What is Energy?

Revisions & Definitions

Revisions

Energy: "is the capacity to do work"

" is the ability to apply a force through a distance"

Fuel: Different types …..

Common forms:

Thermal energy or heat

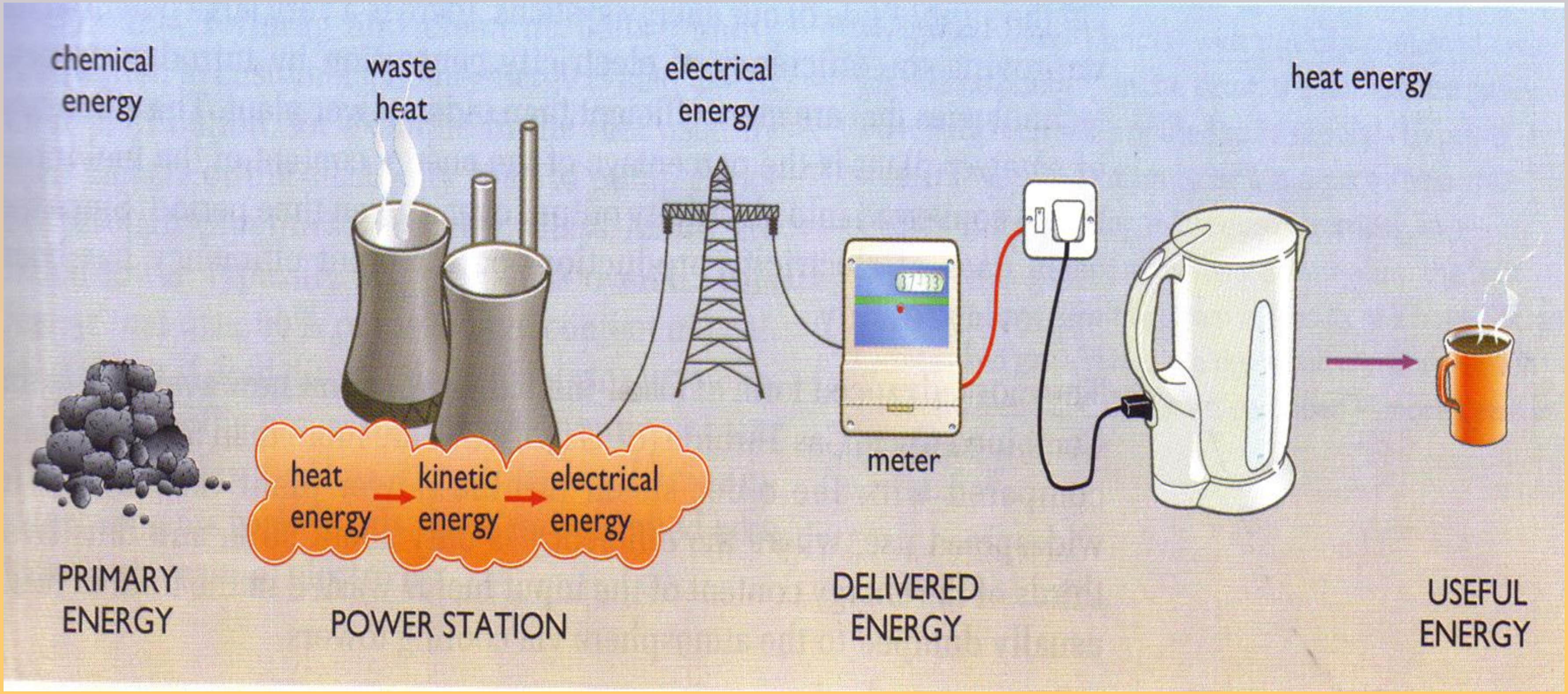
Kinetic energy

Potential energy

Chemical energy

Energy in statistics

- ***<u>Primary energy</u>***
- ***<u>Delivered energy</u>***
- ***<u>Useful or End use energy</u>***



Work

Work can be represented by the following equation:

$$w = F x$$

where

W is the mechanical work, J

F is the applied force on a body, N

and x is the moving distance of the body, m

Newton's Second Law of Motion

Force = rate of change of momentum

$$F = \frac{d}{dt}(\text{mass x velocity})$$

$$F = \frac{d}{dt}\left(m\frac{dx}{dt}\right)$$

$$F = m\frac{d^2x}{dt^2}$$

$\therefore$ force is the product of mass and acceleration

Definitions

- ***Power*** : the rate of work, w (J/s)
- ***Kinetic energy***: ½ mu^2
- ***Potential energy***: mgz
- ***Chemical energy***: the energy stored in a substance due to the chemical composition. This form is released by combustion.
- ***Internal energy***: the intrinsic energy of a body or a fluid at rest. It is measured by certain measurable properties such as temperature or pressure.

