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جامعة الجيلالي بونعامة خميس مليانة
كلية علوم المادة والإعلام الآلي
قسم الفيزياء

L1 Material Science

Renewable Energies

Discovery Teaching Unit (S2)

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2023/2024

Content

- Forms of Energy
- Conventional sources of energy
- Some key concepts
- Different types of renewable energies
- Energies of the future

Forms of Energy

- **How we define energy?**

Etymologically: the word energy comes from the Latin: energia (énergia). It means «force in action»! In opposition to dynamic (dynamis) which means «powerfull force».

Physically: «It is the ability of a body or a system to produce mechanical work or its equivalent»

Historically:

1807: Thomas YOUNG uses the term «energy» to designate the quantity $m.v^2$

1829: Gaspard-Gustave CORIOLIS uses the term «work» to describe this quantity

1853: William RANKINE formulates the conservation of mechanical energy

Forms of Energy

- How we define energy?

Revised definition: «Energy is a quantity that measures the ability of a system to modify a state, to produce work involving motion, electromagnetic radiation or heat»

In the International Unit System (SI), Energy is expressed in joules:

$$Joule = J \equiv [M].[L]^2.[T]^{-2} \equiv kg.m^2.s^{-2}$$

Forms of Energy

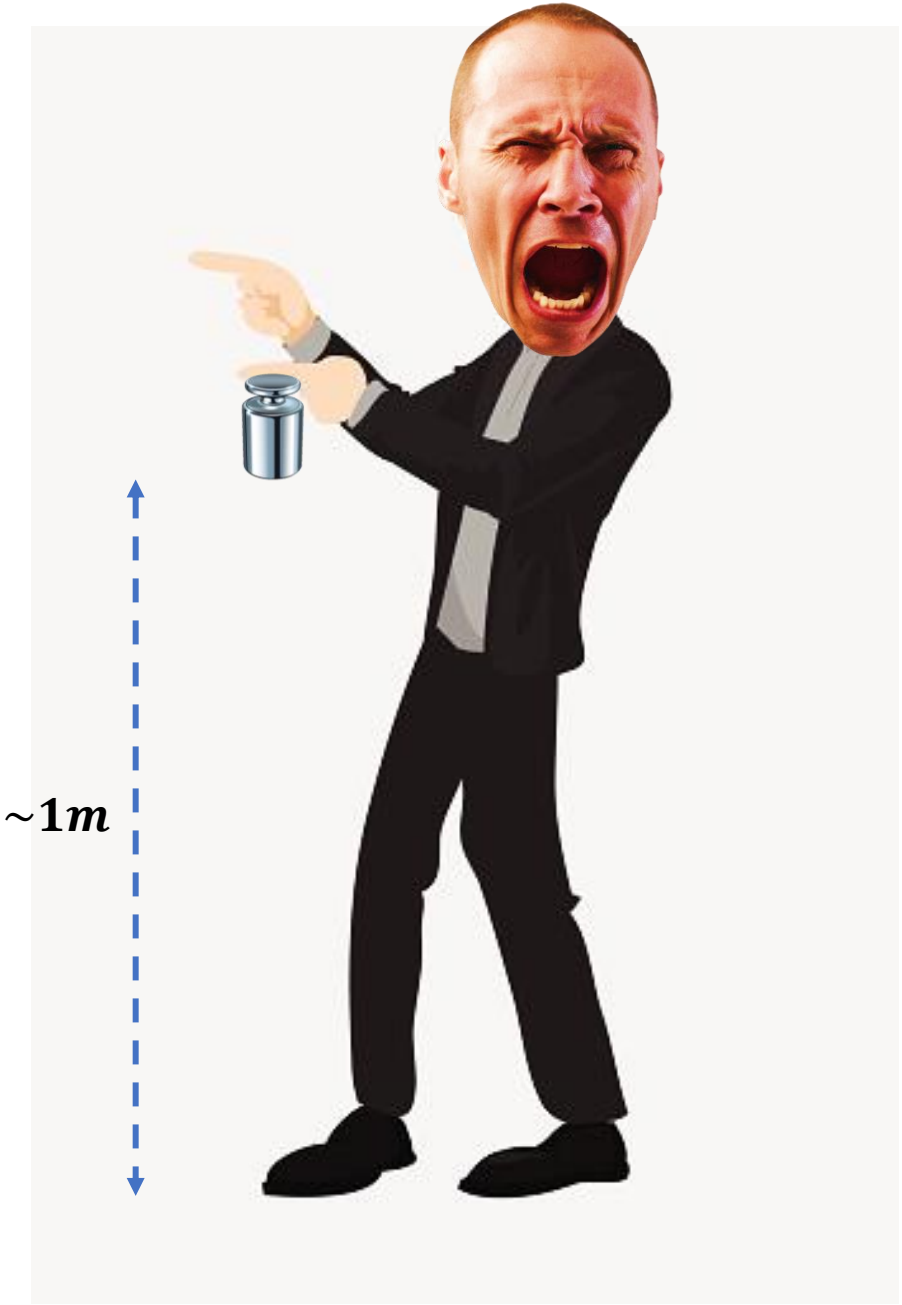
- Dimensional analysis of energy

How could we evaluate1 $joule$ of energy ?

$$J \equiv kg.m^2.s^{-2}$$

This is equivalent of a free-fall of a 100g weight from about 1M of height, under the gravitational acceleration $g = 9,81m.s^{-2}$.

$$E_p = mgh = E_c = \frac{1}{2}mv^2$$



Forms of Energy

- **Dimensional analysis of energy**

We can also redefine energy as a function of other physical values (dynamics)

$$J \equiv kg.m^2.s^{-2} \equiv kg.m.s^{-2}.m \equiv [F] \times [L] \equiv N.m \equiv Travail\ de\ force$$

$$J \equiv \frac{[F]}{[S]} \times [S] \times [L] \equiv [P] \times [V] \equiv Pa.m^3$$

Another useful unit is also used to design energy quantity (thermal)

$$1\ calorie = 1cal = 4.184Joules$$

$$1kcal = 1Cal = 4184J = 4.184kJ$$

Forms of Energy

- **Dimensional analysis of energy**

We can also redefine energy as a function of other physical values (electric)

$$J \equiv N.m \equiv [Q] \times [E] \times [L] \equiv C.\frac{V}{m}.m = C.V = [Q] \times [U]$$

$$J \equiv C.V \equiv [I] \times [T] \times [U] \equiv [UI].[T] \equiv VA.s \equiv [Puiss.][T] \equiv W.s$$

$$1eV \equiv 1.6 \times 10^{-19} J$$

Usual unit to measure the domestic/inudstiral consumption of electrical energy:

$$1Wh = 3600Ws = 3.6kWs = 3.6kJ$$

$$1kWh = 3600kWs = 3.6MWs = 3.6MJ = 3.6 \times 10^6$$

Forms of Energy

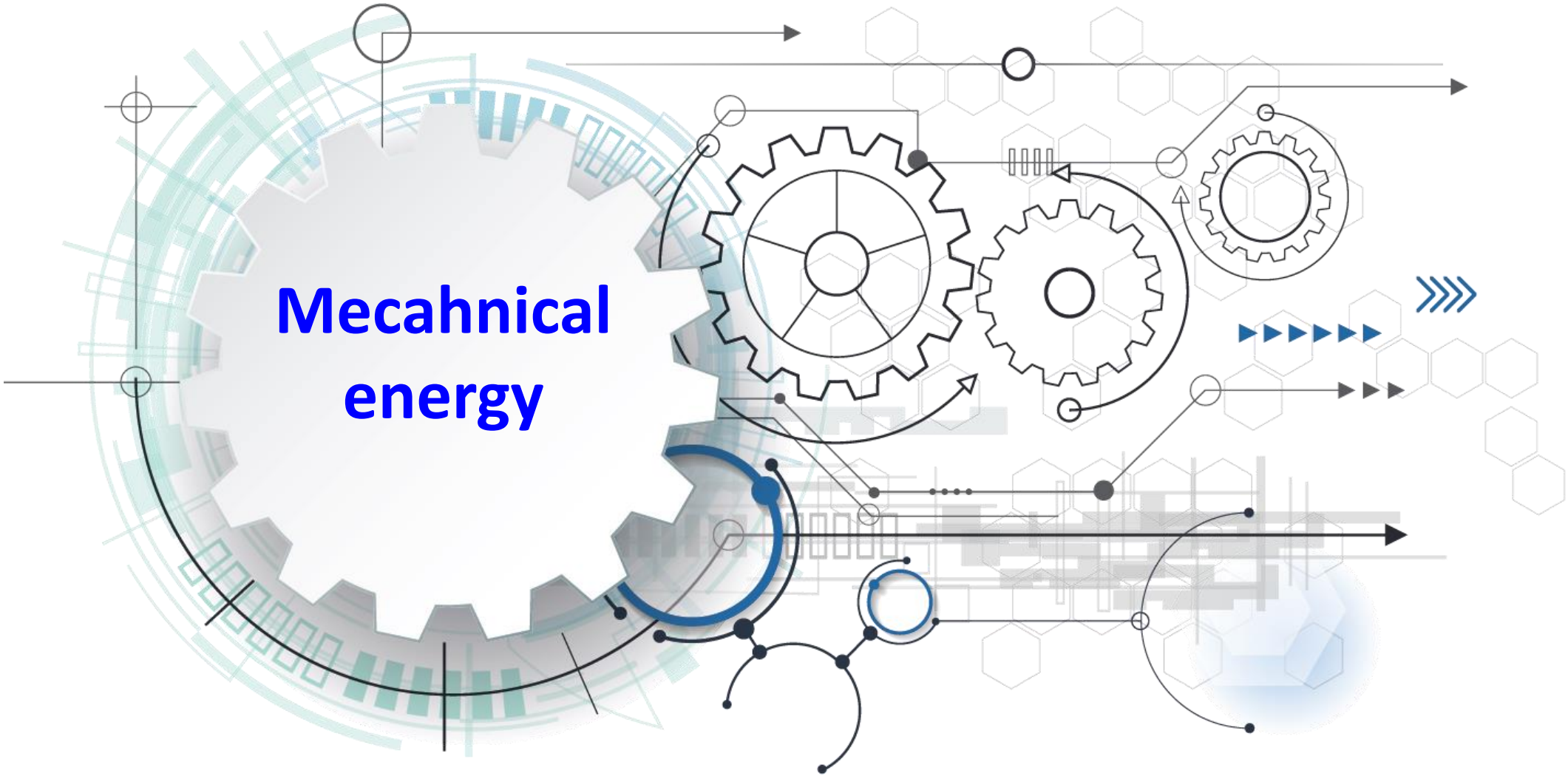
- **Dimensional analysis of energy**

Good to know

Facteur	Nom	Symbole	Facteur	Nom	Symbole
10^{1}	deca	da	10^{-1}	deci	d
10^{2}	hecto	h	10^{-2}	centi	c
10^{3}	kilo	k	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{9}	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

