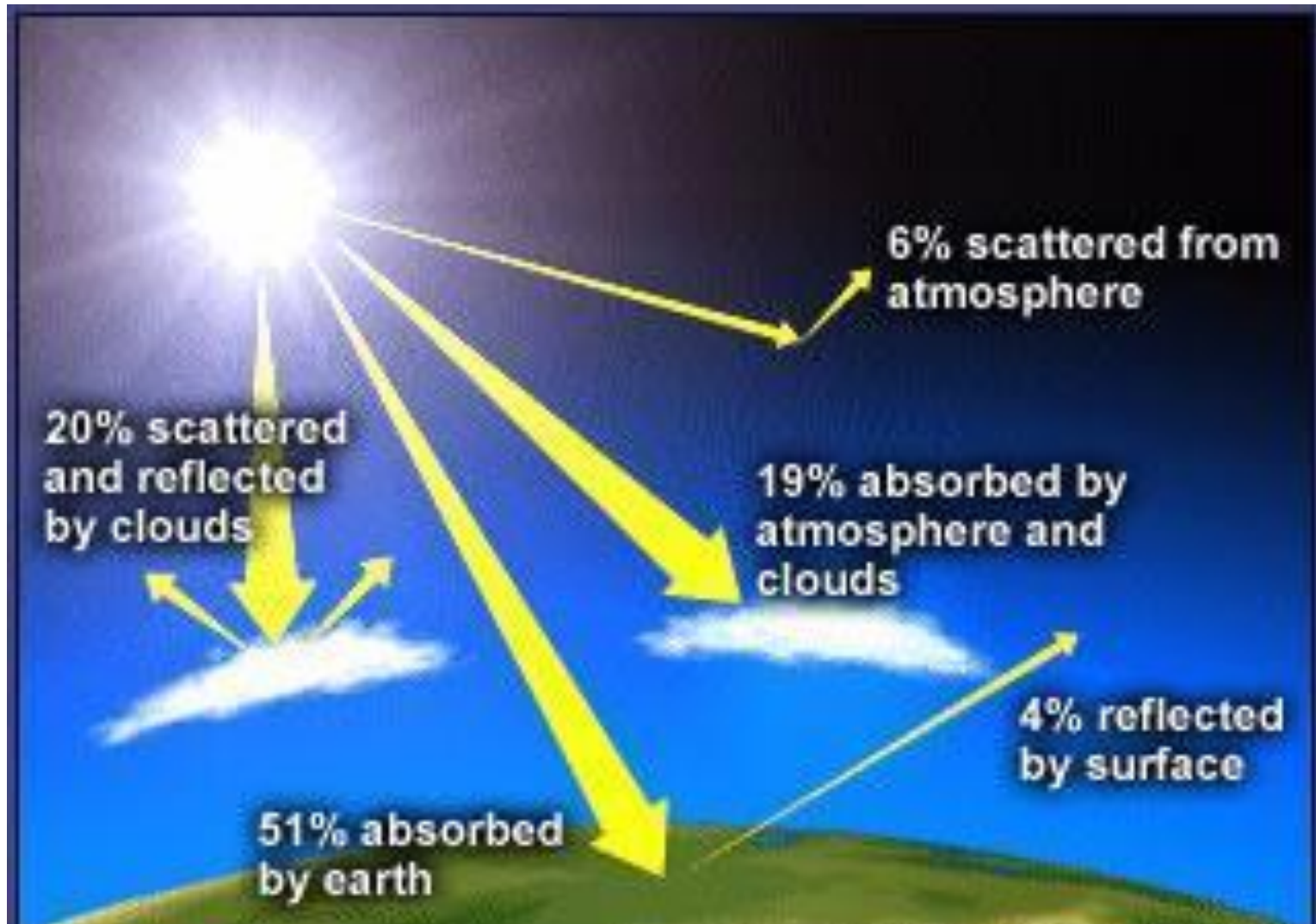
Beer Analogy for Power Factor



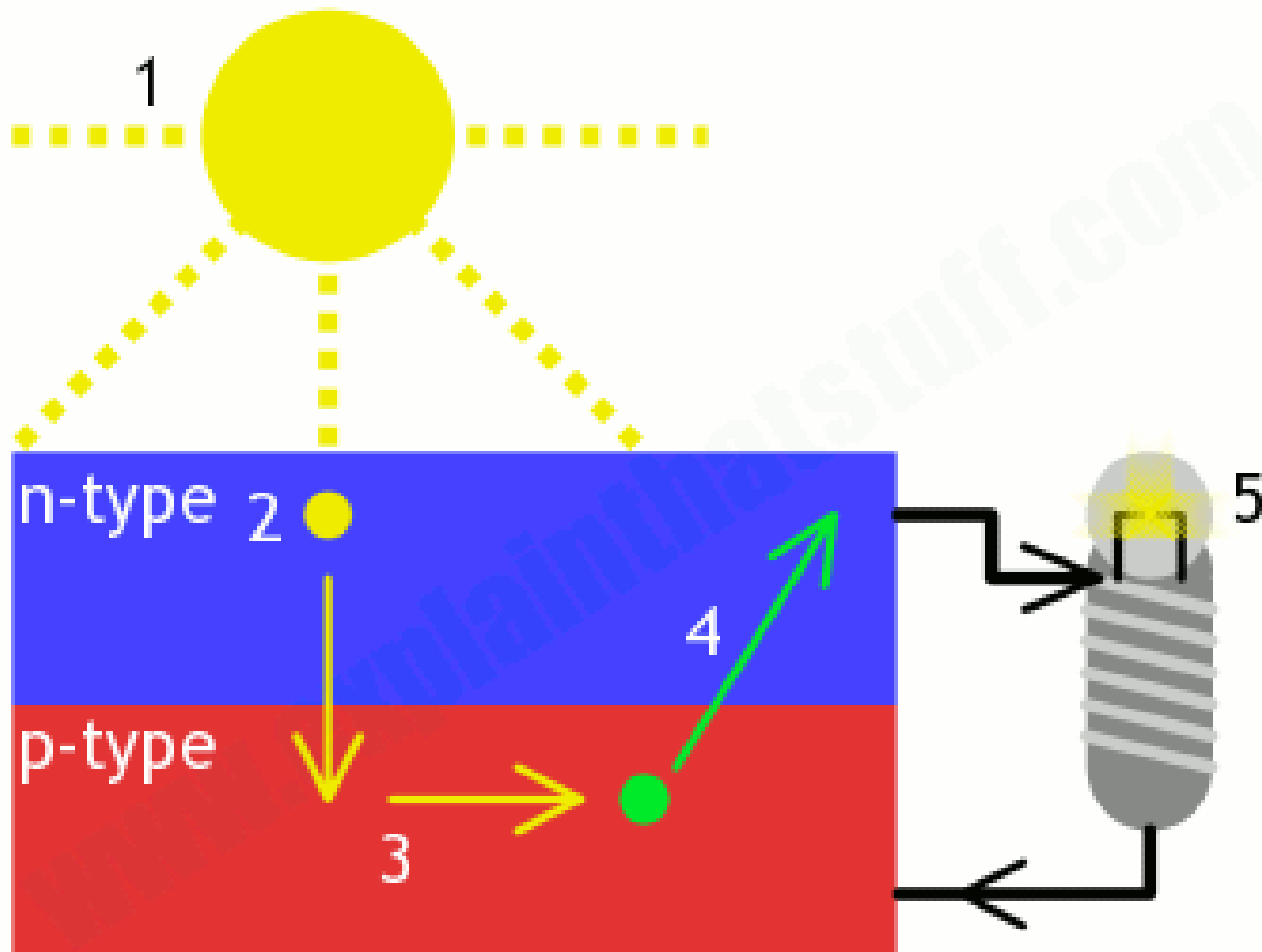
Renewable Energy Comparison



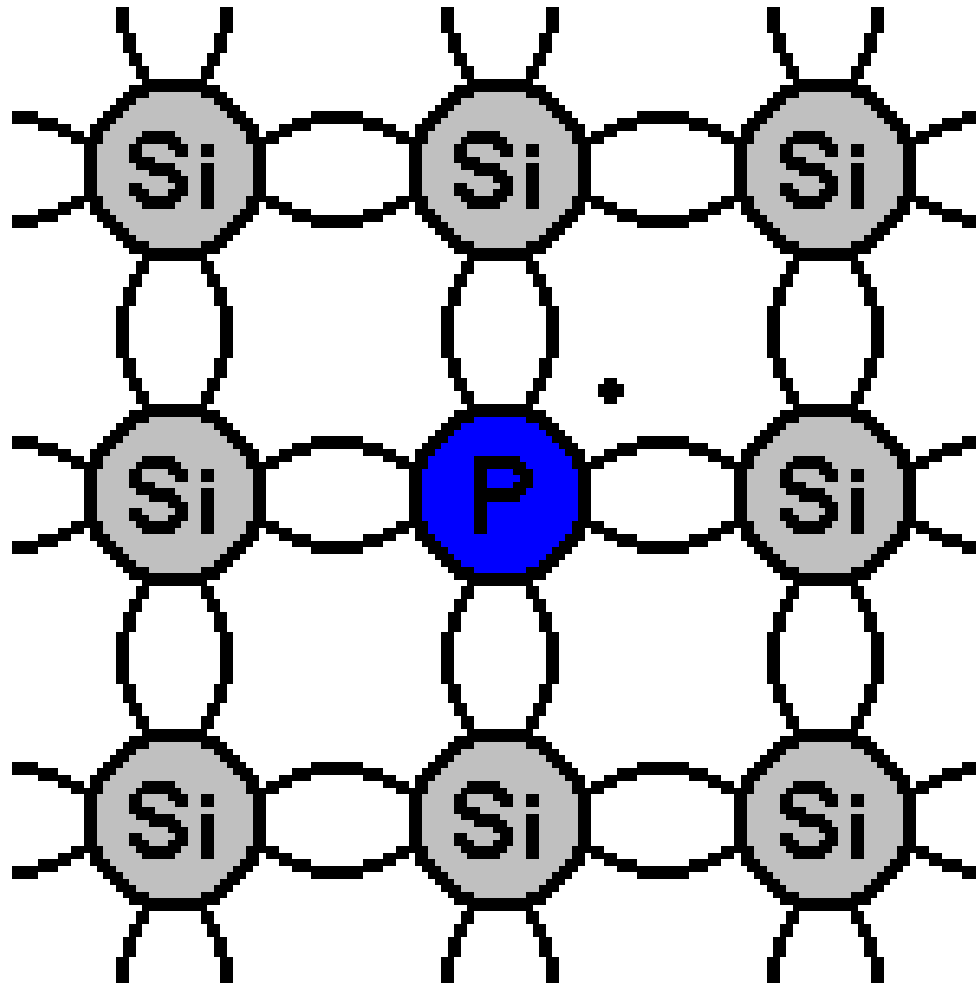