- ***Thermal energy or heat***: energy in transition. There are 3 modes of heat; conduction, convection, radiation. Engineering applications involve a combination of all three modes of heat transfer.
- ***Note***: work and heat are treated as energy in transition. They are not contained or possessed by the body. Work is an organized form of energy whilst heat is a disorganized form of energy.

Mass-Energy dependence

- Energy conservation law means that energy must be conserved in any process.
- Nuclear energy, electricity, magnetism, sound and light are all examples of different forms of energy. Mass is also a form of energy.
- Mass conservation means that mass can be neither created or destroyed.
- The following relation correlates mass and energy:

$$E = mc^2$$

- ***Where***

  E: energy released, J

  m: mass converted into energy, kg

  c: velocity of light, $3x10^8$ m/s

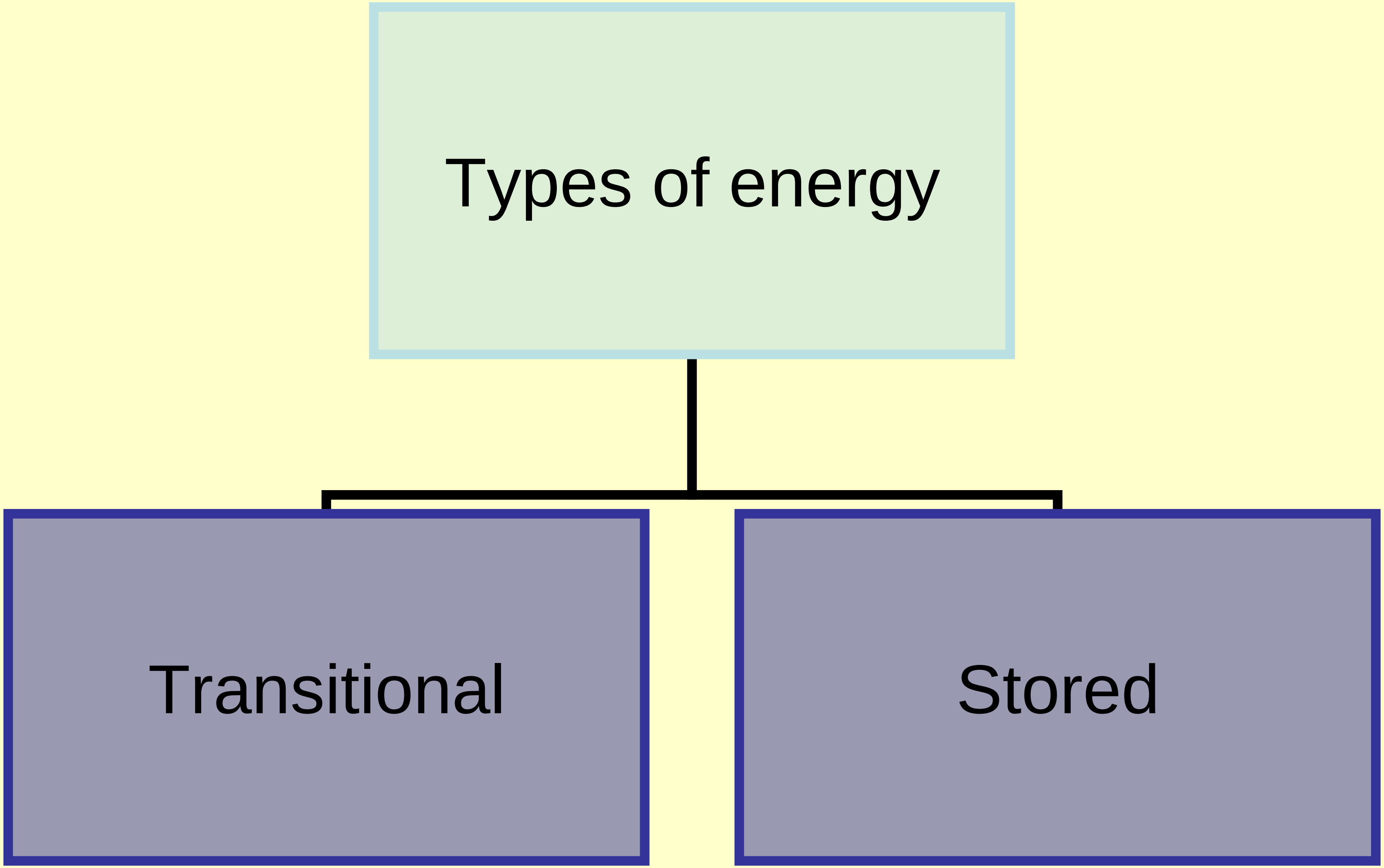
- ***Example***:

