Energy

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What is Energy ?

Energy

(Wikipedia) In physics, energy is the quantitative property that must be transferred to a body or physical system to perform work on the body, or to heat it.

Important property : Energy is a conserved quantity. It can be converted from one form to another, but not created or destroyed.

What is Energy ?

Energy :

- Mechanical energy – The sum of kinetic and potential energies
- Chemical energy – energy contained in molecules
- Gravitational energy – energy from gravitational fields
- Electrical energy – energy from electric fields
- ....

Informal definition [1] : quantitative property that measures the change (speed, temperature, shape, chemical composition, etc) of state of a system

- The more transformation you observe, the more energy there is
- ... and any transformation requires energy

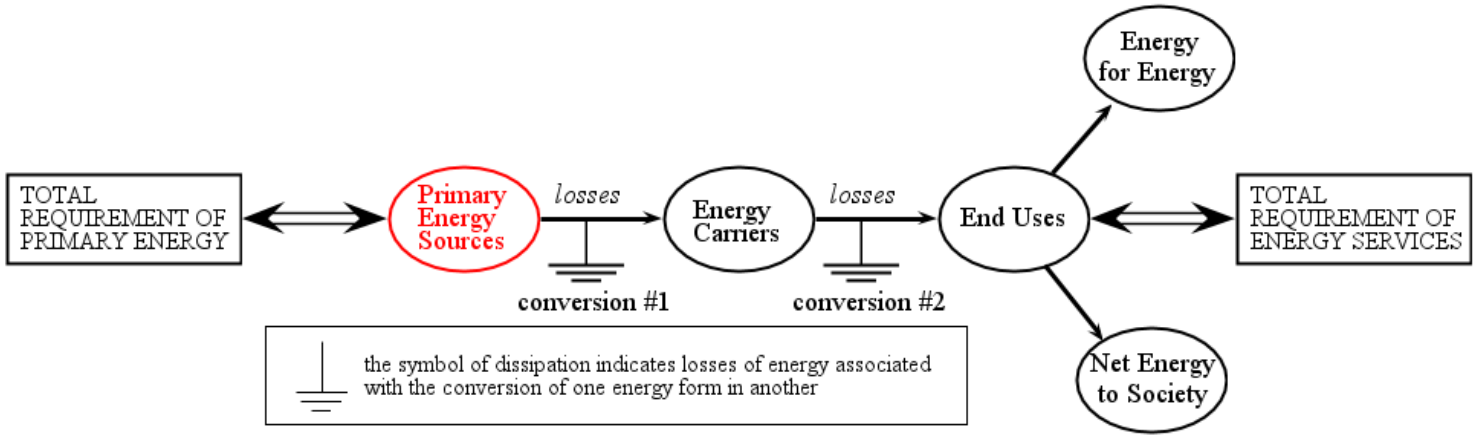
1. Borrowed from J.-M. Jancovici `https://jancovici.com`

Primary and Secondary Energy

Energy

- Primary energy : energy form found in nature
- Secondary energy or energy carrier : what is eventually consumed

Losses along the chain (source : wikipedia) :



Primary and Secondary Energy

Primary Energy (in nature)

- Non renewable
  - Fossil (coal, petroleum, gaz)
  - Fissile (uranium, etc)
- Renewable
  - Solar energy and its by-product (biomass, wind, hydraulic)
  - Geothermic heat
  - Gravitational (tide)

Losses ==>

Secondary Energy (carrier)

- Liquid
  - Petrol, diesel
- Gaz
  - Natural gaz, biogas,
- Solid (coal, wood)
- Heat
  - Heat network
- Electricity

Losses ==>

Service

- Lightning
- Cold
- Hear
- Mobility
- Kinetic Force (fan, pumping)
- Industrial process
- Information processing

Source : B. Multon ENS Rennes

Energy for ICT

For ICT ecosystem (devices, network) :

- the main source of energy is electricity (a secondary energy)
- ... which is released as heat eventually

Energy Unit

Joule (J)

- The unit of Energy in the International System (SI) of units
- $J = \frac{kg.m^2}{s^2} = N.m = W.s = \Omega A^2.s$
  - The energy required to accelerate a 1 kg mass at 1 m/s^2 through a distance of 1 m.
  - The energy transferred to (or work done on) an object when a force of one newton acts on it through a distance of one metre (wikipedia)
  - Also the energy dissipated (heat) when an electric current of one ampere passes through a resistance of one ohm for one second (wikipedia)

SI Units

- SI consists of : second (s), which is the SI unit of the physical quantity of time ; metre (m) ; kilogram (kg) ; ampere (A, electric current) ; kelvin (K, thermodynamic temperature) ; mole (mol, amount of substance) ; and candela (cd, luminous intensity)
- Joule is a derived unit (out of base units)