Forms of Energy

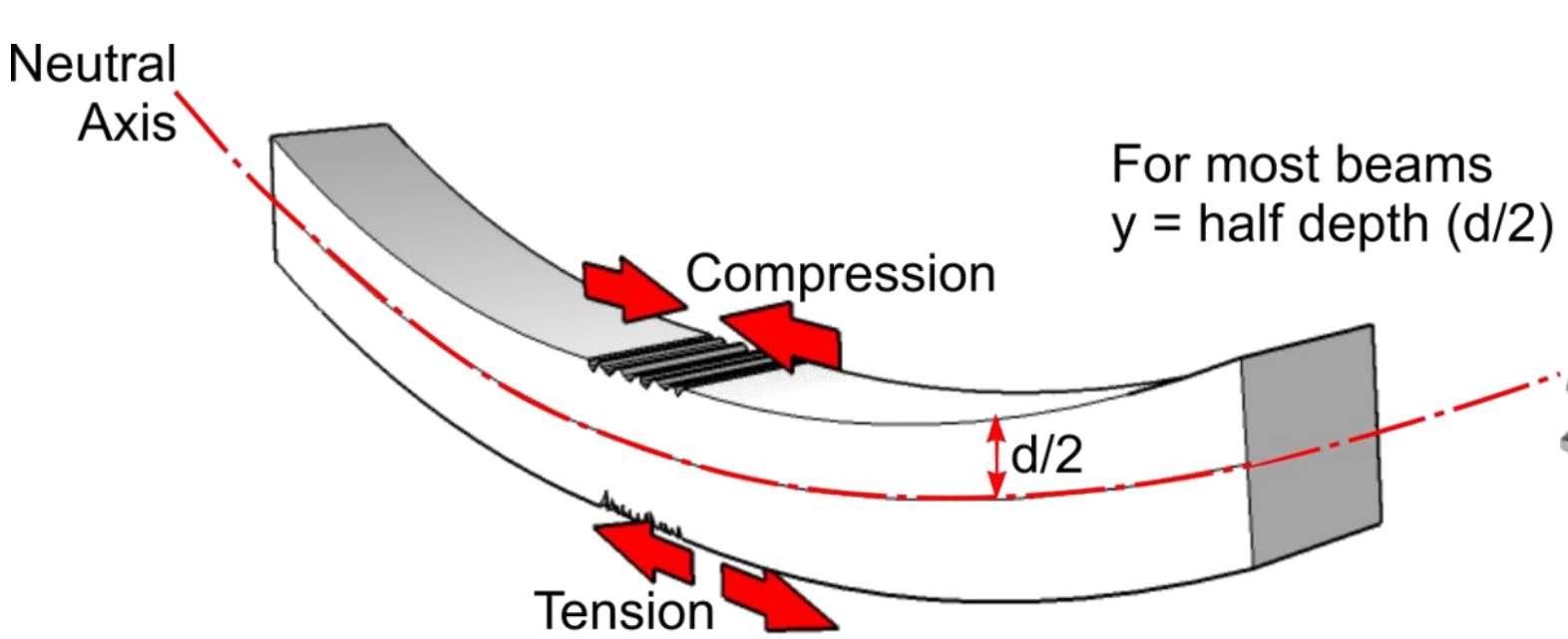
- Different forms of energy

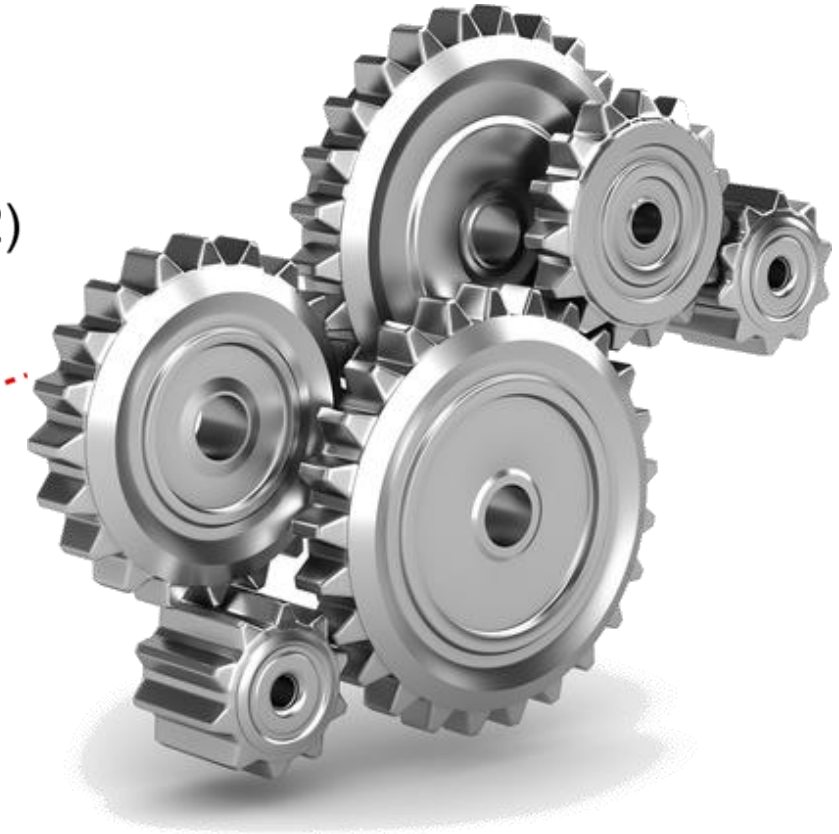


Forms of Energy

- **Different forms of energy**

Mechanical energy: it is an energy form producing a motion (linear, circular or curved) or a deformation





Forms of Energy

- **Different forms of energy**

Mechanical energy (Kinetics) :

Kinetic energy of translation: $E_k^{trans} = \frac{1}{2}mv^2$

With : $m[kg]$ **mass of the body in motion**

$v[m/s]$ **body speed**

Kinetic energy of rotation: $E_k^{rot} = \frac{1}{2}I\omega^2$

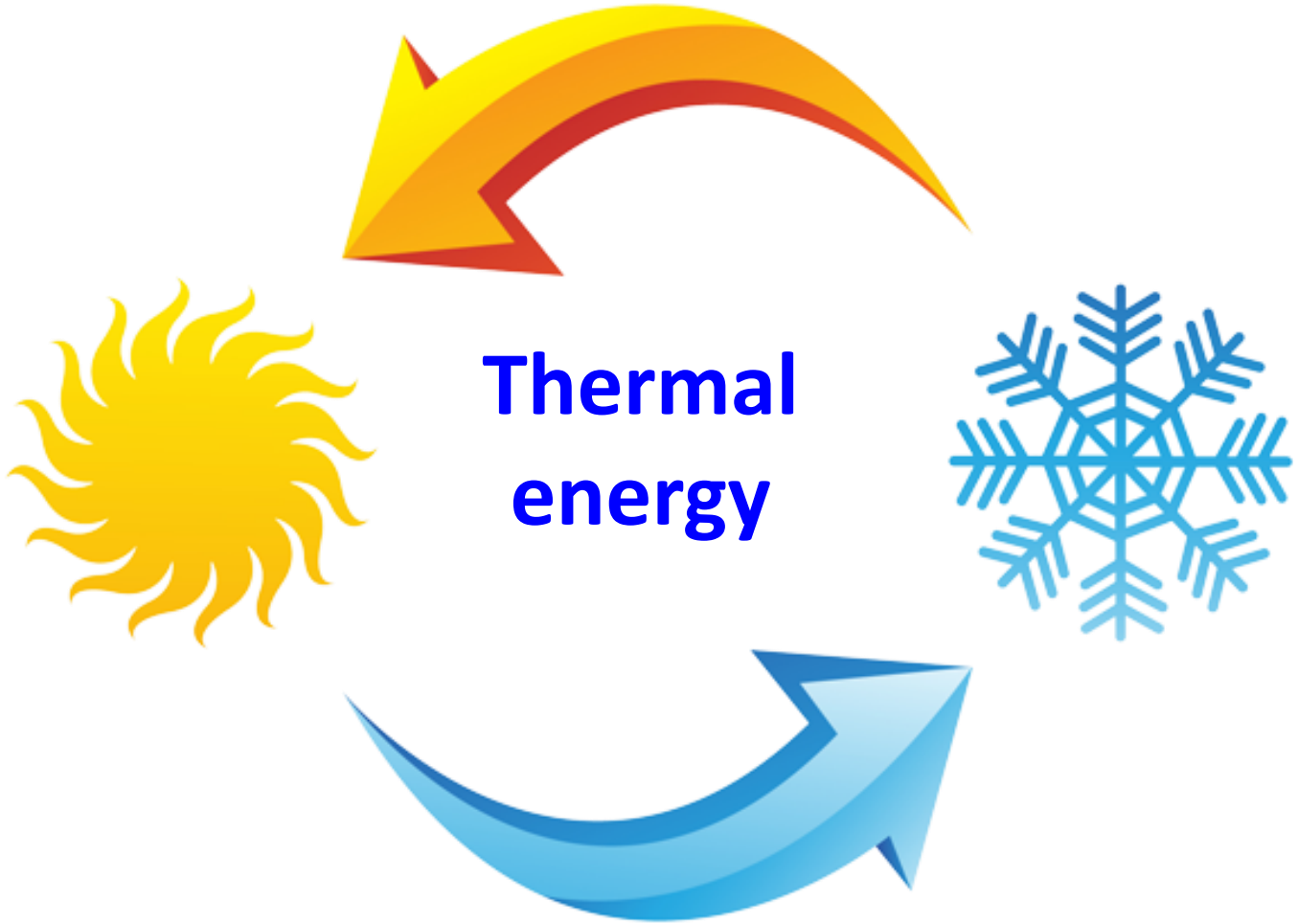
With : $I[kg.m^2]$ **Inertial momentum of the rotating system,**