  \# Suppose 600,000 kW power plant.

  \# According to the previous equation, the mass which is completely annihilated is about 640 g.

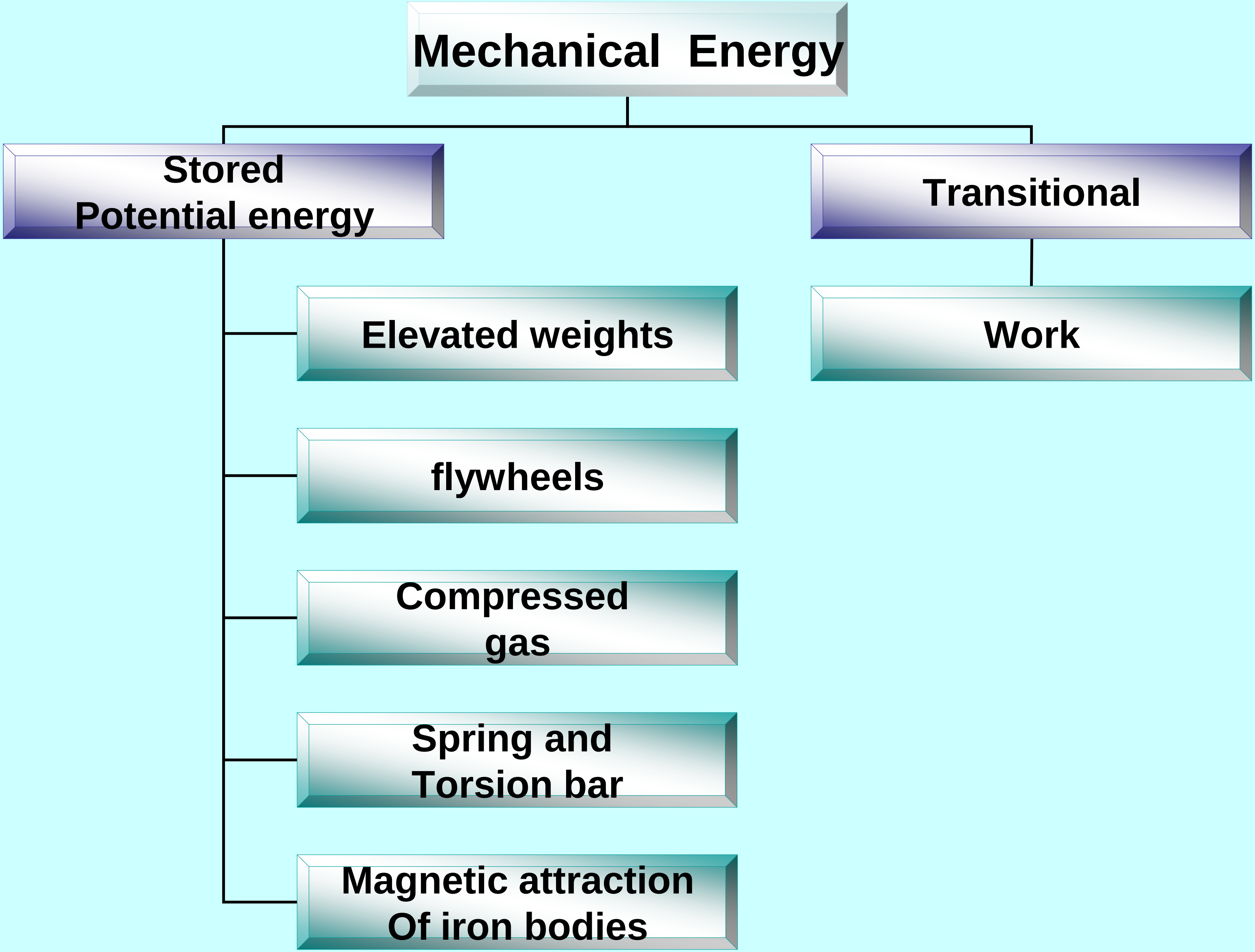
  \# If we run the plant on coal, it will consume 220 tons of coal per hour or 2,000,000 tons of coal per year.

