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Department of Physics

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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Content

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

The principle source of renewable energies

- **The principle source of renewable energies:**

The interaction Earth-Sun is responsible of several natural phenomena on Earth, like:

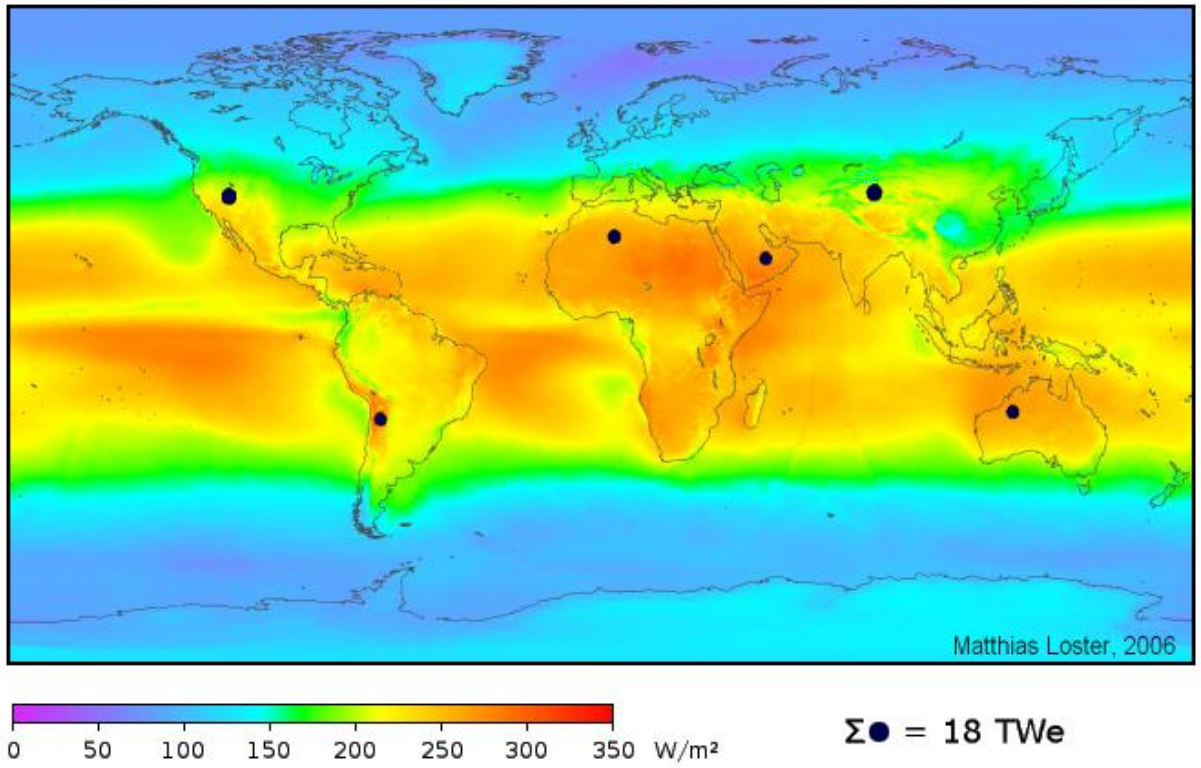
- ❑ *Wind (Air dynamics)*
- ❑ *Sea waves, tides, and ocean currents (Water dynamics)*
- ❑ *surfaces heating (Solar radiations)*
- ❑ *Water cycle (rain falls, clouds, wetting…)*
- ❑ *…*

Thermal solar energy

This the most simple and basic form of solar energy use, since antiquity (mainly for drying and heating). Nowadays, it concerns more sophisticated devices to pull a maximum of efficiency rate from solar radiations energy, arriving on Earth surface.