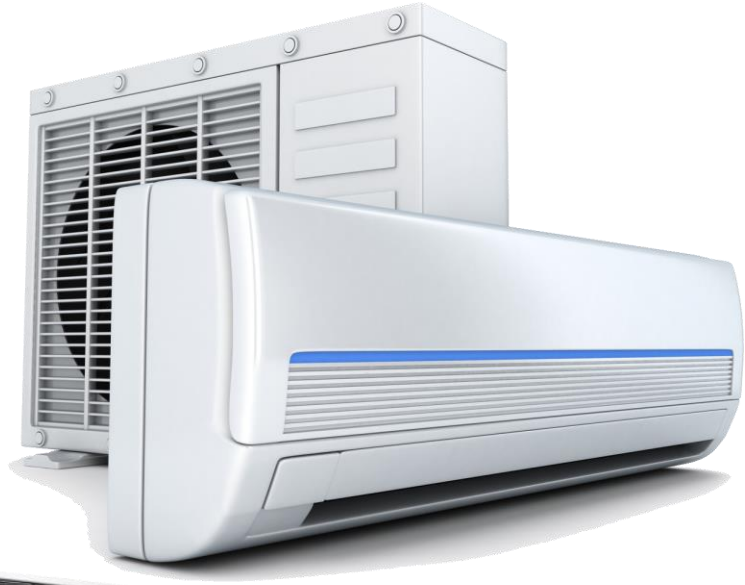
$\omega[rad/s]$ **angular speed**

For example: $I_{disk} = \frac{1}{2}mR^2$

Forms of Energy

- Different forms of energy



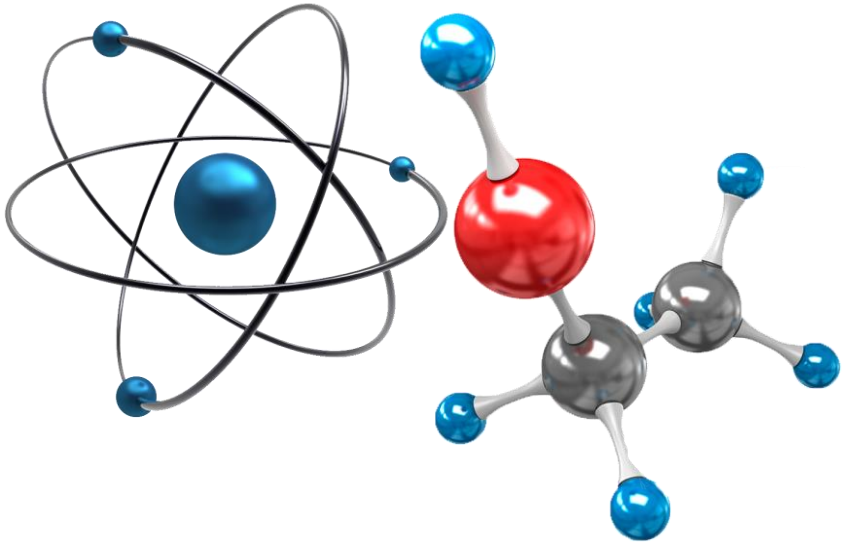


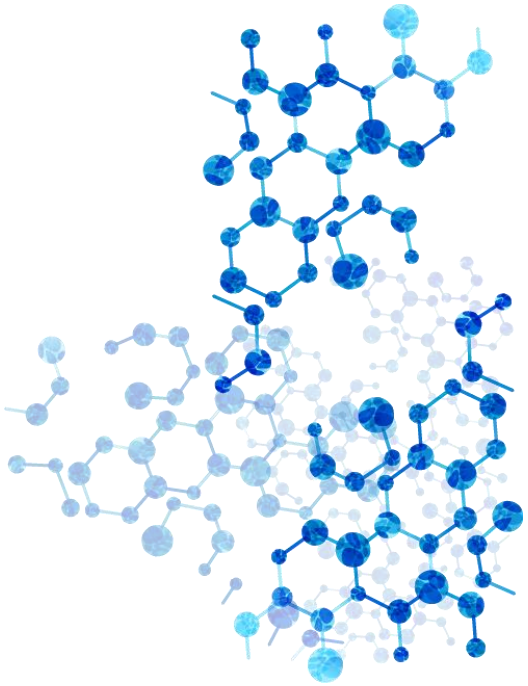
Forms of Energy

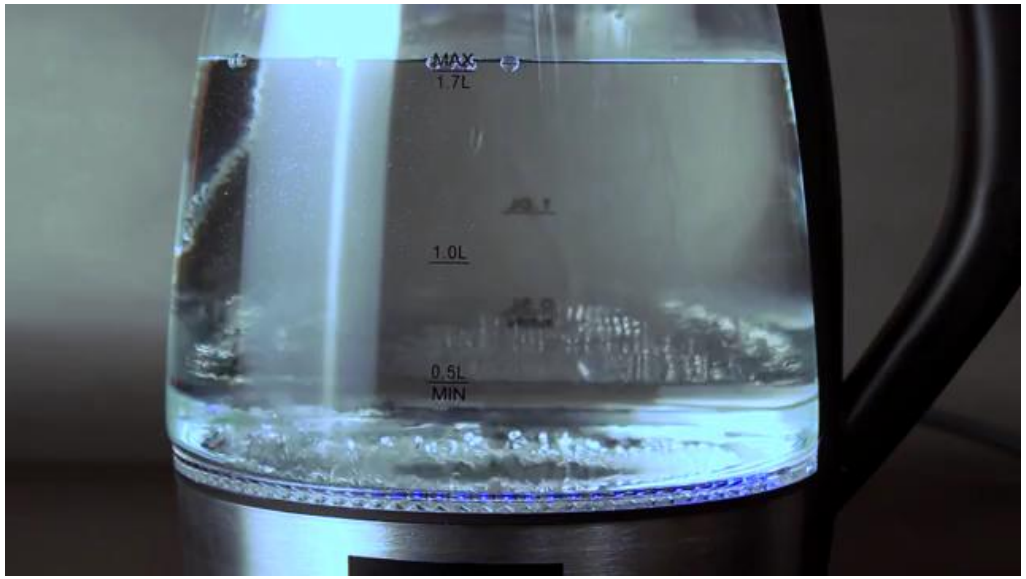
- Different forms of energy

Boltzmann constant: $k_B = 1,38 \times 10^{23} \left[\frac{kg.m^2}{s^2.K}\right]$

Thermal energy: it is due to atoms and molecules dynamics at microscopic scale, or any other constituent of macroscopic systems. $(e_c = \frac{3}{2} k_B T)$







Forms of Energy

- Different forms of energy

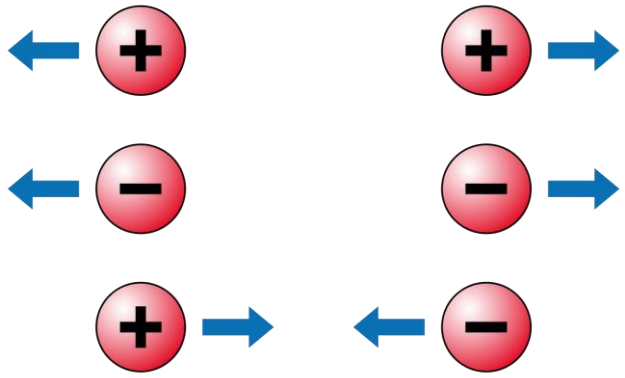
Electromagnetic energy

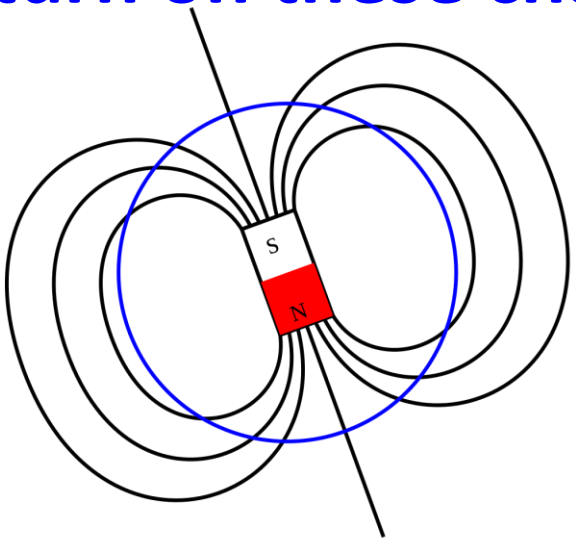
Forms of Energy

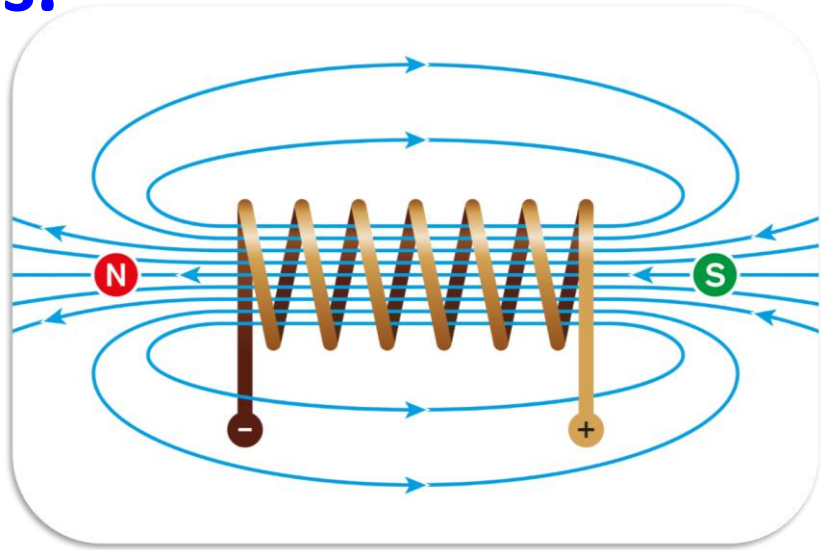
- Different forms of energy

Electromagnetic energy:

This energy is based on two physical vectorial quantities, called electric field $\vec{E}$ and magnetic field $\vec{B}$. The electric field is created by electrical charges, once in motion they induced a magnetic field. The latter acts in turn on these charges.







Forms of Energy

- Different forms of energy

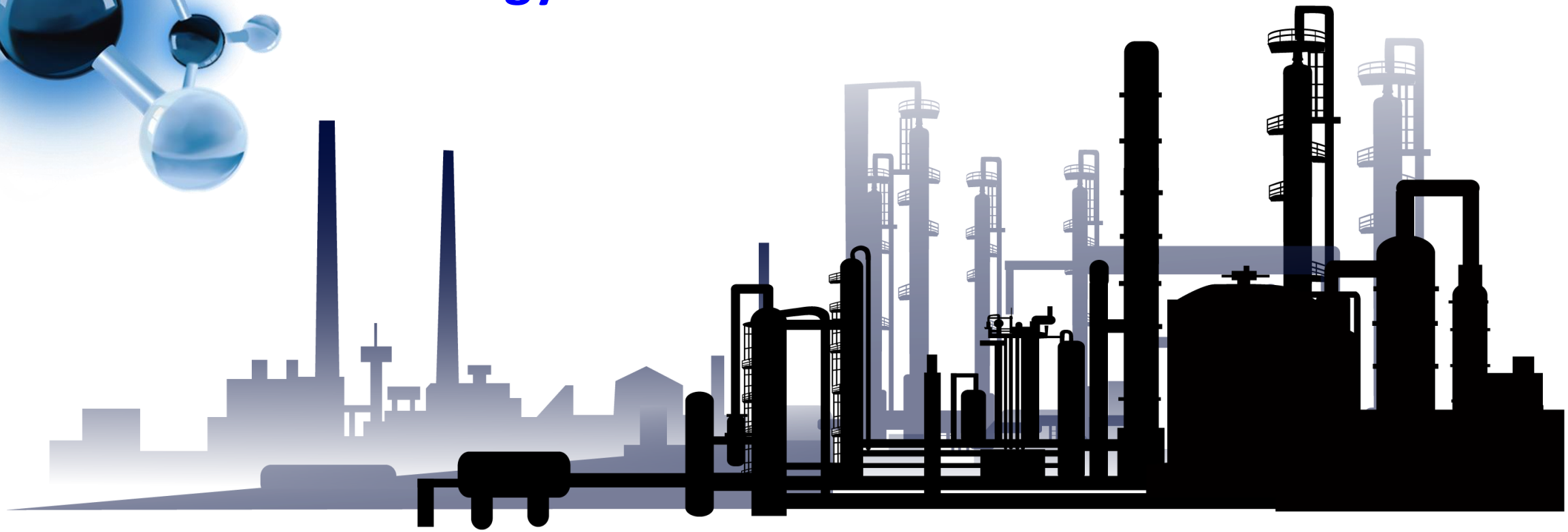
Electromagnetic energy:

It allows to power electrical machines, electronic instruments, emit radio waves, …

Forms of Energy

- Different forms of energy

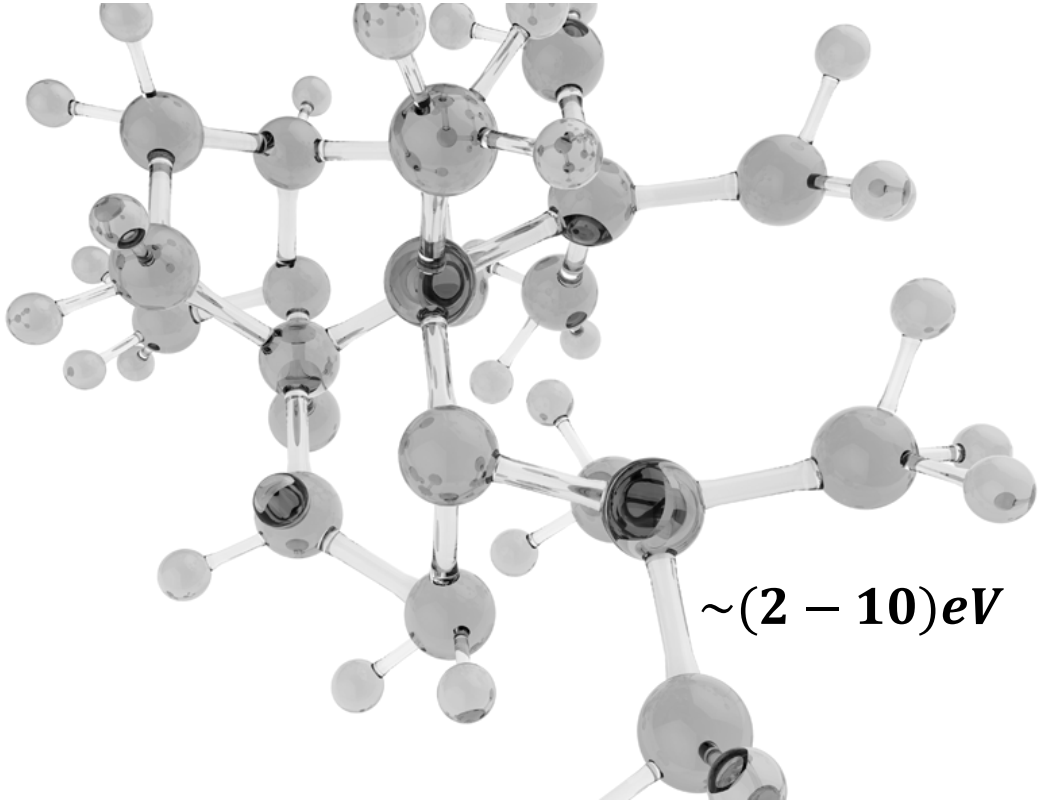
Chemical energy

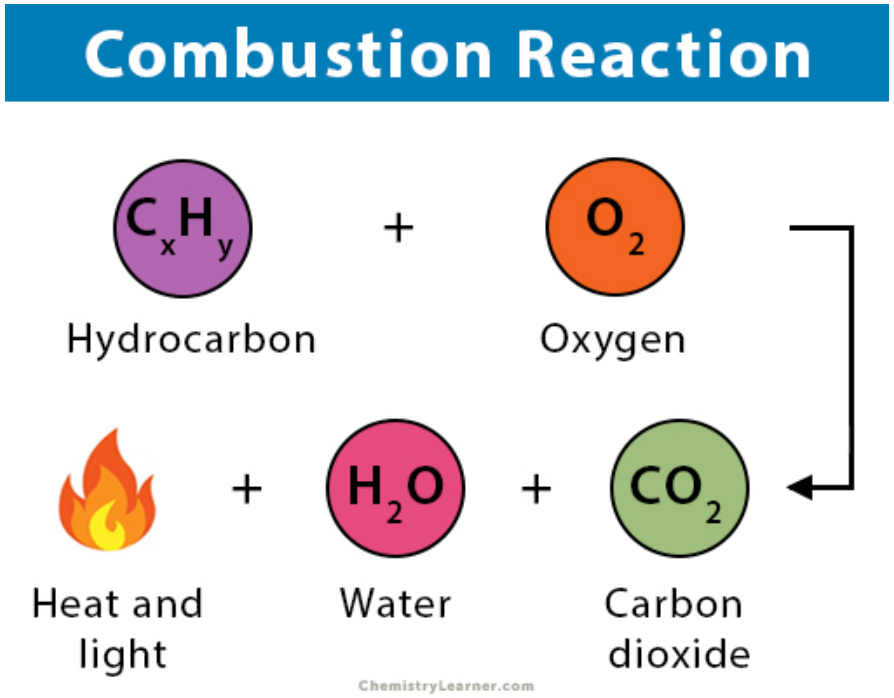


Forms of Energy

- Different forms of energy

Chemical energy: it is an stored energy in the chemical bonds of molecules. It could be released under the effect of chemical induction (Redox reaction, combustion, …)