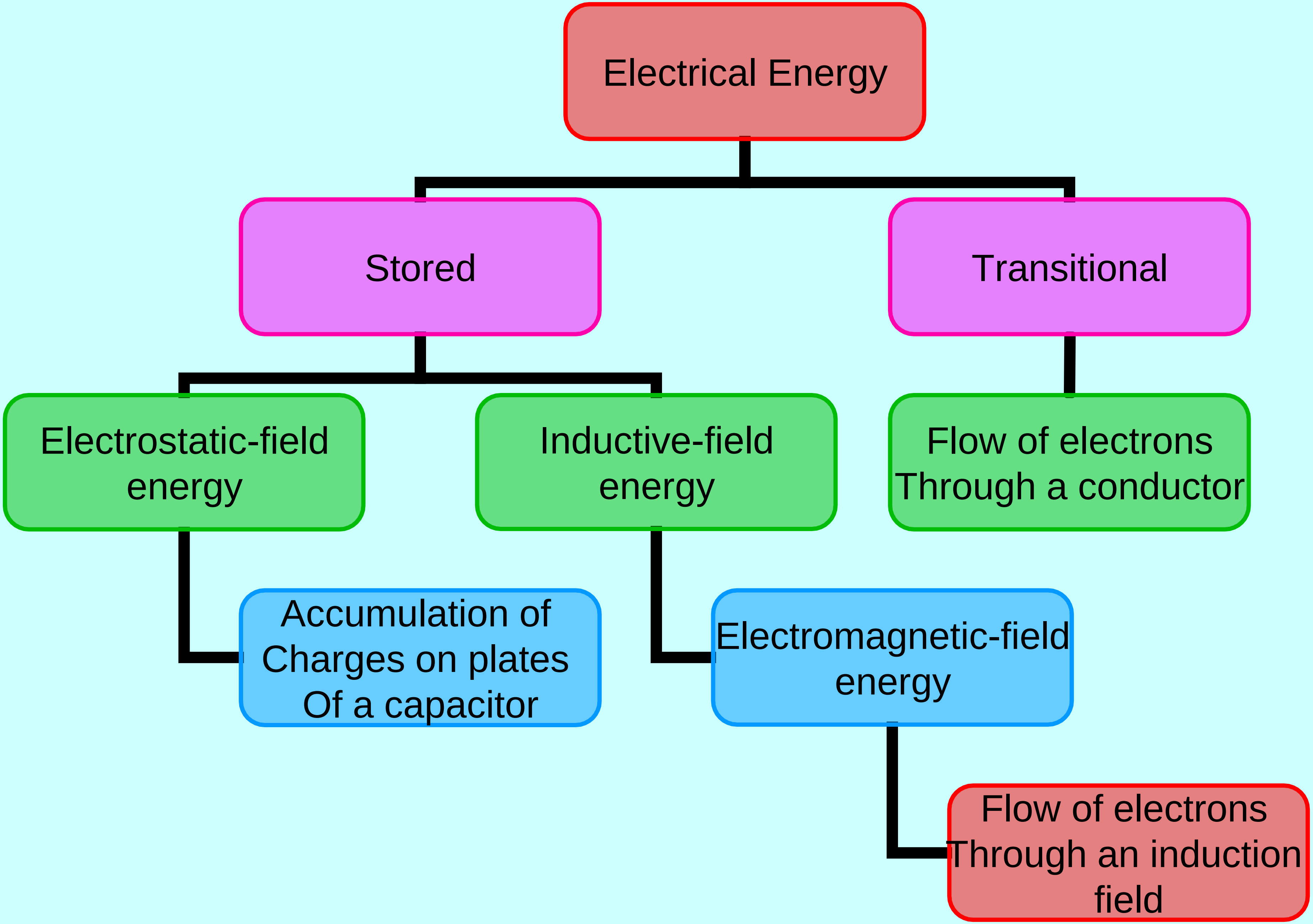
  \# If we run the unit on uranium, it will consume one ton of uranium per year.