Potential Solar Energy



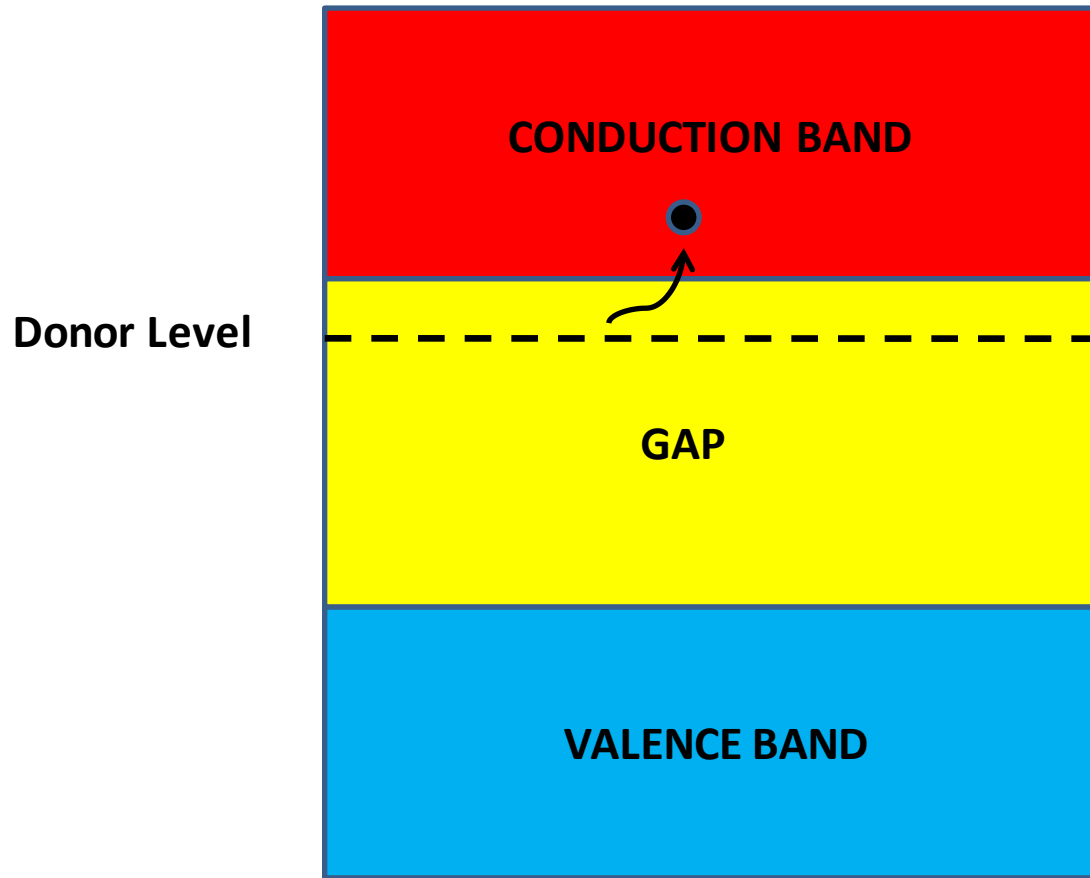
Solar Cells Principle



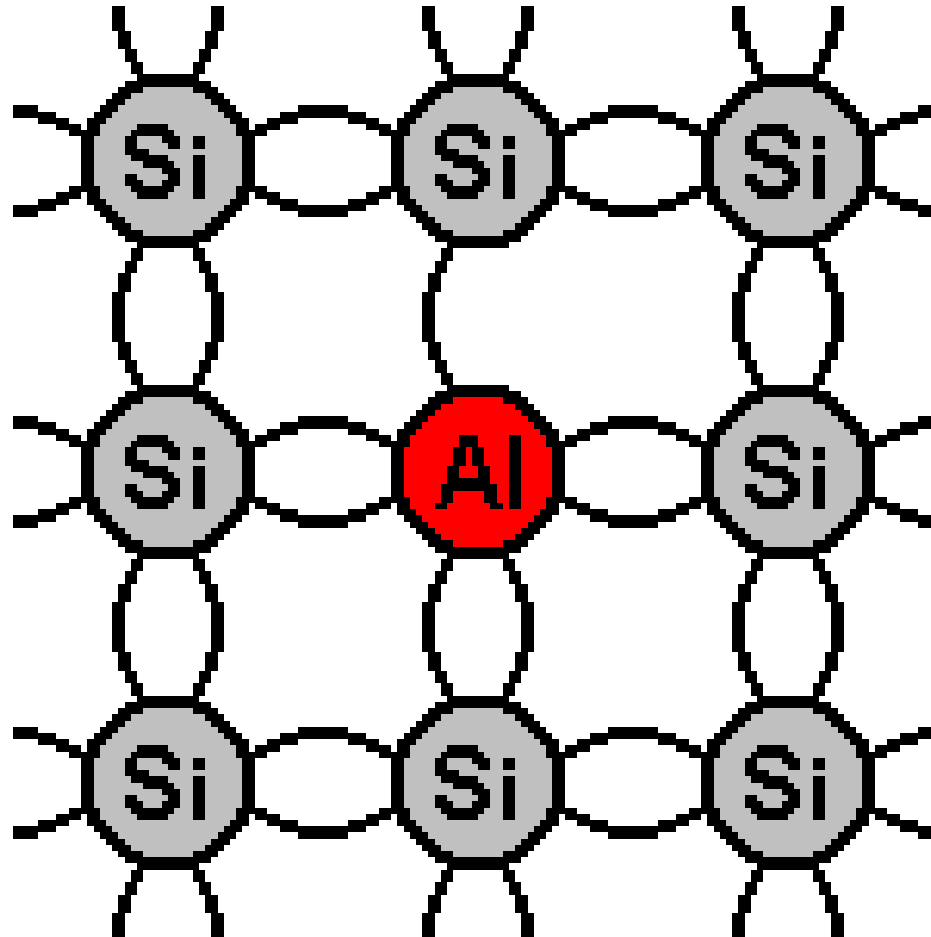
N(Negative) Doped Semiconductor Structure (Phosphorous in Silicon)