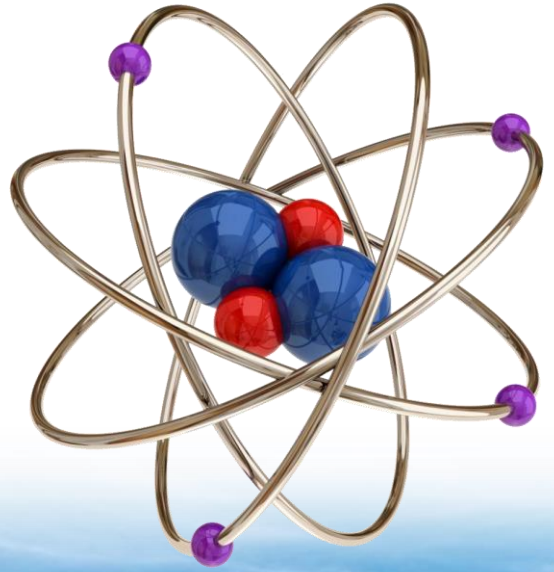


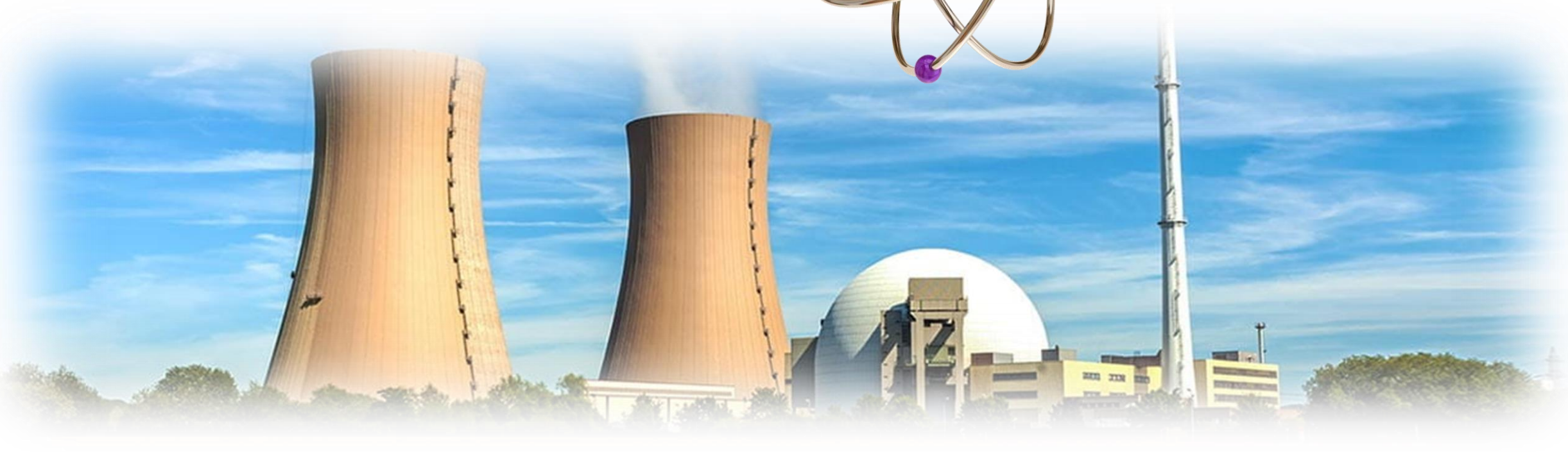


Forms of Energy

- Different forms of energy

Nuclear Energy

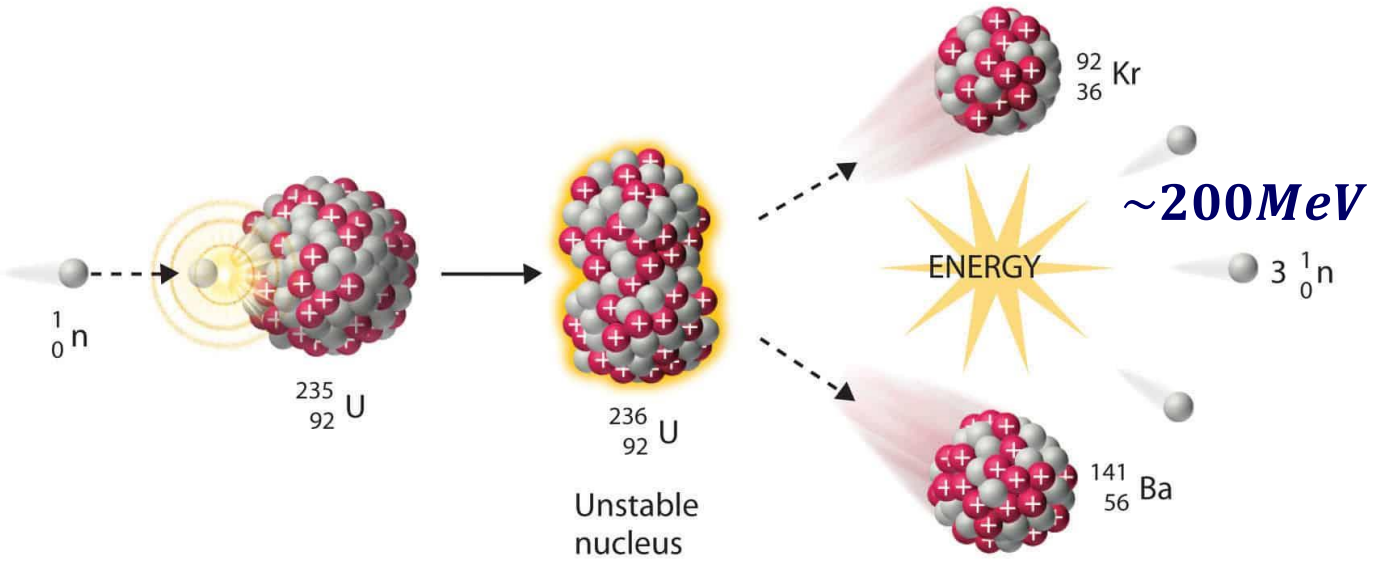


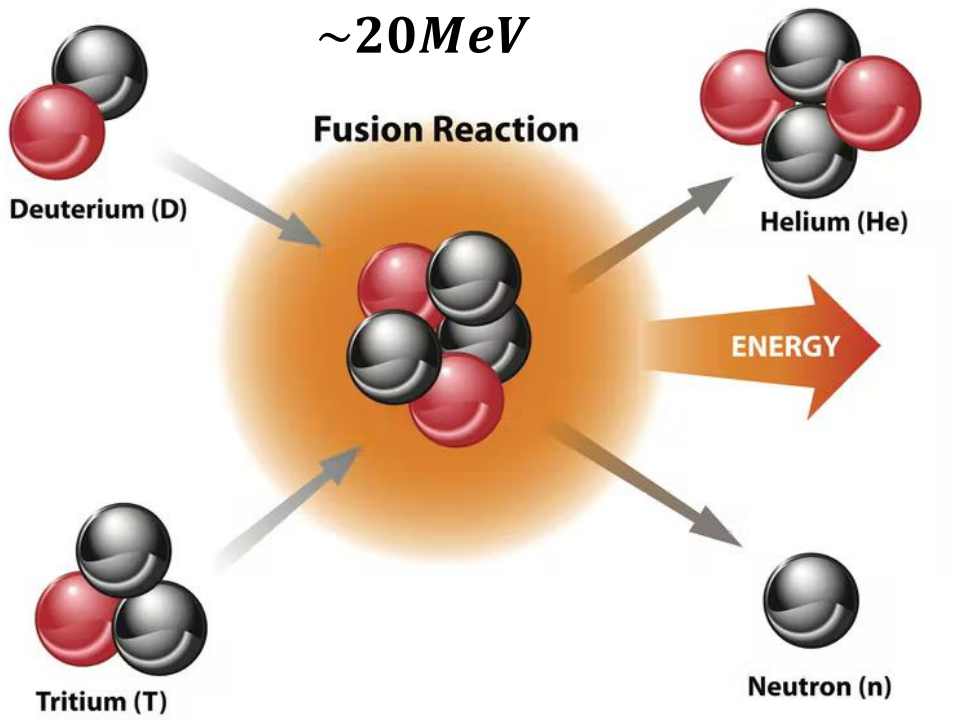


Forms of Energy

- Different forms of energy

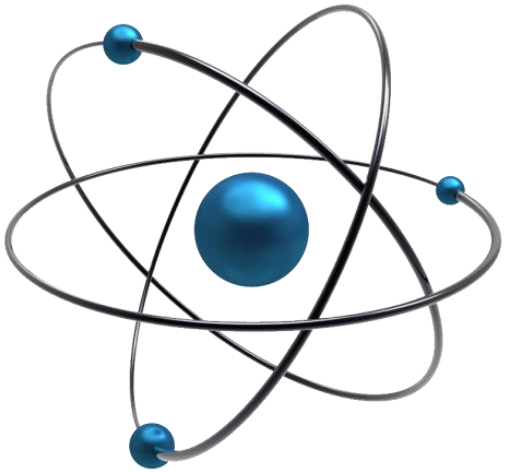
Nuclear energy: this is a very powerful energy, which could be released either by nucleus fission or fusion of light nuclei.