Energy Unit

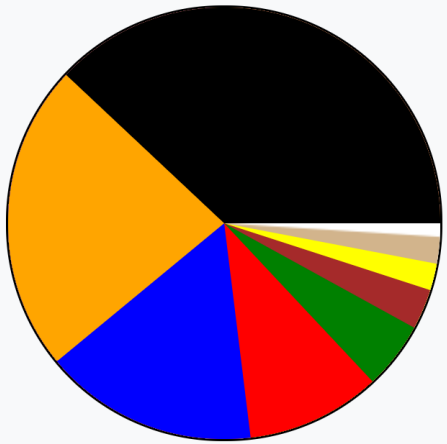
Alternative (often used !) Units

- KiloWatt-hour or TeraWatt-hour
- Tonne of oil equivalent (toe) : amount of energy released by burning one tonne of crude oil

- 1 kWh = 3,6 MJ
- 1 TWh = 1 billion of kWh
- 1 toe $\approx$ 11600kWh
- 1 Mtoe $\approx$ 11,6TWh

Electricity

Electricity comes from (source :Wikipedia and IAE) :



World electricity generation by source in 2018. Total generation was 26.7 PWh.[2]

Electricity among other Energy

- Difference between first and second column due to losses in conversion ! !
- Electricity is about 20% of total secondary energy (source : wikipedia)

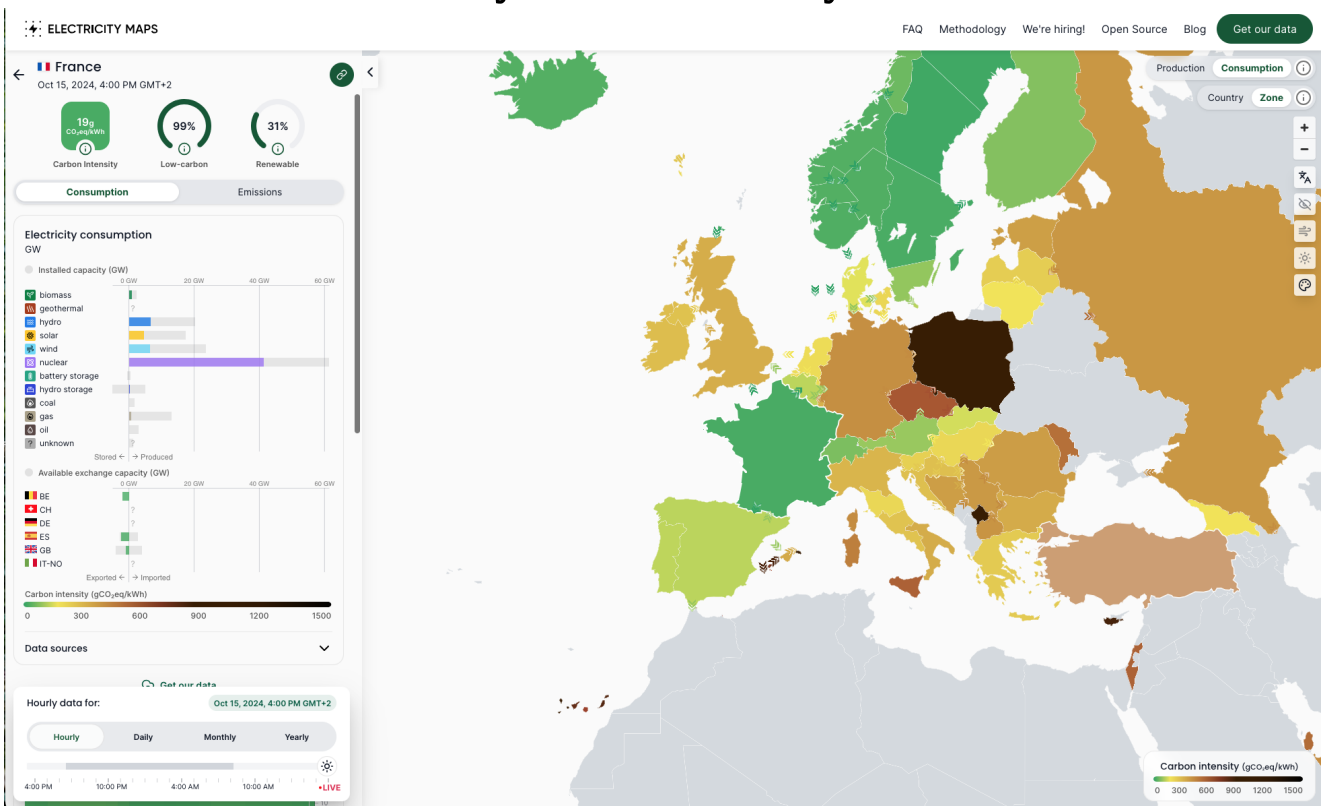
History (TWh)