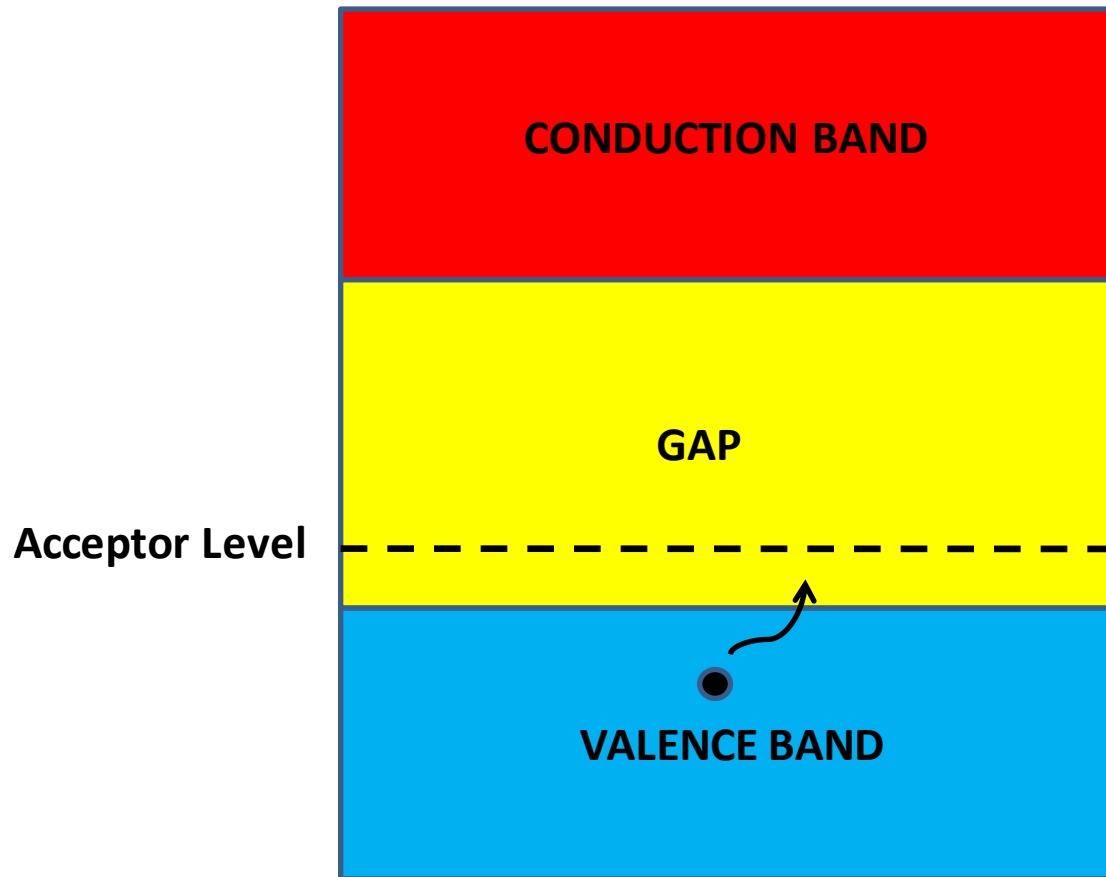
Doping of Semiconductors N Type



P(Positive) Doped Semiconductor Structure (Aluminium in Silicon)