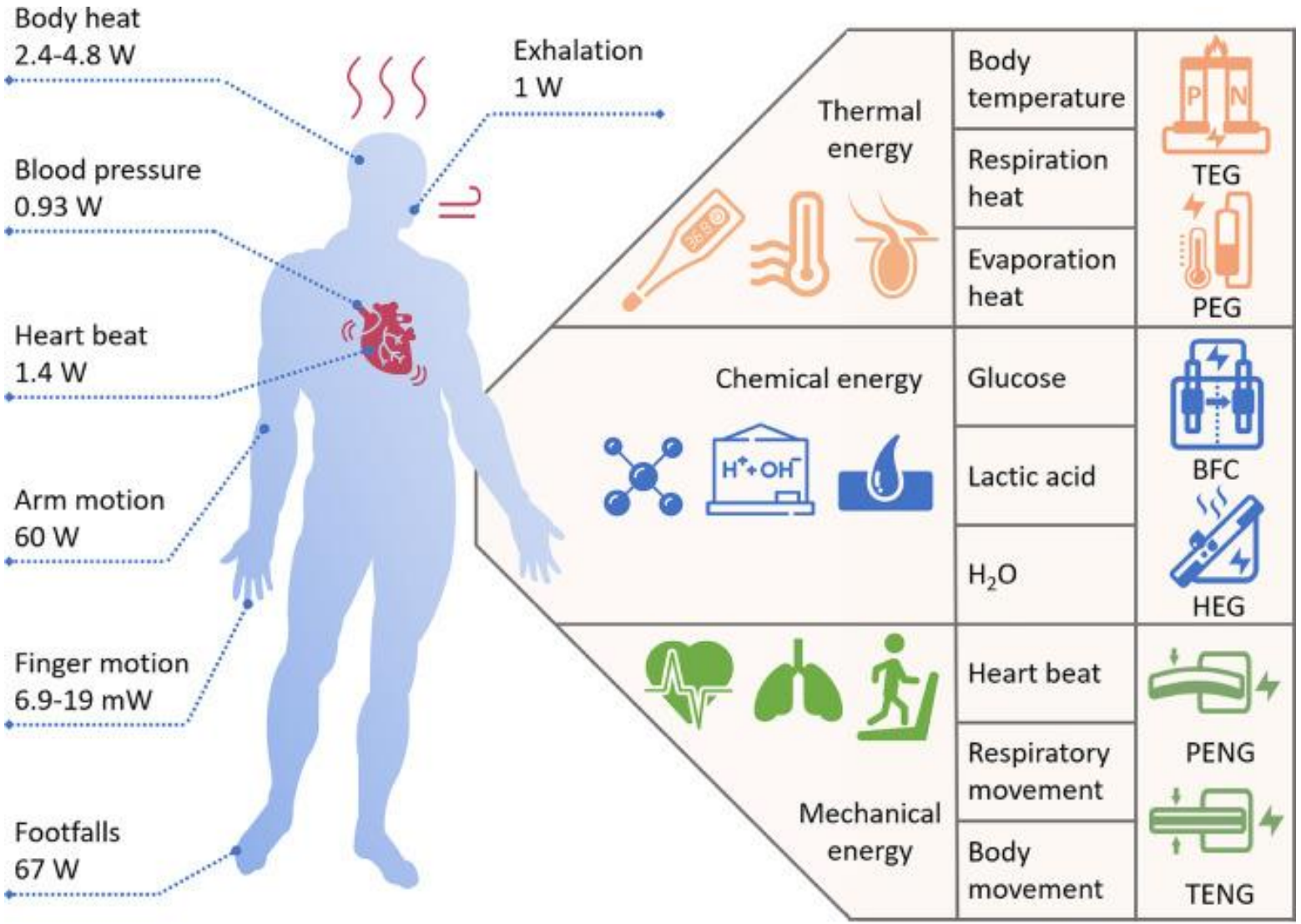
Forms of Energy

- **Energy scales**



Forms of Energy

- **Energy scales**



$\sim 133W$

$\rightarrow 133Wh \equiv 480kJ$

$\sim 12MJ/\text{day}$

Forms of Energy

- **Energy scales**

$$\rightarrow 200kWh/yr \equiv 2MJ/day$$

Forms of Energy

- **Energy scales**

$$1l\ ess. \equiv 9,63kWh$$
$$1l\ dies. = 10,74kWh$$

Forms of Energy

- **Energy scales**

$$\rightarrow 80 - 400 \left[\frac{Wh}{passeng.km}\right]$$

Forms of Energy

- **Energy scales**

$$\rightarrow 60 - 100 \left[\frac{Wh}{passeng.km}\right]$$

Forms of Energy

- **Energy scales**

$$\rightarrow 360 - 450 \left[\frac{Wh}{passeng.km}\right]$$

Forms of Energy

- **Energy scales**

Public facility needs in energy

$$\sim 300 \left[\frac{kWh}{m^2.yr}\right]$$

Forms of Energy

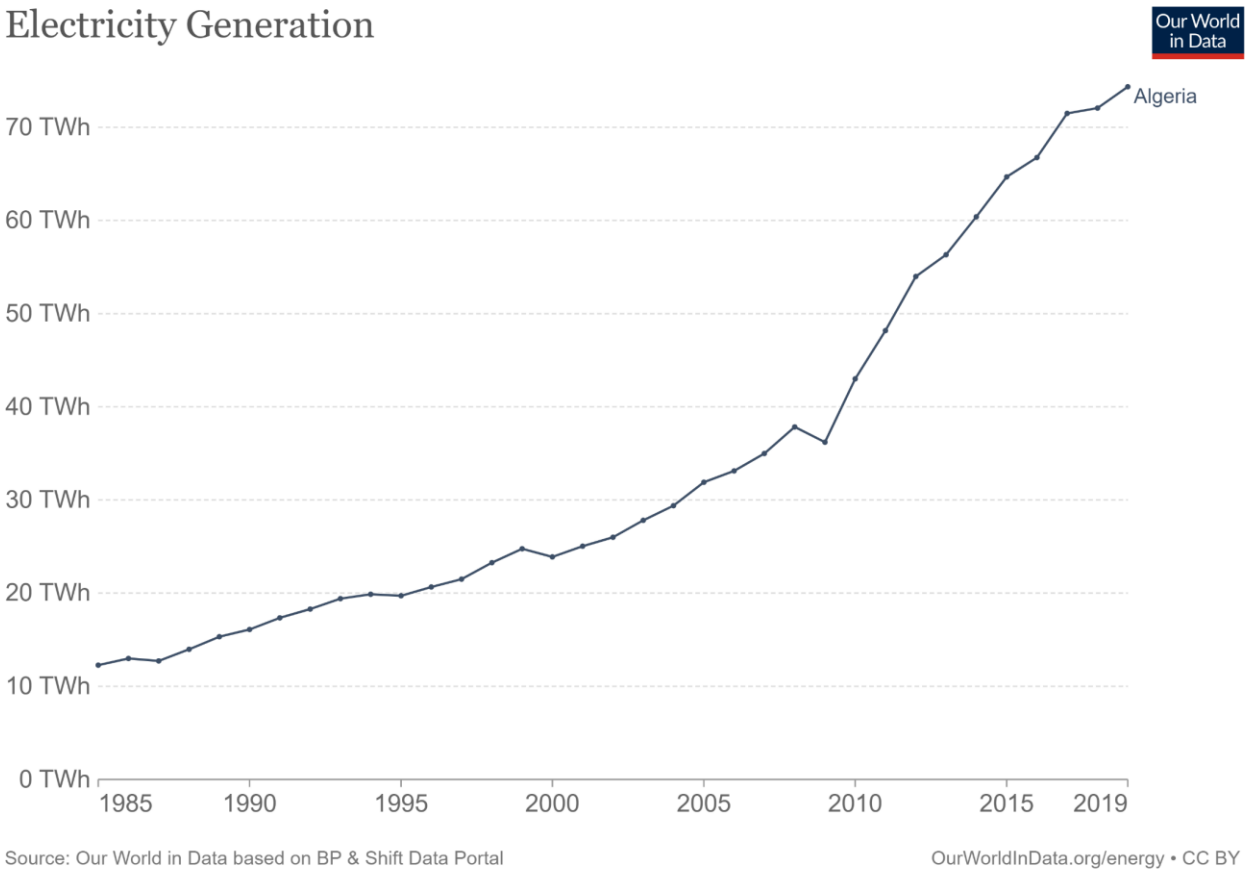
- **Energy scales**

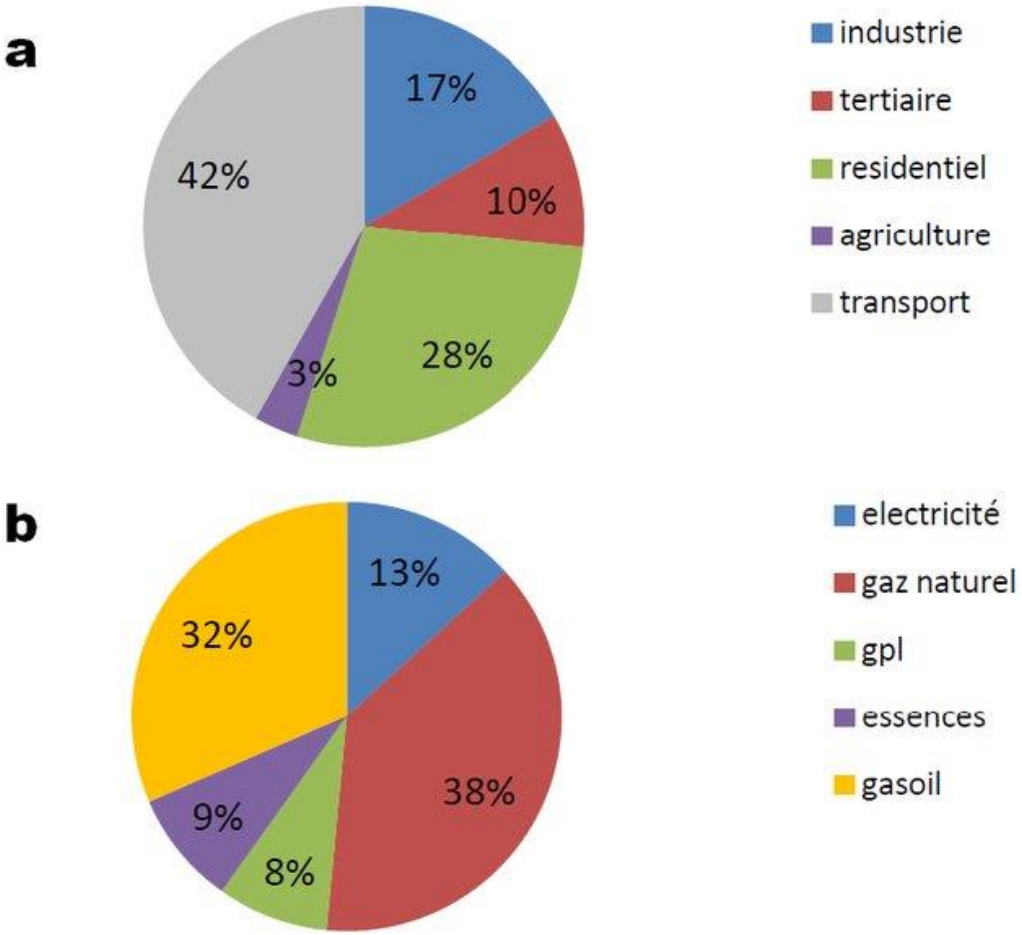
Small to large size factory needs in energy

$$\sim (3 - 133) TWh$$

Forms of Energy

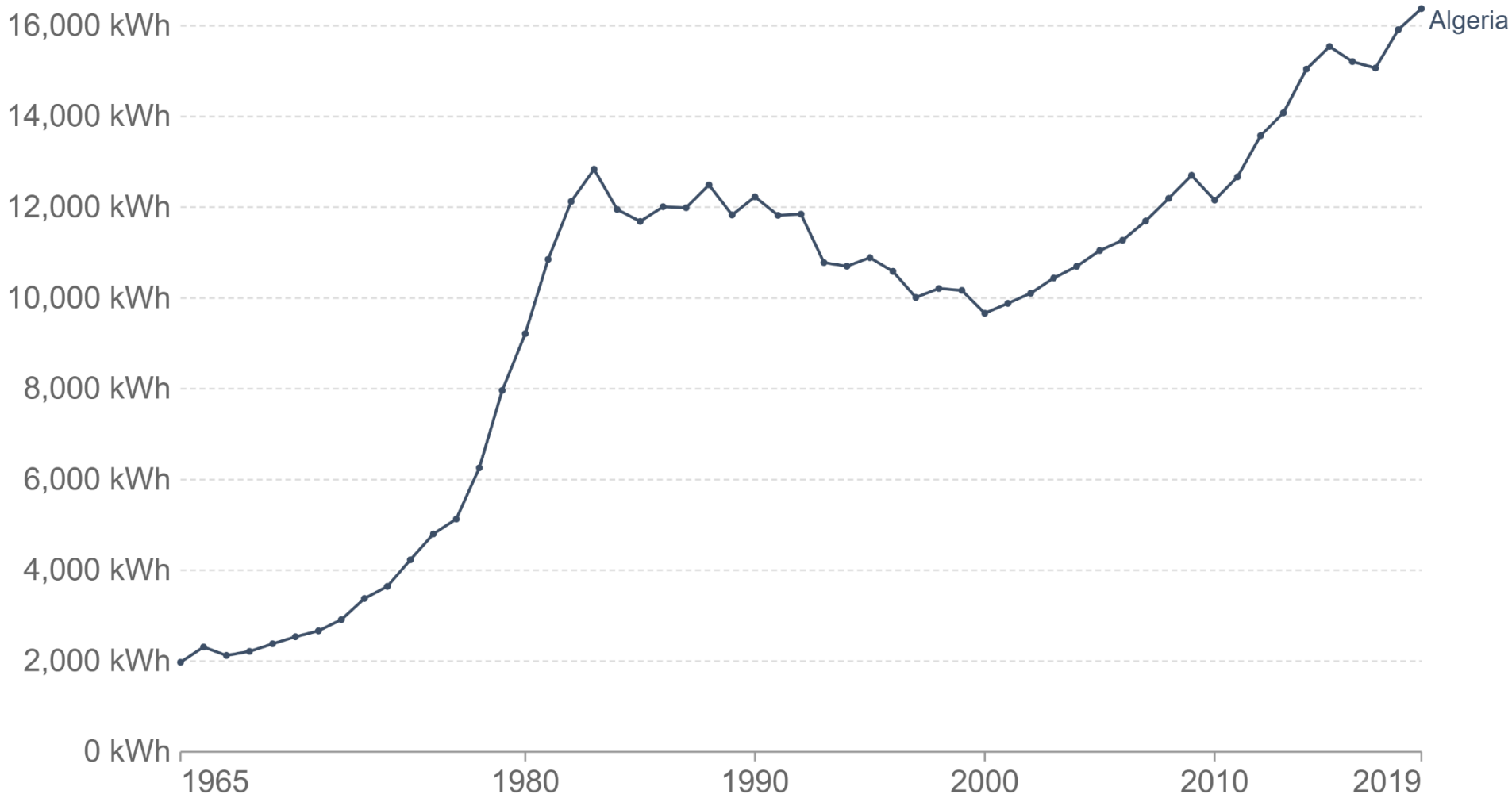
- **Energy scales**





Energy use per person

Energy use not only includes electricity, but also other areas of consumption including transport, heating and cooking.



Source: Our World in Data based on BP & Shift Data Portal

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Note: Energy refers to primary energy – the energy input before the transformation to forms of energy for end-use (such as electricity or petrol for transport).

Forms of Energy

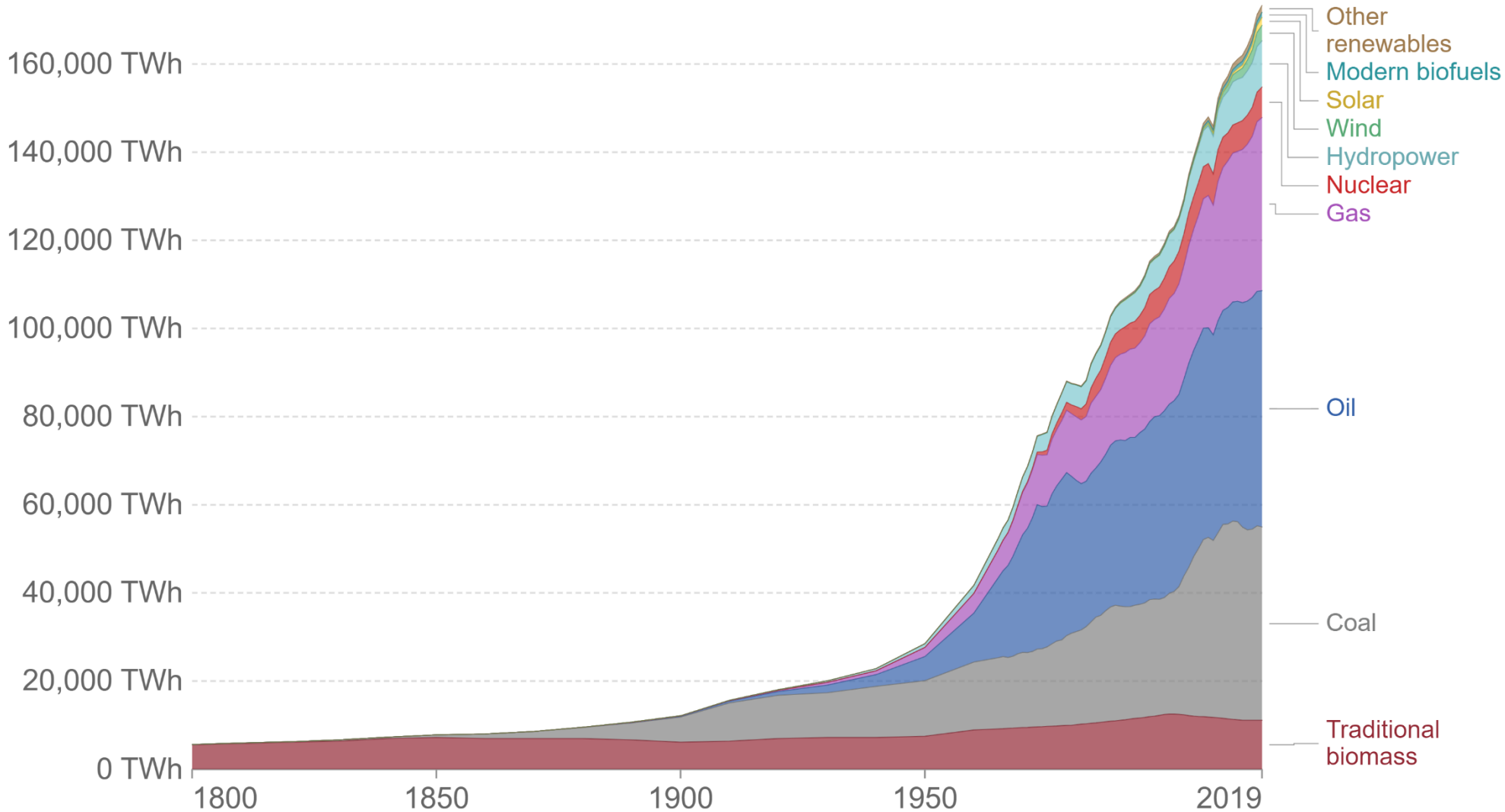
- Energy scales

The world needs in energy:
(Transport, Industry, Homes, …)
$\sim 200,000 TWh$

Global primary energy consumption by source

Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.