We will distinguish two main uses of the thermal solar energy:

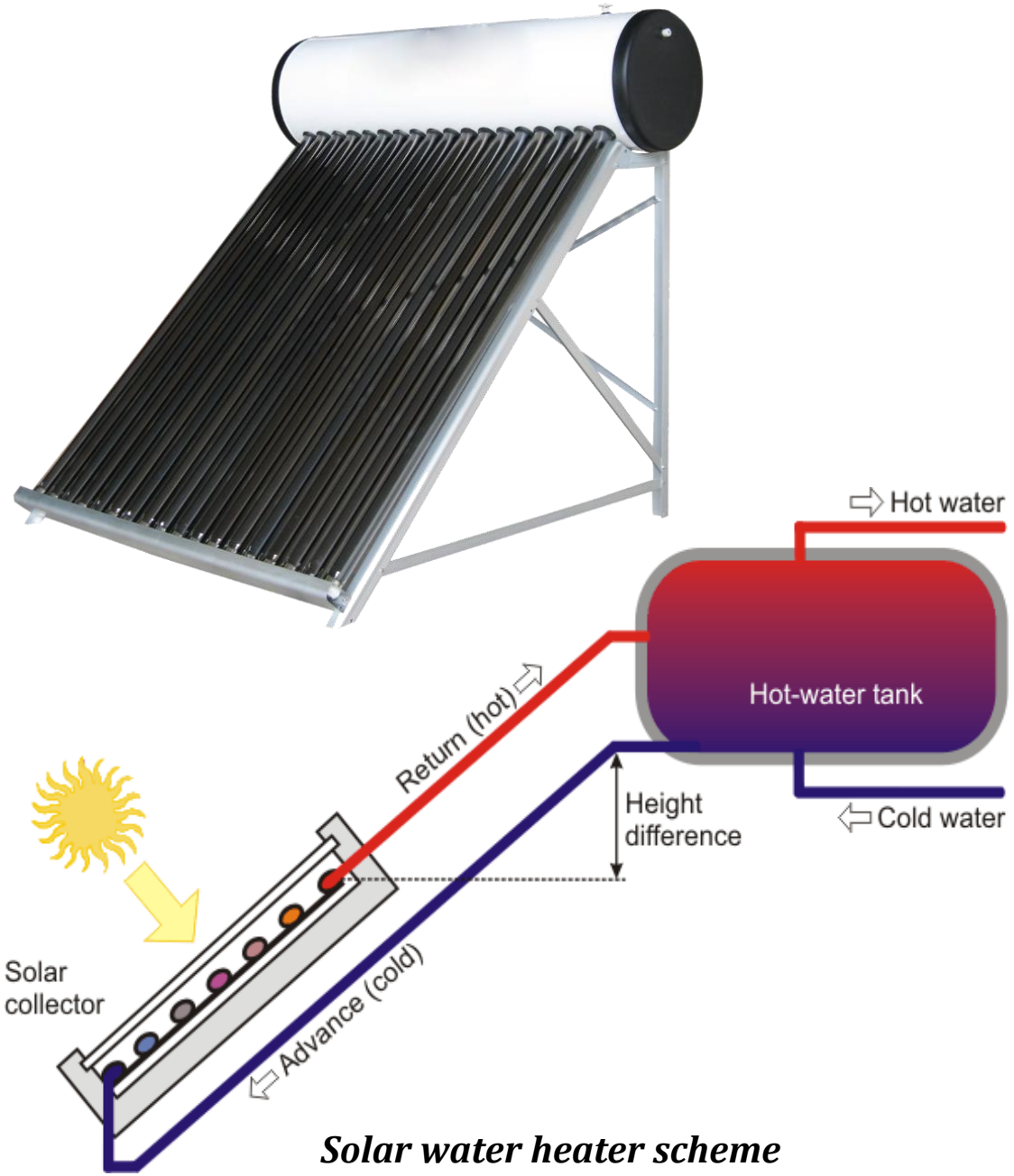
- **Direct use: water heater, solar heater, solar dryer, solar oven, …**
- **Indirect use: thermal solar power plants (solar concentrators)**