Year	Total energy supply (TES)[1]	Final energy consumption[1]	Electricity generation	Ref
1973	71,013 (Mtoe 6,106)	54,335 (Mtoe 4,672)	6,129	[11]
1990	102,569	–	11,821	–
2000	117,687	–	15,395	–
2010	147,899 (Mtoe 12,717)	100,914 (Mtoe 8,677)	21,431	[12]
2011	152,504 (Mtoe 13,113)	103,716 (Mtoe 8,918)	22,126	[13]
2012	155,505 (Mtoe 13,371)	104,426 (Mtoe 8,979)	22,668	[14]
2013	157,482 (Mtoe 13,541)	108,171 (Mtoe 9,301)	23,322	[15]
2014	155,481 (Mtoe 13,369)	109,613 (Mtoe 9,425)	23,816	[16]
2015	158,715 (Mtoe 13,647)	109,136 (Mtoe 9,384)		[17][18]
2017	162,494 (Mtoe 13,972)	113,009 (Mtoe 9,717)	25,606	[19]

[1] converted from Mtoe into TWh (1 Mtoe = 11.63 TWh) and from Quad BTU into TWh (1 Quad BTU = 293.07 TWh)

Electricity mix and carbon intensity

The carbon intensity of electricity is a function of the country energy mix

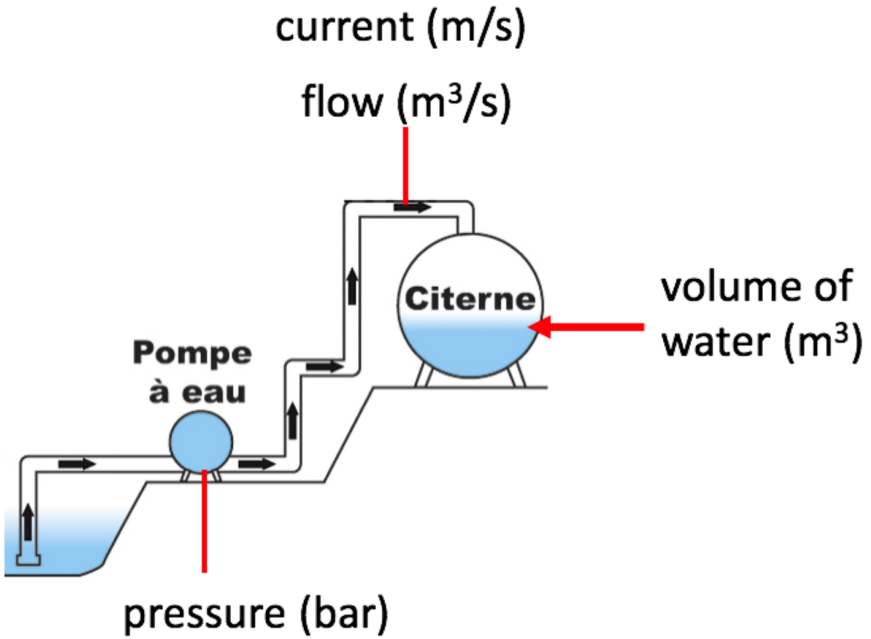


https://app.electricitymaps.com/zone/FR

Power, Energy, etc (source : A. Blavette)

- Current I (A : amperes) → current
- Voltage V (V : volts) → pressure
- Power P (W : watts) →flow
- Energy E (J : joules or kWh) → volume of water