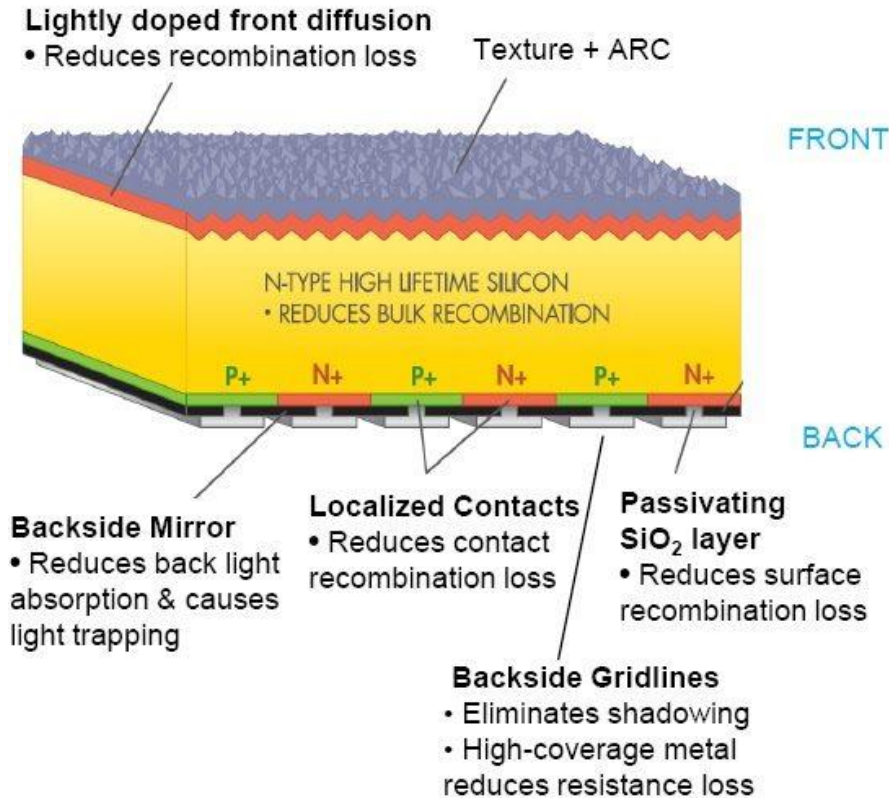


Doping of Semiconductors P Type



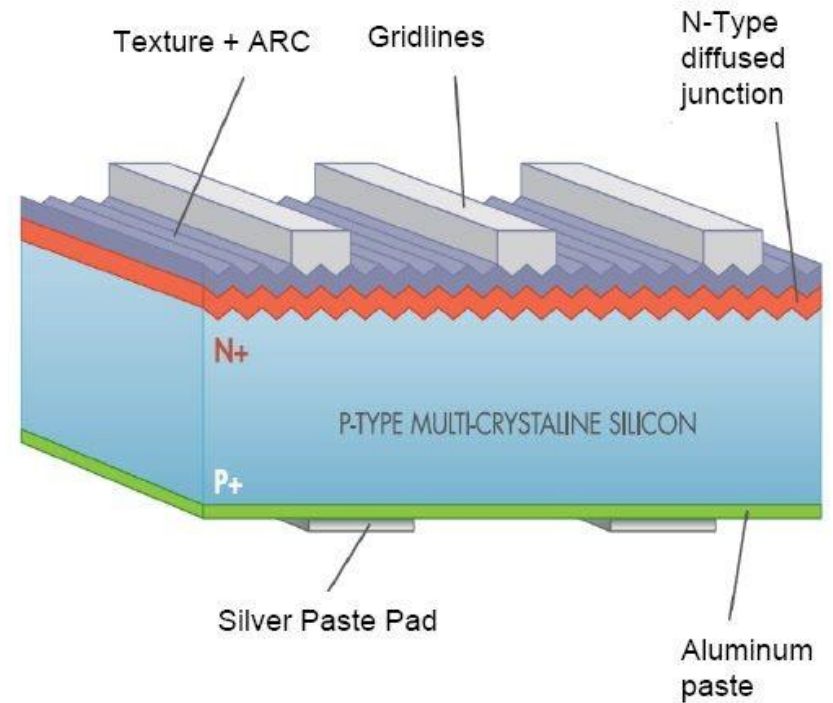
SUNPOWER

SOLAR CELL 22% EFFICIENCY

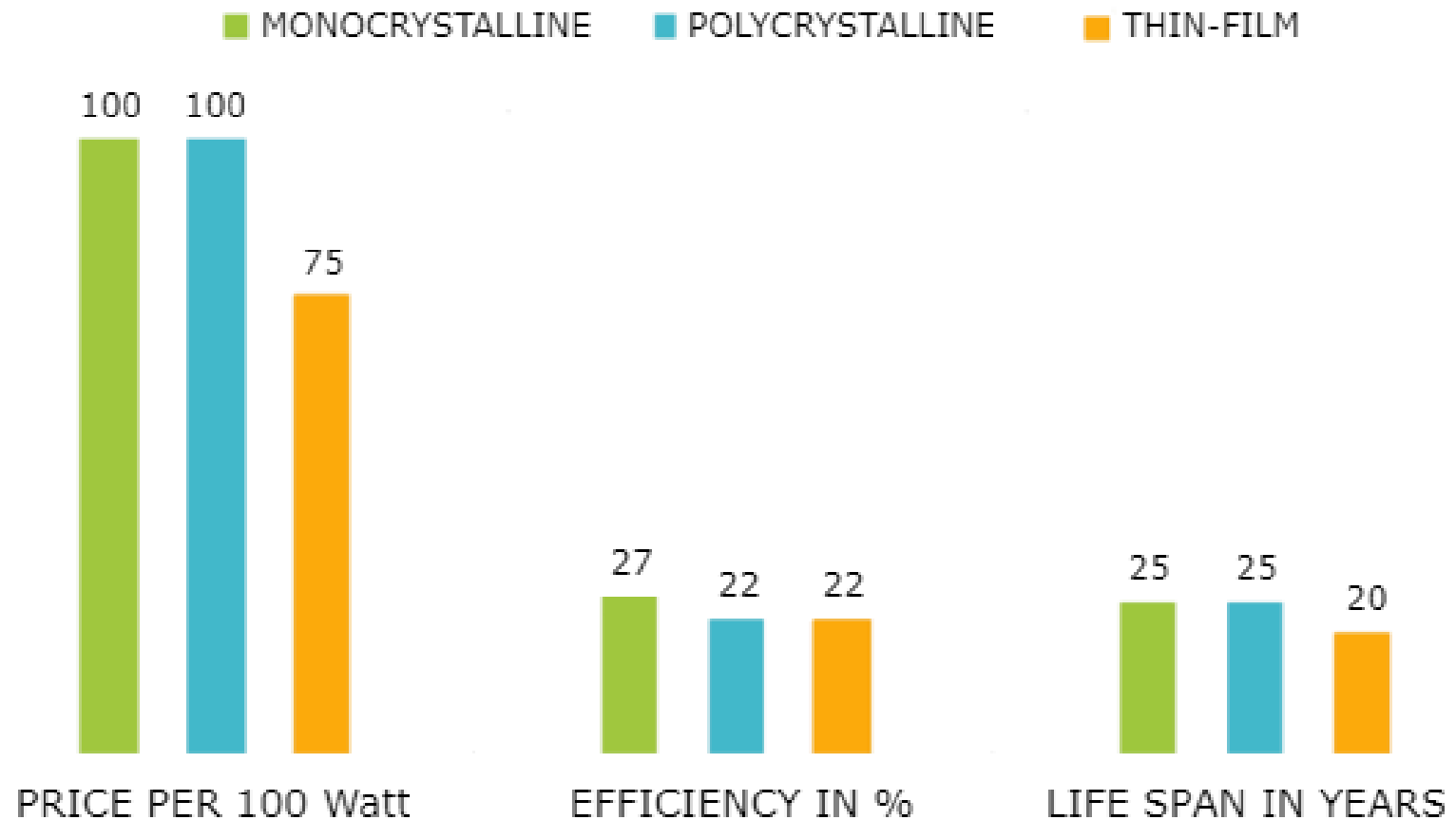


CONVENTIONAL

SOLAR CELL 15% EFFICIENCY



Efficiencies of Solar Panels



Solar cell Efficiency (Maximum):-

$$\eta_{max} = \frac{P_{max}}{E * A_c} \times 100 \%$$

P_{max} = Maximum Power Output (in W)

E = incident radiation flux (in W/m²)

A_c = Area of Collector (in m²)

The Wind Power Equation

$$P = 0.5 \times \rho \times A \times V^3 \times C_p \text{ (watts)}$$

Where :