Thermal solar energy

- **Direct thermal solar energy:**

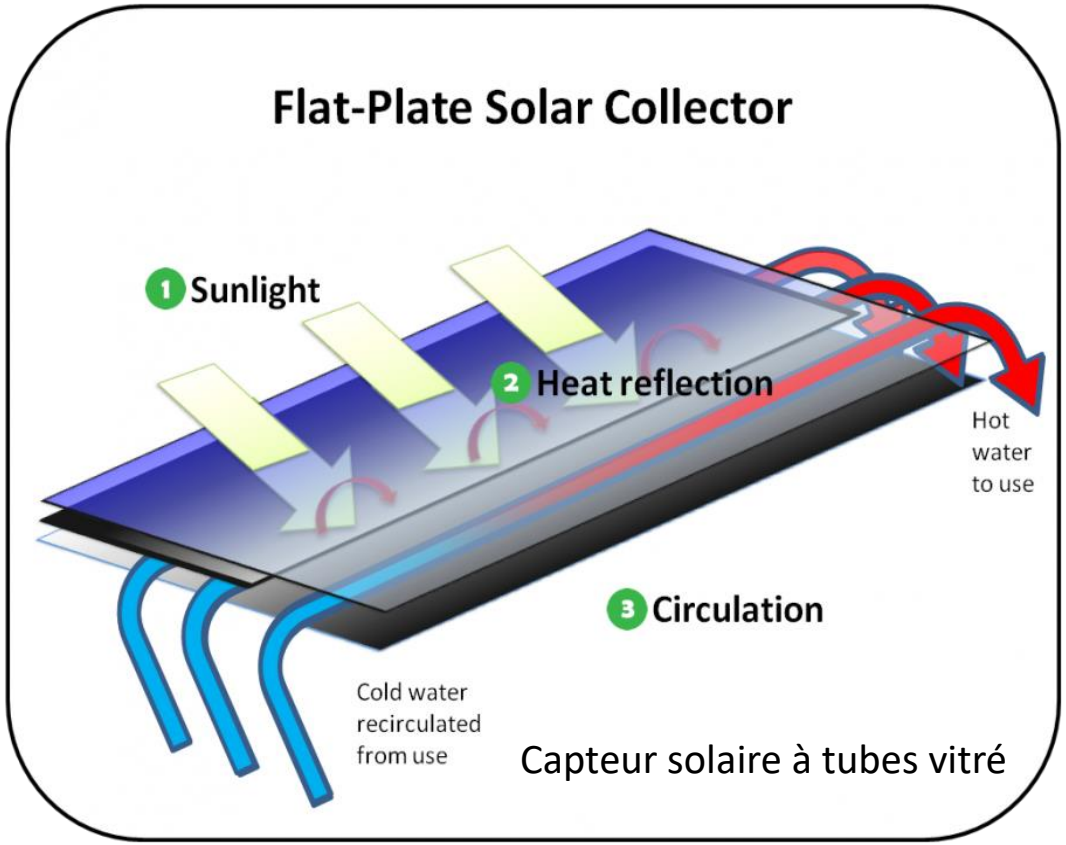
The principle of direct thermal solar energy consists on the direct transformation of the solar energy (radiations) to heat water for a practical direact use: home heating or daily use of hot water (bathing). The device (thermal solar heater) consists to circulate a coolant fluid (water or other antigel liquids) in the piping of a solar radiations collector painted in black under vacuum glazing for a better retention of the transferred heat by solar radiations. Then, an exchanger (serpentine shaped tube) will transfer this heat to water tank.