Our World in Data



Source: Vaclav Smil (2017) & BP Statistical Review of World Energy

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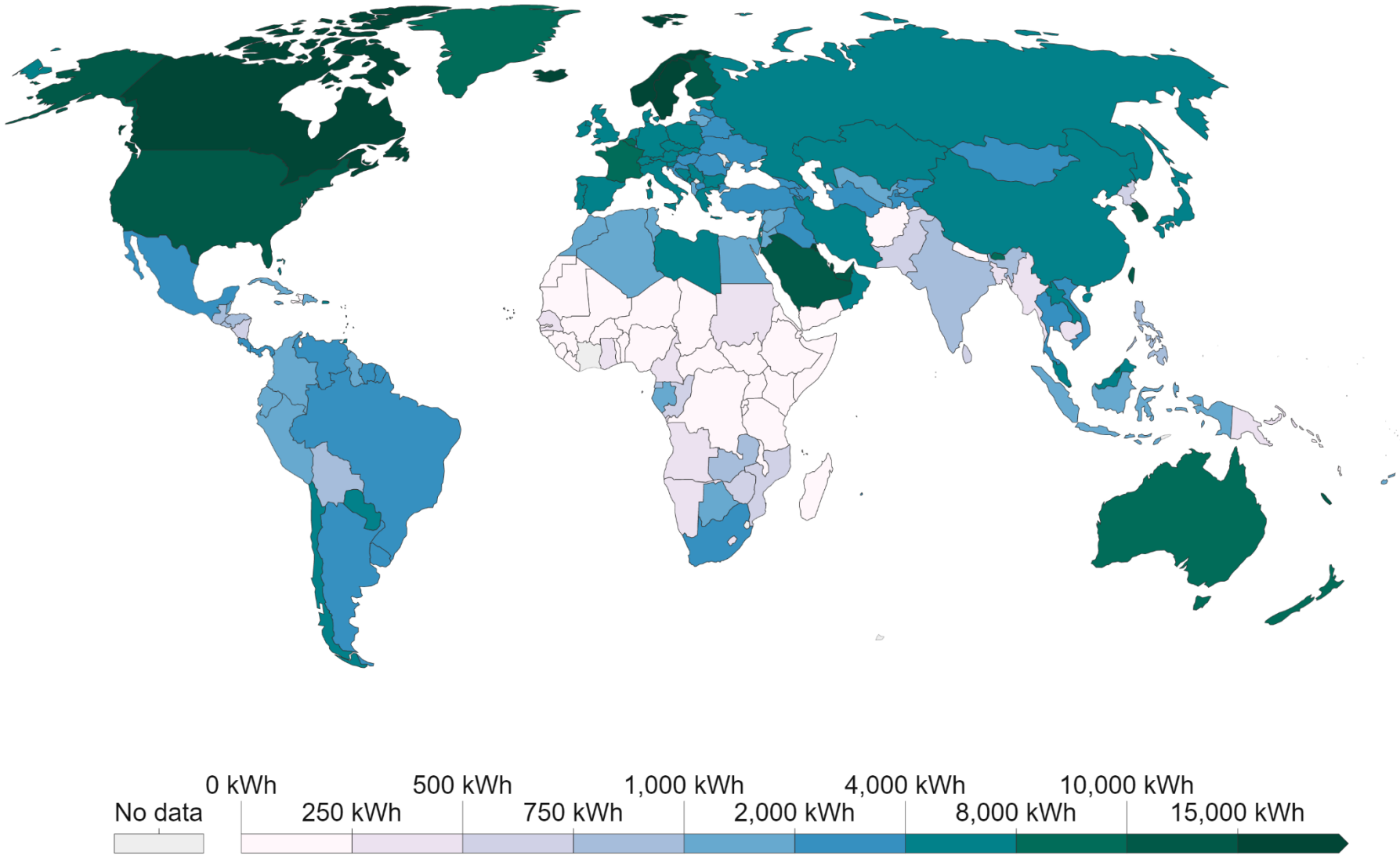
Per capita electricity generation, 2021

This is annual average electricity generation per person, measured in kilowatt-hours.

Our World in Data



Source: Our World in Data based on BP Statistical Review of World Energy & Ember (2022)

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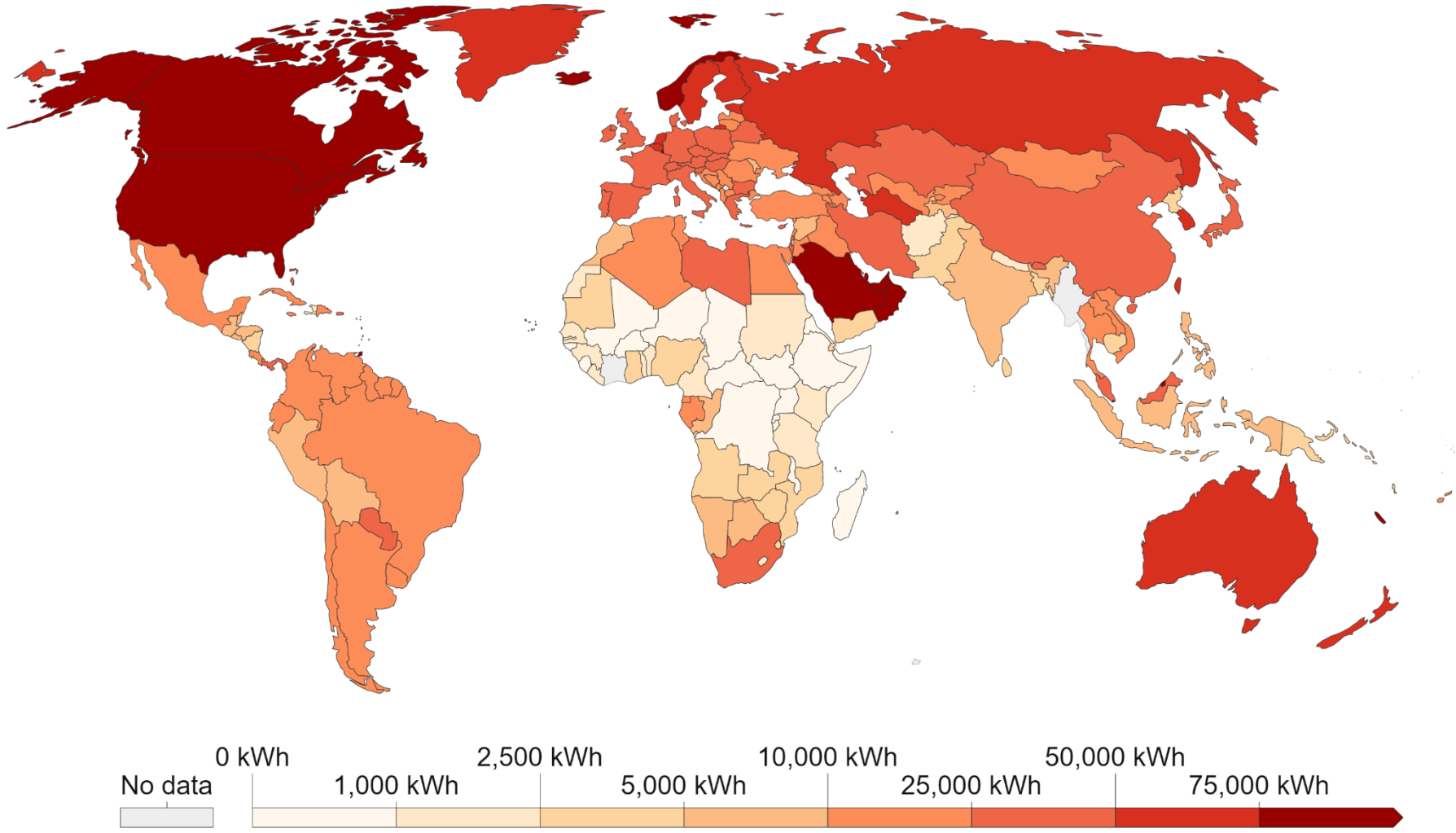
Energy use per person, 2019

Energy use not only includes electricity, but also other areas of consumption including transport, heating and cooking.