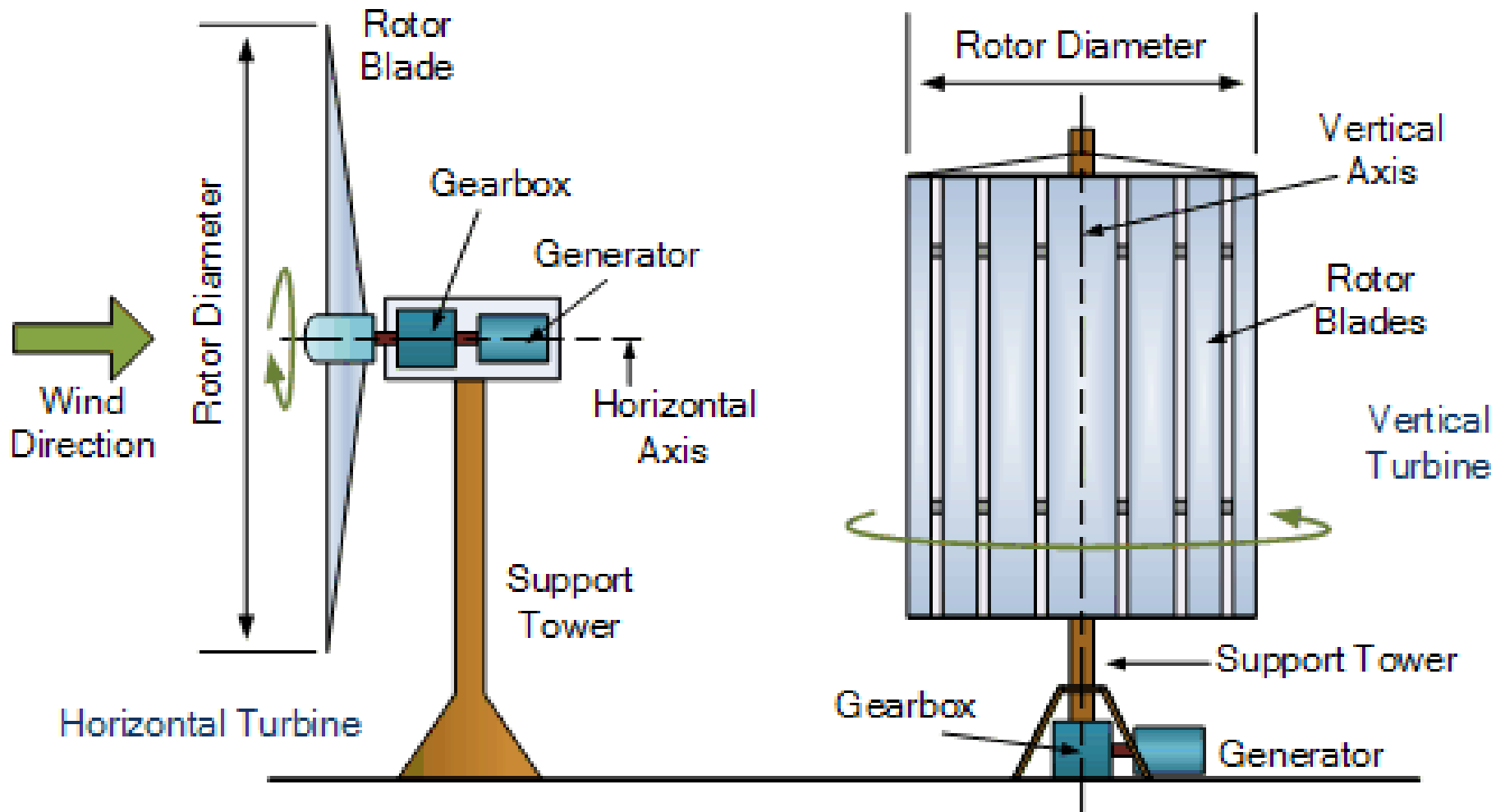
P is the Power in watts generated

ρ is the air density

A is the frontal area

C_p is coefficient of performance

Horizontal and Vertical Wind Turbines



Wind Turbine Calculation

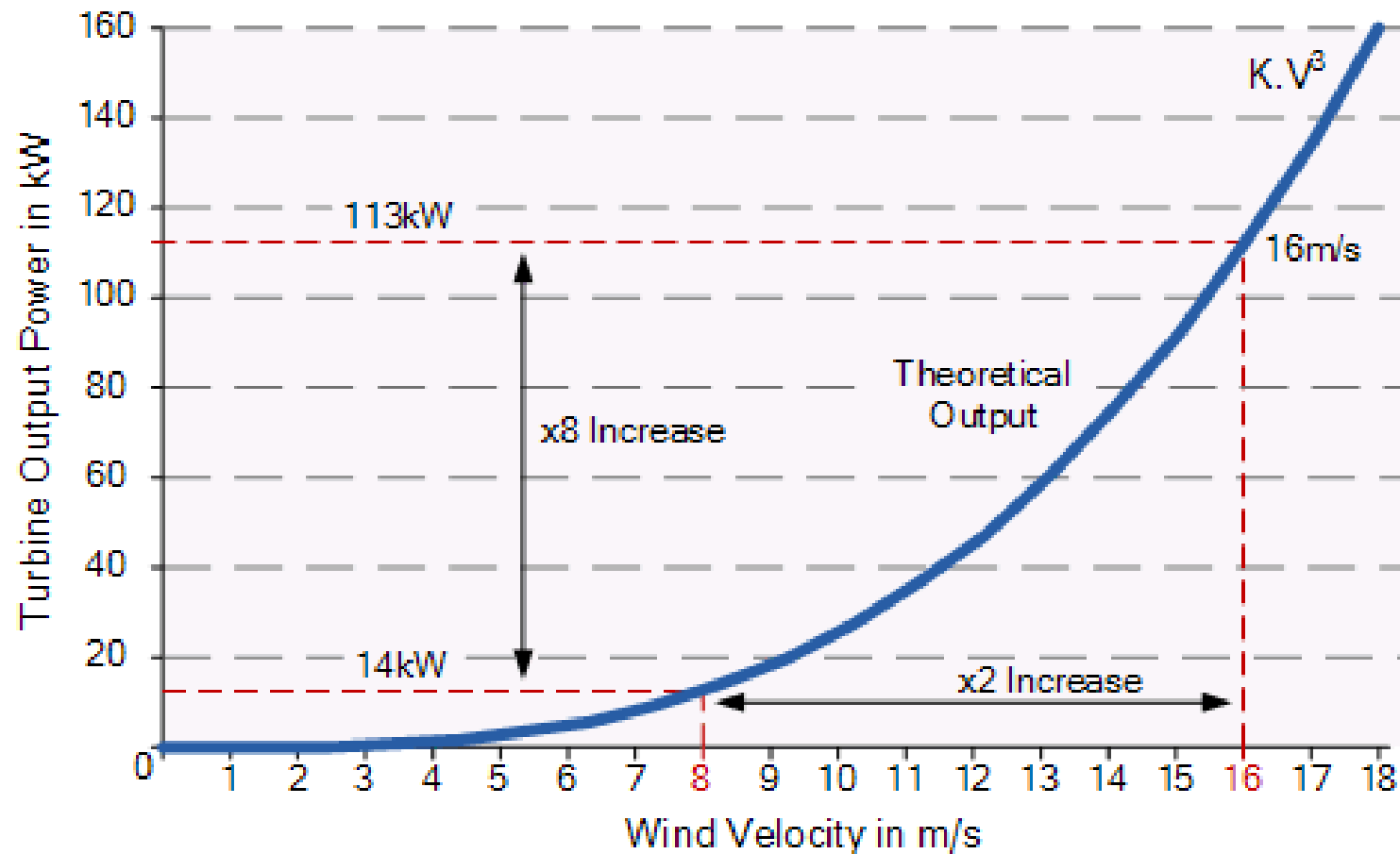
Calculate the output power from a wind turbine at a wind speed of 8 metres/second (8m/s) and again at double the velocity of 16 metres/second (16m/s). Assume that we live in an area slightly above sea level that has an air density of 1.225Kg/m and we have installed a 40% efficient wind turbine which has a rotor blade radius of 6 metres.

Wind Turbine Solution

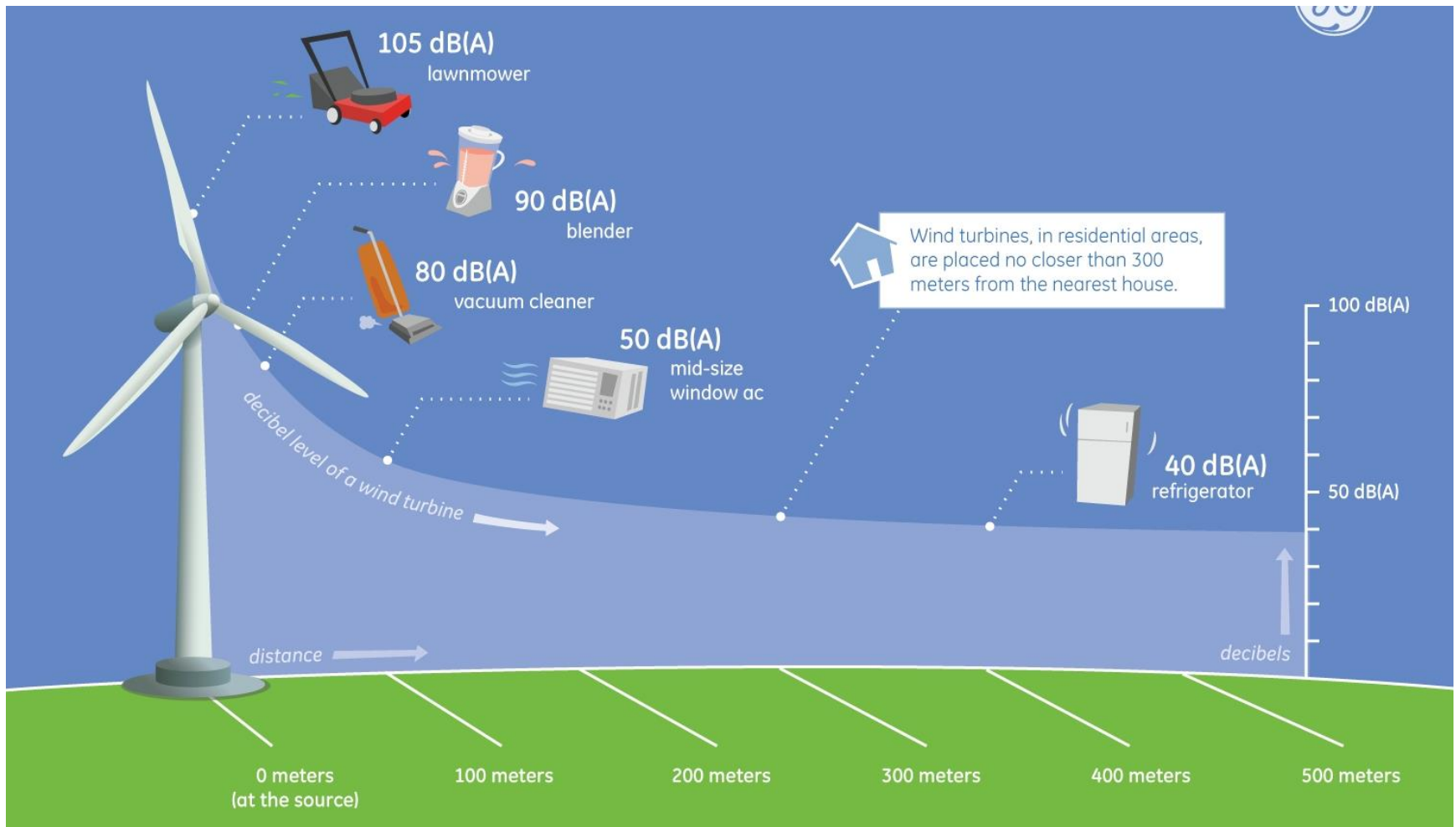
$$\begin{aligned} P &= 0.5 \times \rho \times A \times V^3 \times C_p \\ &= 0.5 \times 1.225 \times (\pi 6^2) \times 8^3 \times 0.4 \\ &= 14187 \text{ Watts or } 14.2\text{KW} \end{aligned}$$