Types of energy
Transitional
Stored

Energy Classification

- Mechanical energy
- Electrical energy
- Electromagnetic energy
- Chemical energy
- Nuclear energy
- Thermal energy


Mechanical Energy
Stored
Potential energy
Transitional
Elevated weights
Work
flywheels
Compressed
gas
Spring and
Torsion bar
Magnetic attraction
Of iron bodies


Electrical Energy
Stored
Transitional
Electrostatic-field energy
Inductive-field energy
Flow of electrons Through a conductor
Accumulation of Charges on plates Of a capacitor
Electromagnetic-field energy
Flow of electrons Through an induction field

Devices & Energy types

Energy Conversion Device	Energy Input	Useful Energy Output
Electric heater	Electricity	Thermal energy
Hair drier	Electricity	Thermal energy
Electric generator	Mechanical energy	Electricity
Electric motor	Electricity	Mechanical energy
Battery	Chemical energy	Electricity
Steam boiler	Chemical energy	Thermal energy
Furnace	Chemical energy	Thermal energy
Steam turbine	Thermal energy	Mechanical energy
Gas turbine	Chemical energy	Mechanical energy
Automobile engine	Chemical energy	Mechanical energy
Fluorescent lamp	Electricity	Light
Silicon solar cell	Solar energy	Electricity
Steam locomotive	Chemical	Mechanical
Incandescent lamp	Electricity	Light

First Law of thermodynamics

- Commonly, this law is derived from energy balance equation.
- For any enclosed system, ignoring potential and kinetic energies of the system, the change of internal energy, ΔE, of the system is equal to the net amount of heat transferred to the system, Q, minus the net external work done by the system, W. Or