Our World in Data



Source: Our World in Data based on BP & Shift Data Portal

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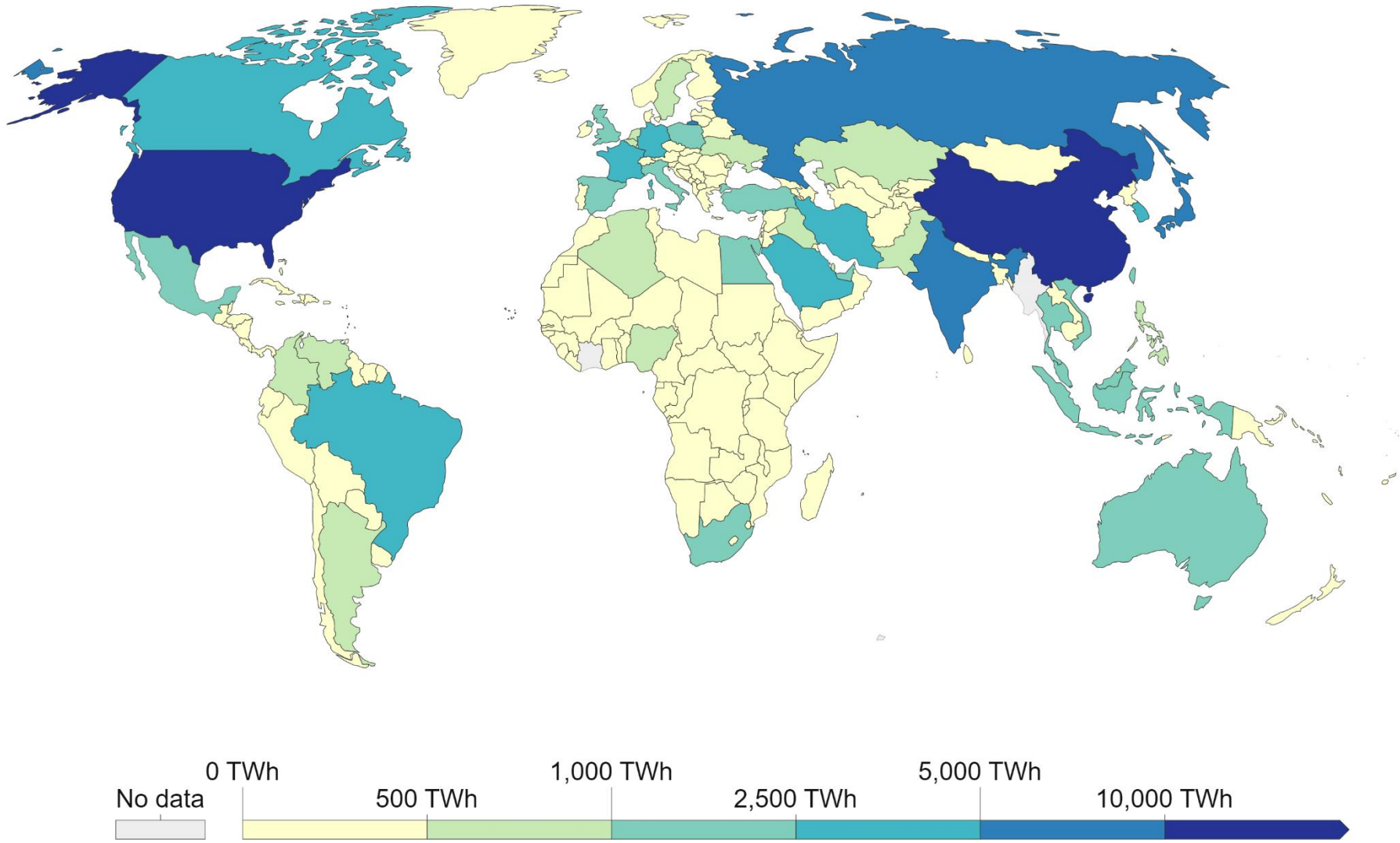
Note: Energy refers to primary energy – the energy input before the transformation to forms of energy for end-use (such as electricity or petrol for transport).

Primary energy consumption, 2019

Primary energy consumption is measured in terawatt-hours (TWh).

Our World in Data



Source: BP Statistical Review of Global Energy

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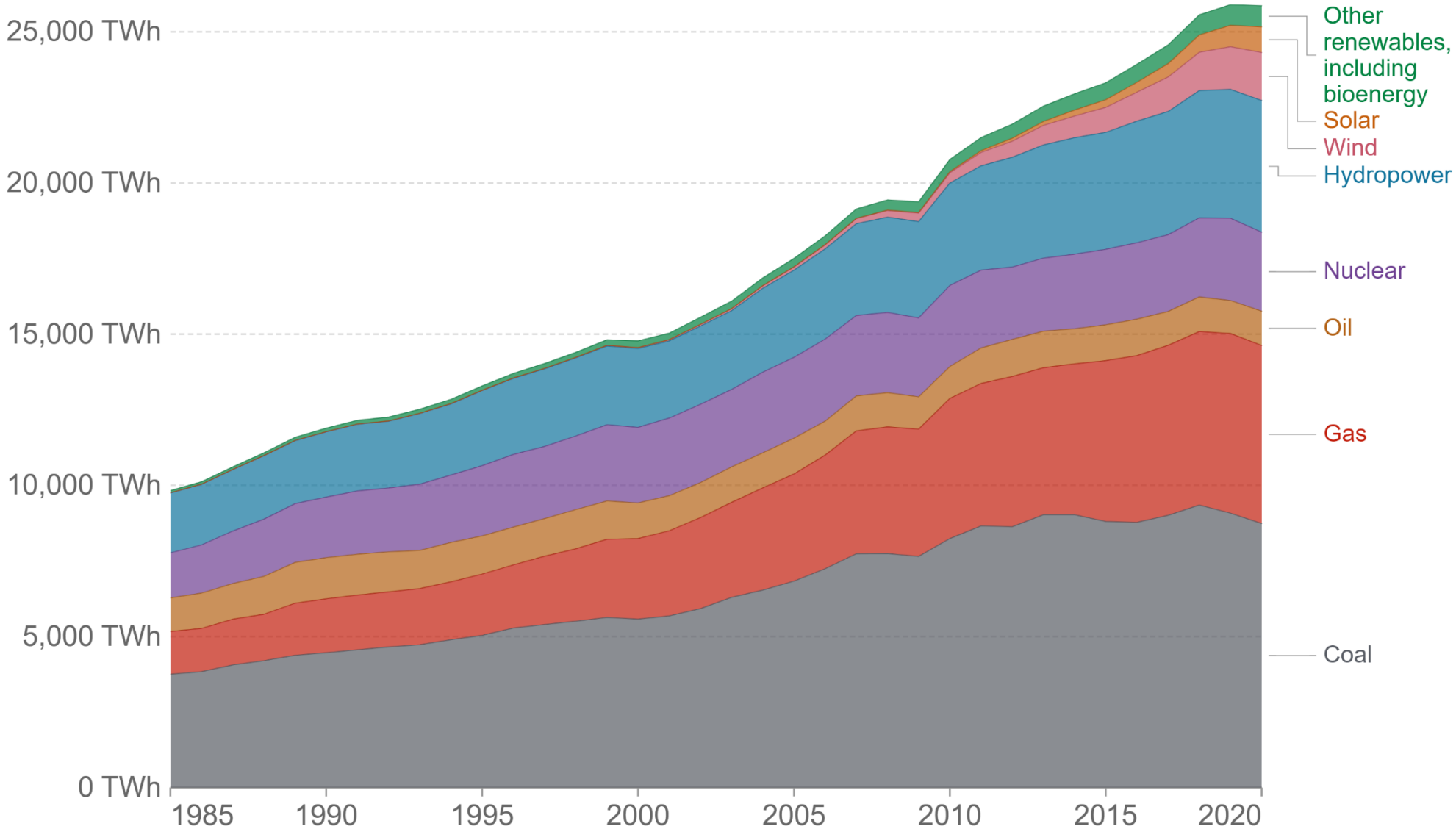
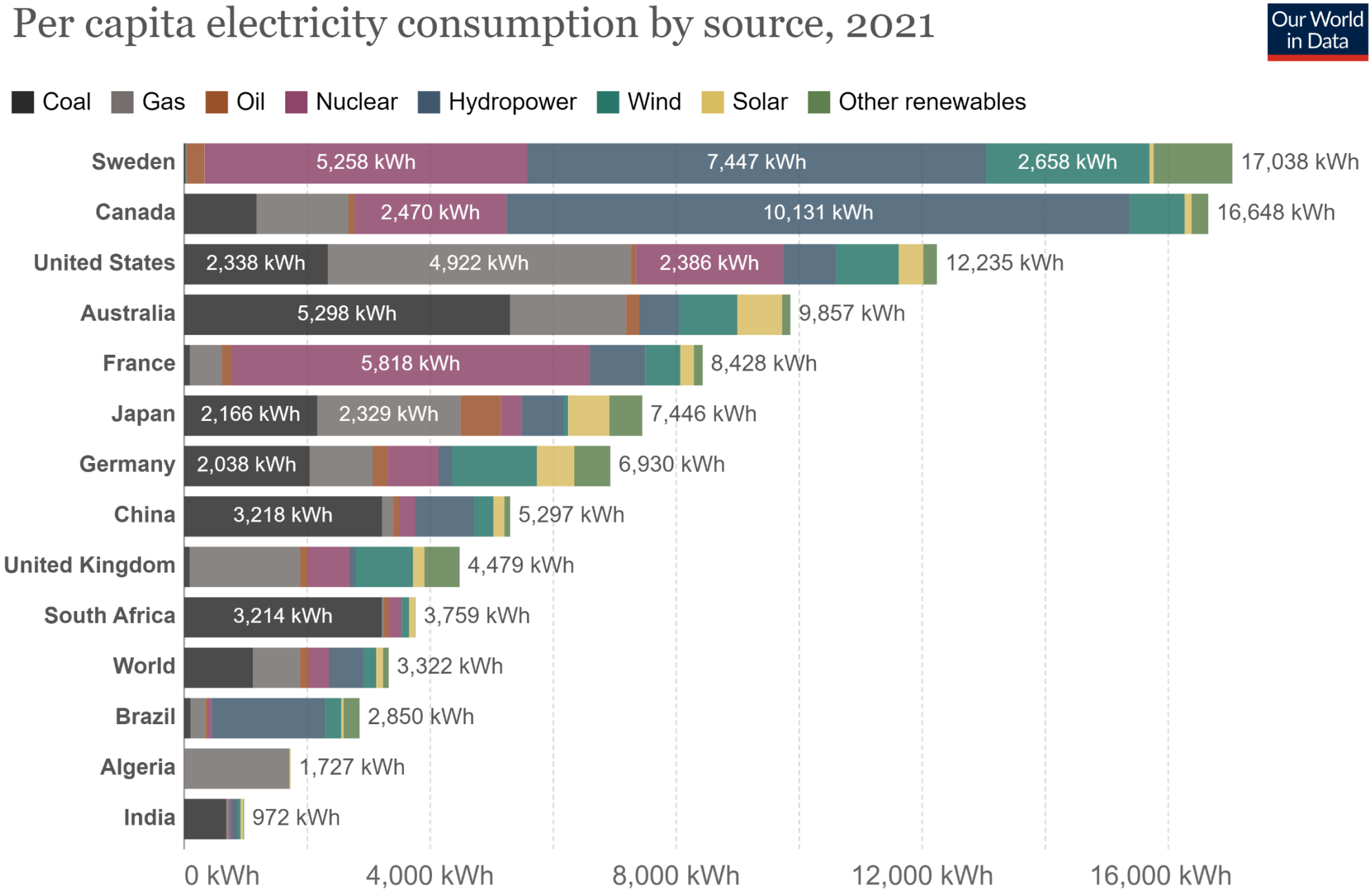
Note: Data includes only commercially-traded fuels (coal, oil, gas), nuclear and modern renewables. It does not include traditional biomass.

Electricity production by source, World



Source: Our World in Data based on BP Statistical Review of World Energy & Ember (2022)
Note: 'Other renewables' includes biomass and waste, geothermal, wave and tidal.

Per capita electricity consumption by source, 2021



Source: Our World in Data based on BP Statistical Review of World Energy & Ember

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Forms of Energy

- Energy scales

$rate \sim 173000\text{TW}$

$conso. \sim 600EJ/yr \equiv 19TW$

$Shores \sim 3\text{TW}$