$$\begin{aligned} P &= 0.5 \times \rho \times A \times V^3 \times C_p \\ &= 0.5 \times 1.225 \times (\pi 6^2) \times 16^3 \times 0.4 \\ &= 113496 \text{ Watts or } 113.5\text{KW} \end{aligned}$$

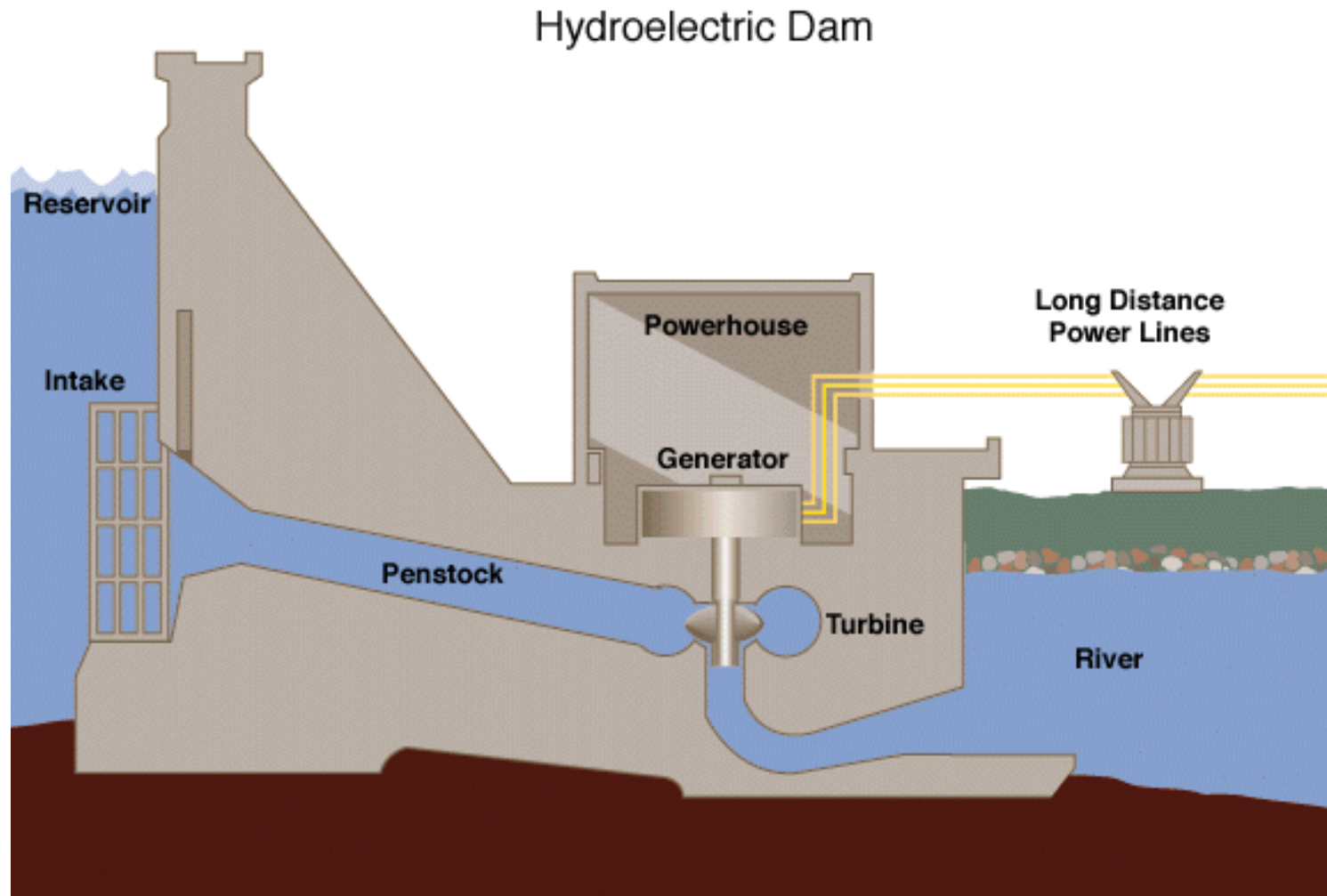
Turbine Output versus Wind Velocity



Wind Turbine Noise Levels



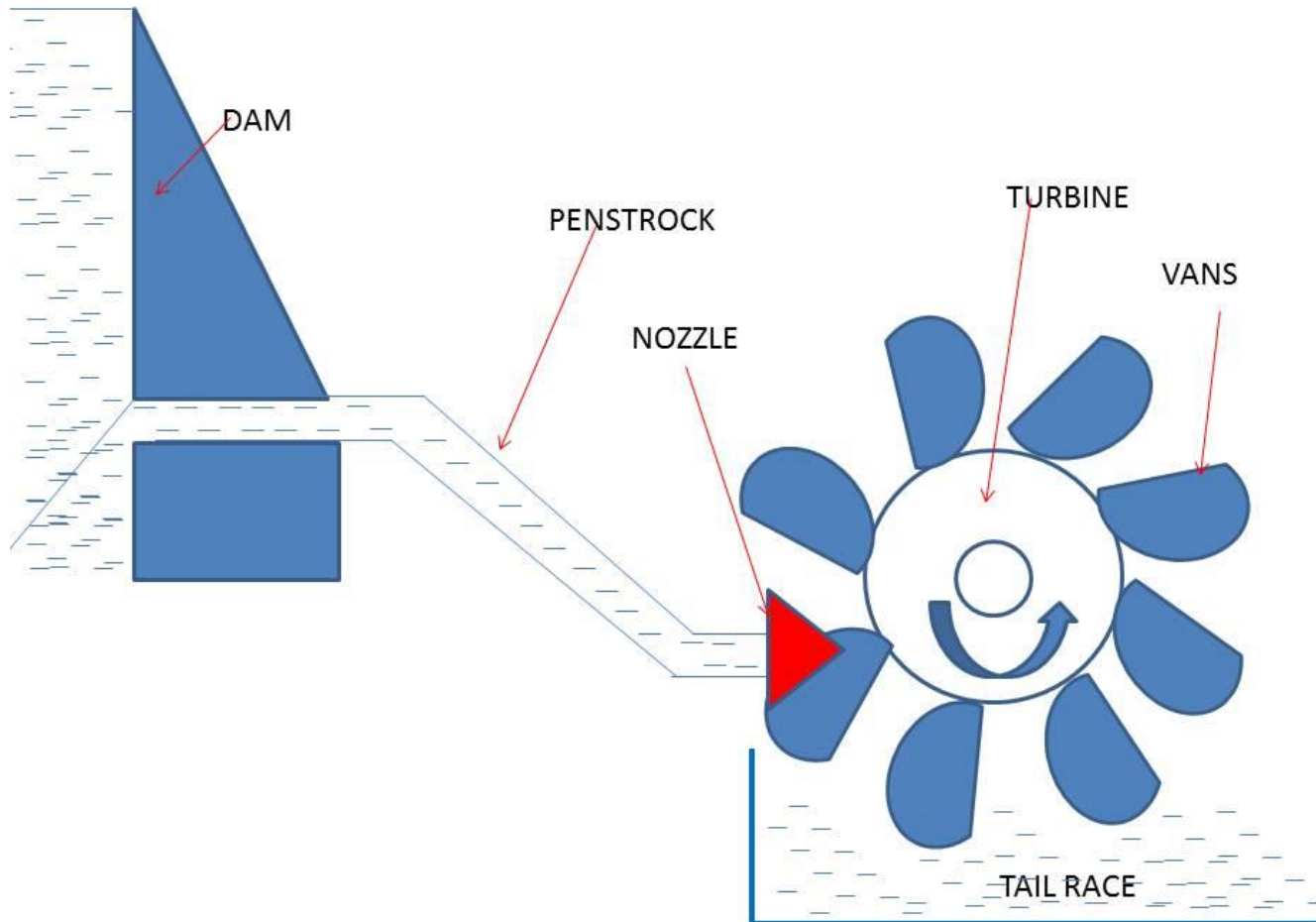
Hydroelectricity



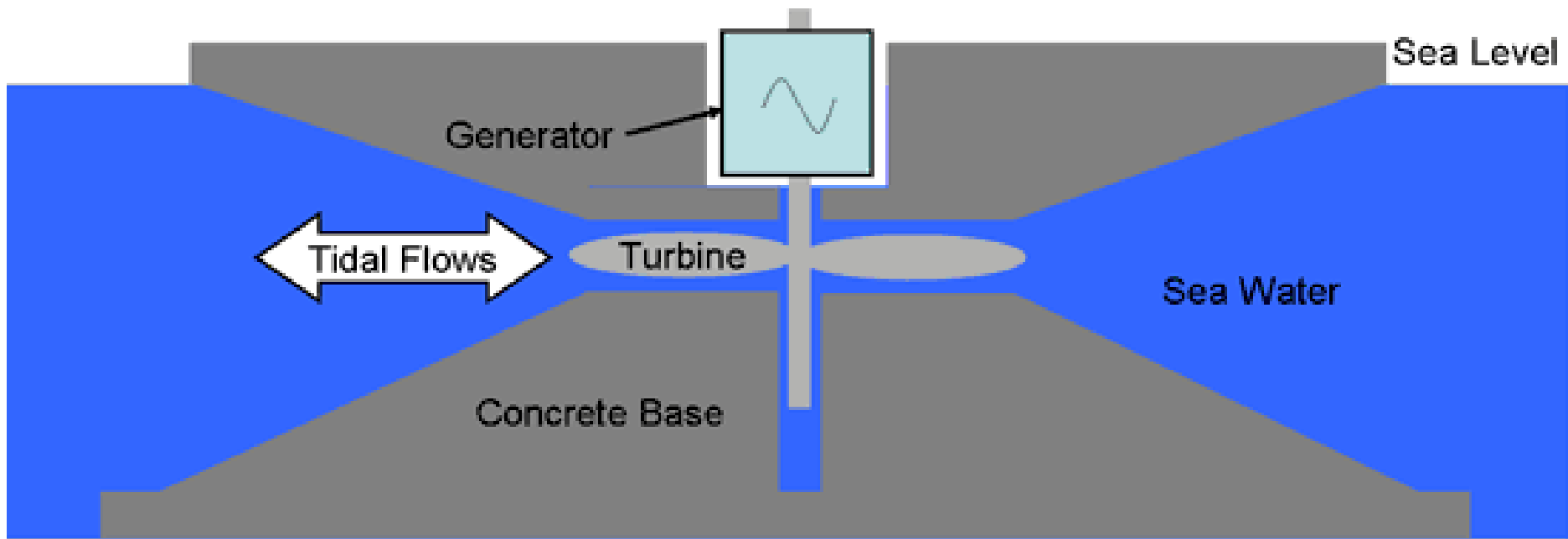
UK (Wales) and Chinese HEP



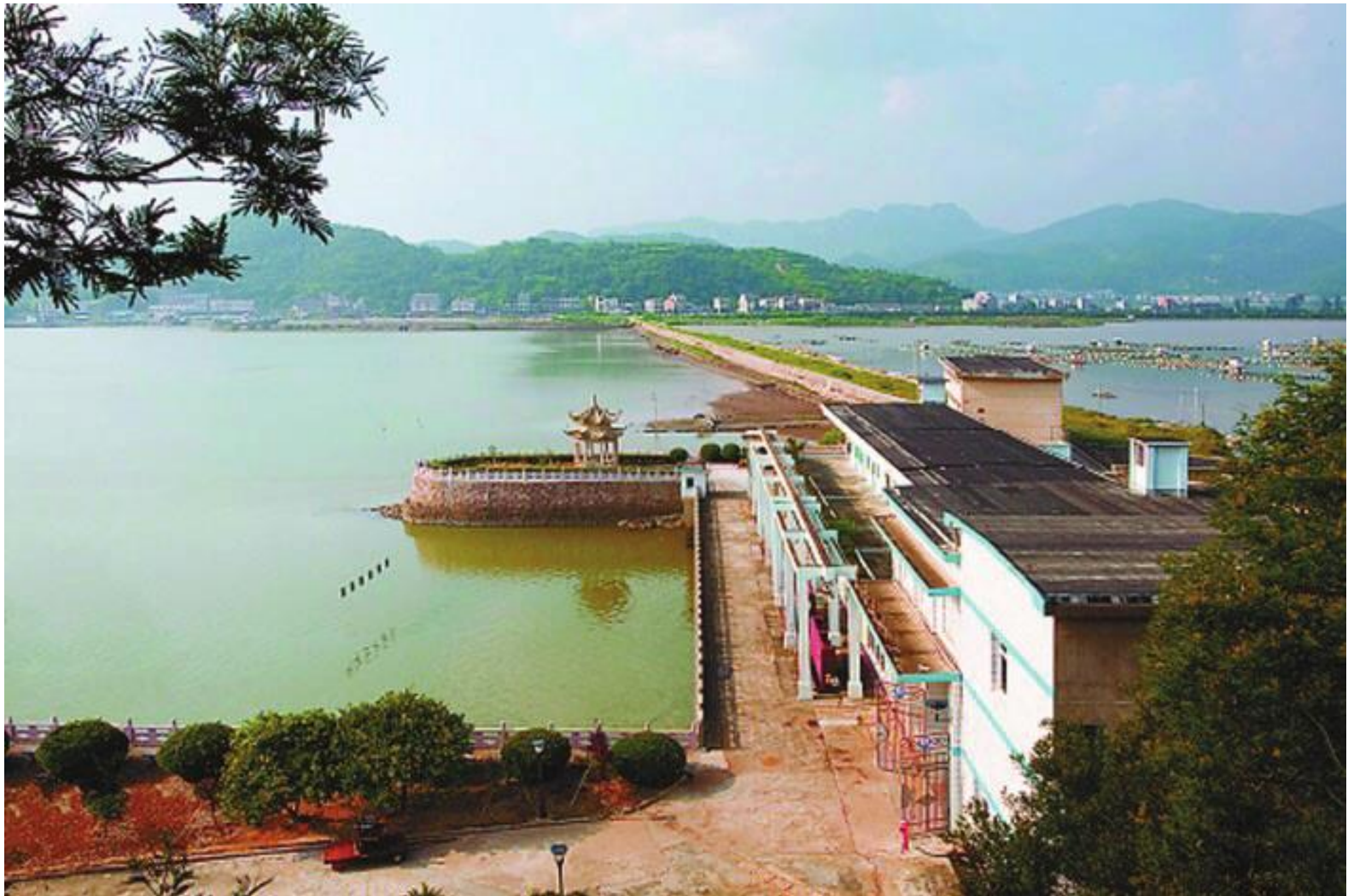
Impulse Turbines



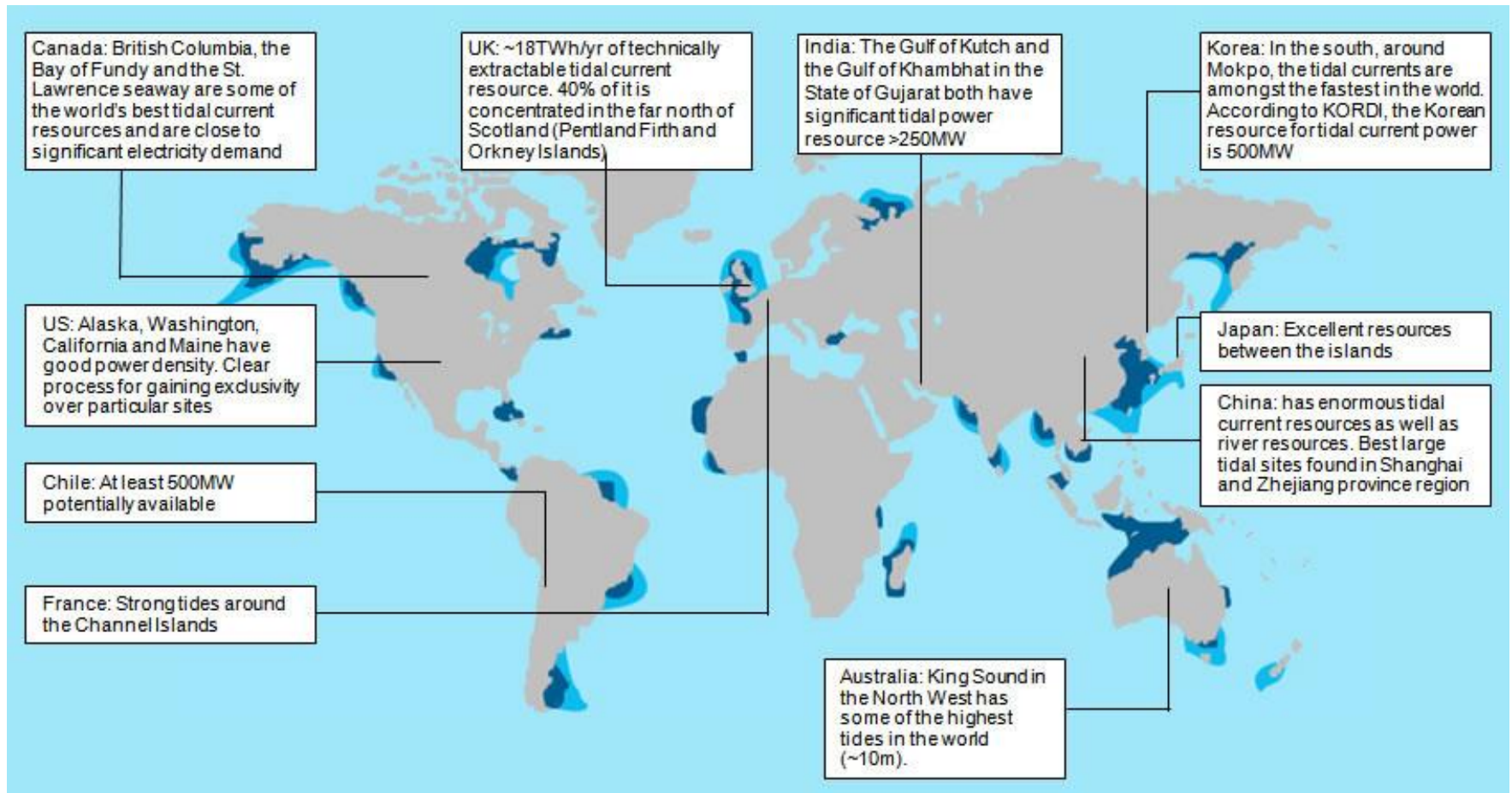
Electric Power from Tidal Flows



Jiangxia Power Station (China)



High Potential Areas for Tidal Power



King Canute



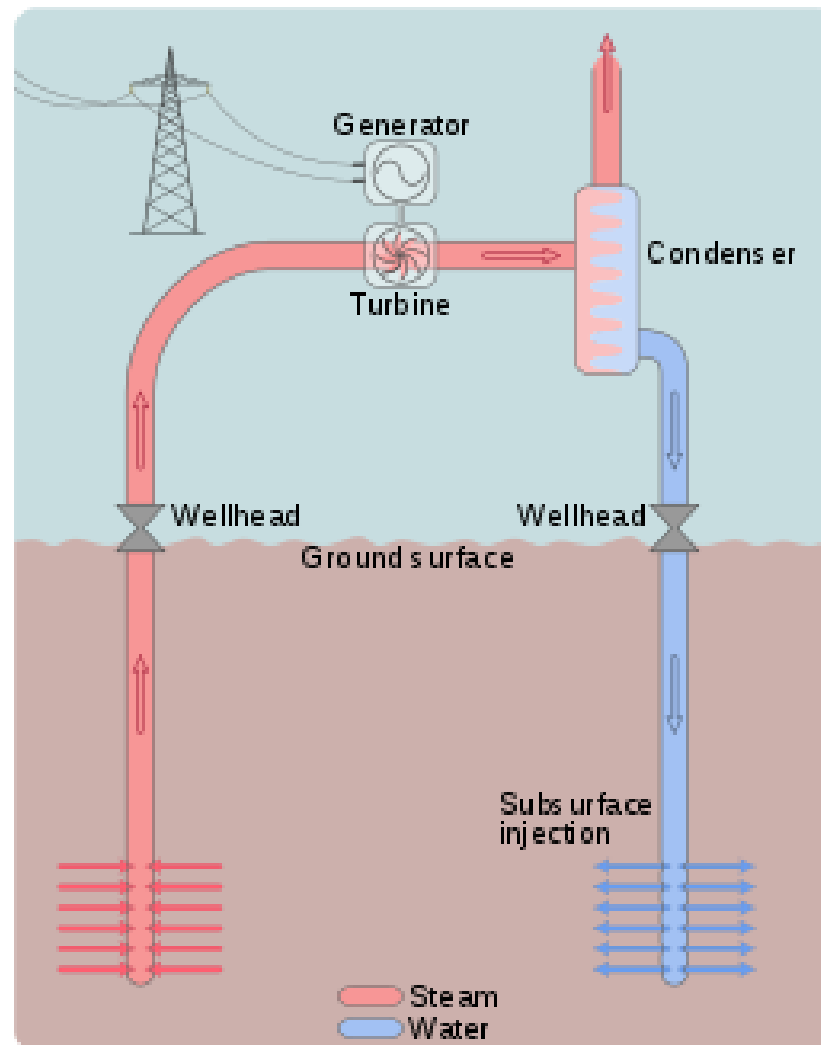
La Rance Tidal Barrage (France)



Proposed Swansea Lagoon