$$Q - W = \Delta E = E_2 - E_1$$

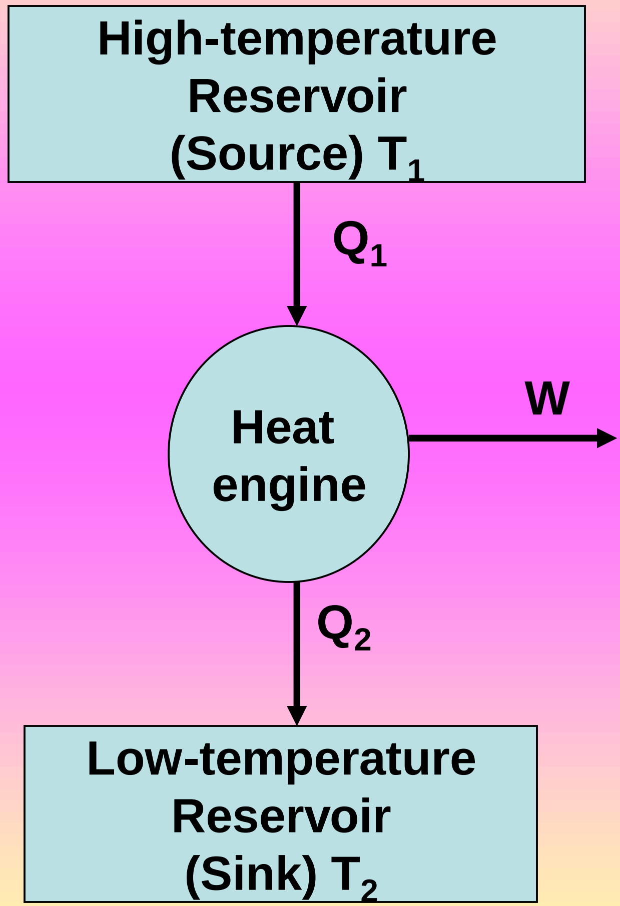
Efficiency

- For any energy conversion system, the efficiency is defined as

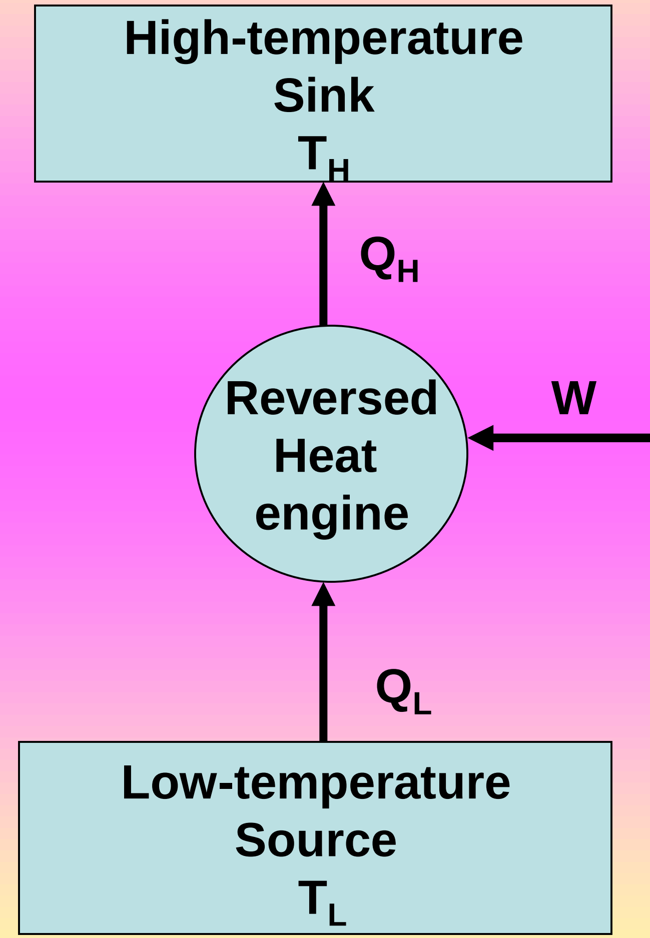
$$\eta = \frac{W}{E} x100\%$$

- Where W is the desired energy or work given by the system and E is the net energy input.
- This equation is known as "the first law efficiency"

Second Law of thermodynamics



Ideal heat engine



Ideal heat pump or refrigerator

The efficiency of the cycle

The efficiency of the cycle, η is

$$\eta = \frac{W}{Q_1}$$

Since cyclic process, $W = Q_1 - Q_2$

$$\therefore \quad \eta = \frac{Q_1 - Q_2}{Q_1} \quad \text{or} \quad 1 - \frac{Q_2}{Q_1}$$

If the absolute temperatures are used instead of heats, then

$$\eta = 1 - \frac{T_2}{T_1}$$

This is called the ideal cycle or "Carnot efficiency"

Coefficient of performance "COP"

- For the reversed heat engine, see previous figure, the heat transferred to the high temperature sink, Q_H is