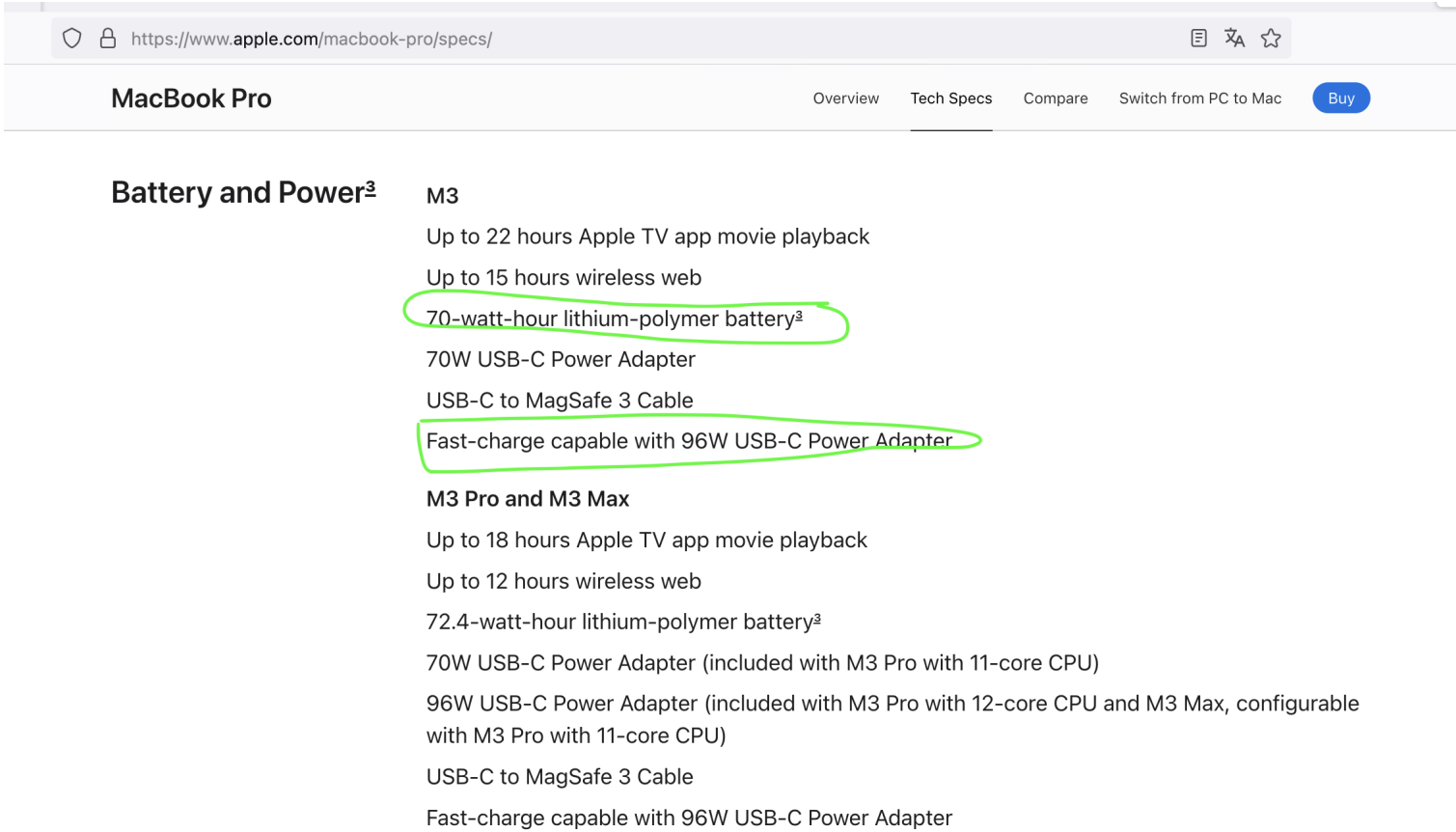
$$E = P\Delta t (= 1kW \times 1h = 1kWh)$$



Energy for ICT (cnt'd)

For ICT ecosystem (devices, network) :

- Energy is the amount of energy stored (in a battery) or consummed over time
- Power is the rate at which one consumes energy



What does 1 kWh represent ?

- A 500-W halogen lamp during 2 hours
- 10 12-W LED lamps during 8 hours
- 1 cyclist pedalling during 10 hours
- 1 oven during 30 minutes

(source : A. Blavette)

Are humans so much inefficient ?...

..or do we use energy without thinking to the environmental consequences ?
Source : José Halloy

AlphaGo defeated Lee Sedol

Published: 19 October 2017

Mastering the game of Go without human knowledge

David Silver ✉, Julian Schrittwieser, Karen Simonyan, Ioannis Antonoglou, Aja Huang, Arthur Guez, Thomas Hubert, Lucas Baker, Matthew Lai, Adrian Bolton, Yutian Chen, Timothy Lillicrap, Fan Hui, Laurent Sifre, George van den Driessche, Thore Graepel & Demis Hassabis

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~100 W per CPU
~200 W per GPU

AlphaGo	Search threads	CPUs	GPUs
Asynchronous	1	48	8
Asynchronous	2	48	8
Asynchronous	4	48	8
Asynchronous	8	48	8
Asynchronous	16	48	8
Asynchronous	32	48	8
Asynchronous	40	48	8
Asynchronous	40	48	1
Asynchronous	40	48	2
Asynchronous	40	48	4
Distributed	12	428	64
Distributed	24	764	112

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..or do we use energy without thinking to the environmental consequences.
Source : José Halloy

AlphaGo defeated Lee Sedol: energy cost

~ 155 kW

Brain ~ 20 W
2500 kCal/day
~ 120 W

130 GJ = 9.7 days

34 years = 130 GJ