Geothermal Electric Power



Lead Acid Battery



Lead acid batteries hold the largest market share of electric storage products. A single cell produces about 2V when charged. In the charged state the metallic lead negative electrode and the lead sulphate positive electrode are immersed in a dilute sulfuric acid (H_2SO_4) electrolyte. In the discharge process electrons are pushed out of the cell as lead sulphate is formed at the negative electrode while the electrolyte is reduced to water.

Lead-acid battery technology has been developed extensively. Upkeep requires minimal labour and its cost is low. The battery's available energy capacity is subject to a quick discharge resulting in a low life span and low energy density

Nickel-Cadmium Batteries



Nickel–cadmium battery (NiCd):
Uses nickel oxide hydroxide and metallic cadmium as electrodes. Cadmium is a toxic element, and was banned for most uses by the European Union in 2004. Nickel–cadmium batteries have been almost completely replaced by nickel–metal hydride (NiMH) batteries.

Nickel-Metal Hydride Batteries



Nickel–metal hydride battery (NiMH): First commercial types were available in 1989.[31] These are now a common consumer and industrial type. The battery has a hydrogen-absorbing alloy for the negative electrode instead of cadmium.

Lithium-Ion Battery



Lithium-ion battery:
The choice in many
consumer electronics
and have one of the
best energy-to-mass
ratios and a very slow
self-discharge when
not in use.