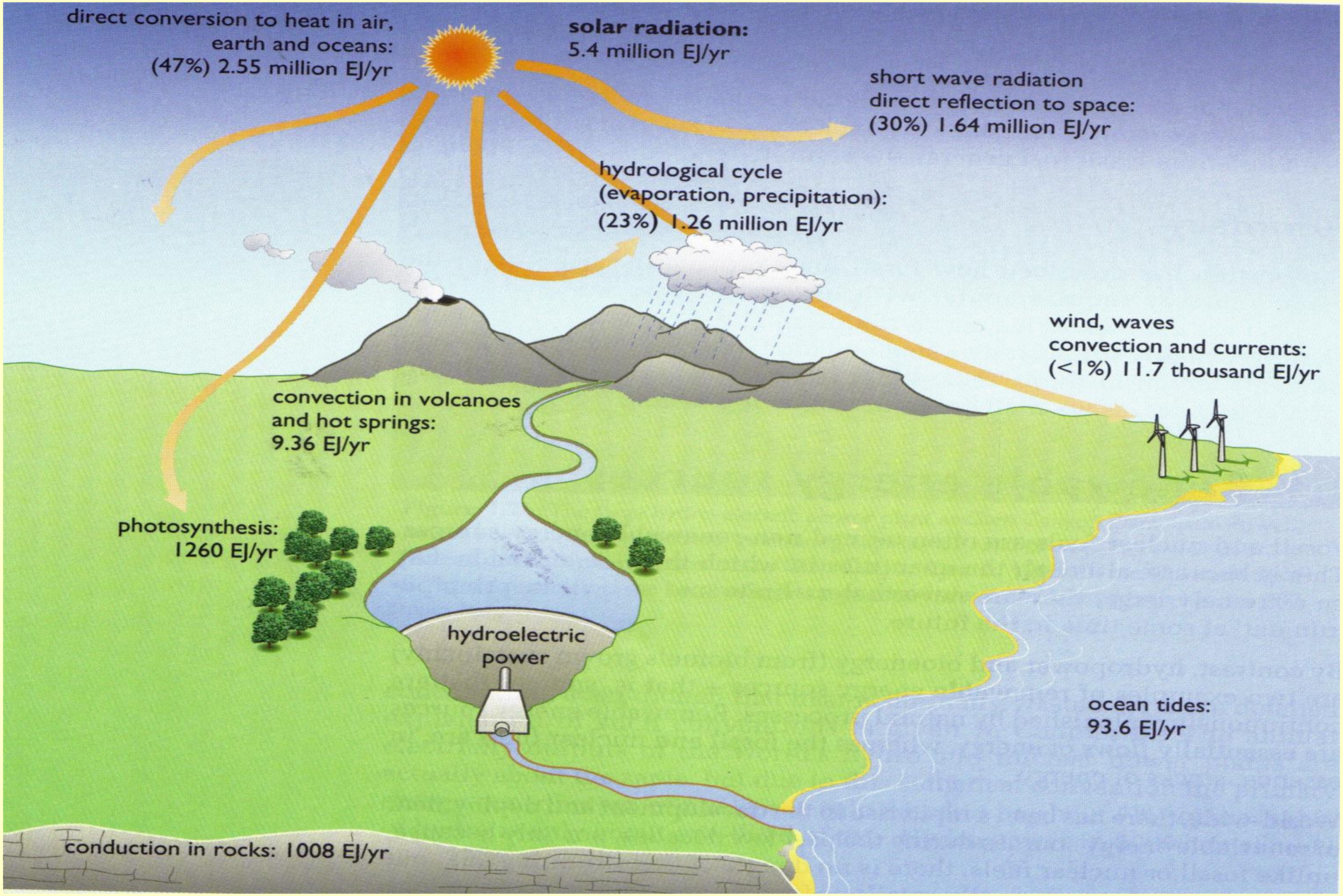
$$Q_H = W + Q_L$$

- In this equation, the system works as an ideal heat pump. The amount of Q_H is greater than W.

- The ratio Q_H/W is called the coefficient of performance (COP) or performance ratio of the heat pump.

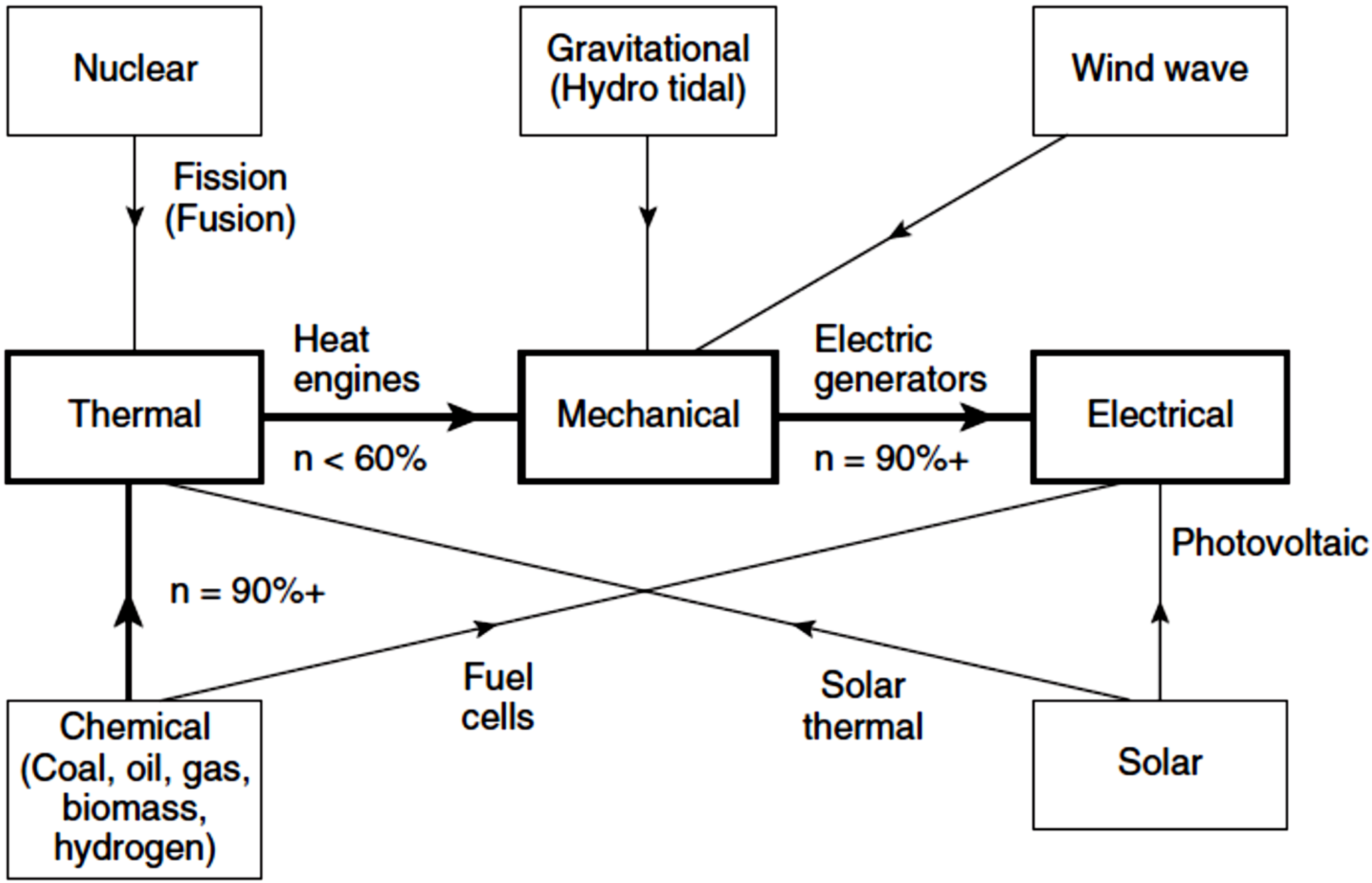
- The system can also be assumed to be a refrigerator, but the COP is Q_L/W, as the heat removed at lower temperature is of great importance.

Solar energy and Earth's energy flow



Planetary energy balance

Source	Process	Power	Radiation
Solar radiation 173,000 TW	Direct reflection	52,000 TW (30%)	Short-wave radiation
	Direct conversion to heat	78,000 TW (45%)	Long-wave radiation
	Evaporation of water	39,000 TW (22%)	
	Wind & waves	3,600 TW (2%)	
	Photosynthesis	40 TW	
Tides		3 TW	
Geothermal	Volcanos & hot springs	0.3 TW	
	Rock conduction	32 TW	



Conversion from a variety of energy forms into electricity

Fuel-Energy Equivalents

Units and definitions

One barrel(42 gal) of oil	= 460 lb_m of coal = 5680 scf of natural gas = 612 kWh of electricity *
One short ton of coal	= 4345 bbl of crude oil = 24, 682 scf of natural gas = 2260 kWh of electricity *
1000 scf of natural gas	= 0.176 bbl of crude oil = 81.0 lb_m of coal = 189 kWh of electricity *

* assumes a conversion efficiency of 36 %

Abbreviations in SI units

Kilo	K	10^3
Mega	M	10^6
Giga	G	10^9
Tera	T	10^{12}
milli	m	10^{-3}
micro	μ	10^{-6}
Nano	n	10^{-9}
pico	p	10^{-12}

Units

Mass

1kg =0.001metric ton=0.001 tonne

=2.205 pounds mass = 2.205 lb_m

= 0.001102 short ton = 0.001102 ton

Heat

1 therm = 10^5 Btu = 29.3kWh

=1.05506×10^8 J

1 kWh = 3.6×10^6 J

Coal

1 million tonnes is equivalent to 0.6 million tonnes of oil or 250 million therm (2.5x 10^{13} Btu) or 7.35 TWh emectric energy or 2 TWh electricity generated or 2.637 x 10^{16} J.

Note: m.t.c.e. ≡ million tonnes of coal equivalent

Oil

1 million tonnes is equivalent to 1.7 million tonnes of coal or 425 million therms (4.25×10^{13} Btu) or 12.5 TWh electrical energy or 3.6 Twh electricity generated, or 4.484×10^{16} J.

Note: m.t.o.e. ≡ million tonnes of oil equivalent

Natural Gas

- 1 million cubic feet is equivalent to 40 tonnes of coal or 10 thousand therms. A common unit is trillion cubic feet (Tcf) which is 10^{12}cubic feet, and equivalent to 40 million tonnes of coal (1.05×10^{18}J).

Note: 1 cubic foot is equivalent of 1000 Btu or 1.05×10^{6}J. This gives 1 cubic meter as the equivalent of 3.71×10^{7}J.

Work and Power

- 1W = 3.413 Btu/h = 1 J/s
- 1 kWh = 3413 Btu/h
- 1 hp = 550 ft lb/s = 33,000 ft lb/min
- 1 therm = 100,000 Btu

  = 25,000 kcal