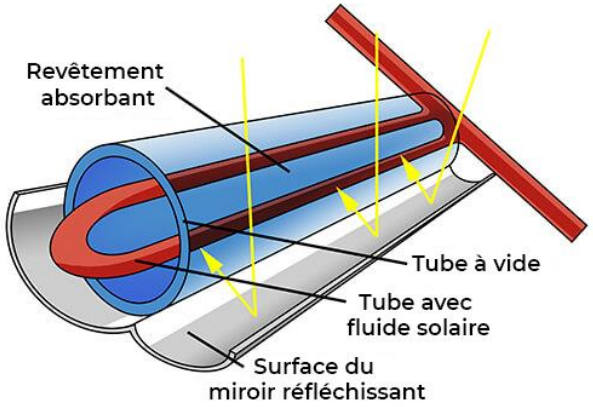
Solar water heater scheme

Thermal solar energy

- **Direct thermal solar energy:**



Capteur solaire à tubes vitré



Solar collector with vacuum tubes

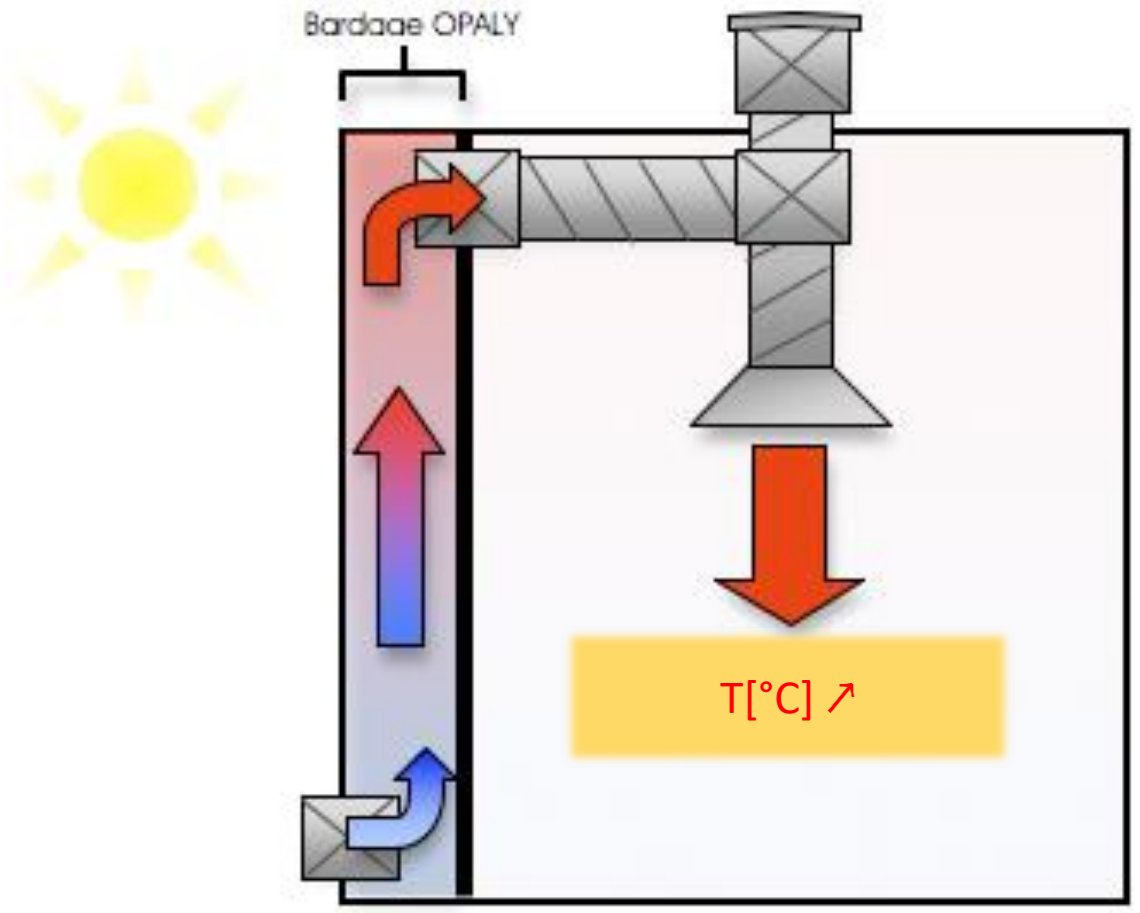
Capteur solaire à tubes non vitré

Thermal solar energy

- **Direct thermal solar energy:**

We can also use the same principle of solar heating on the air to use it in the heating of a building (Aerothermie).

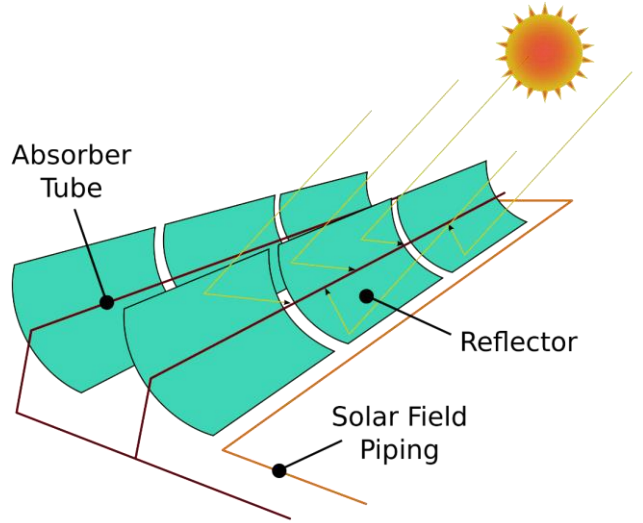
In this case, a solid wall (brick-solid, concrete, etc.) is painted in dark color facing south (northern hemisphere), equipped with glazing (single or double) with low (exterior) and high (interior) opening will allow hot air to circulate to heat the masonry during the sunshine then returned this heat in a soft way during the night or the period of an overcast sky.



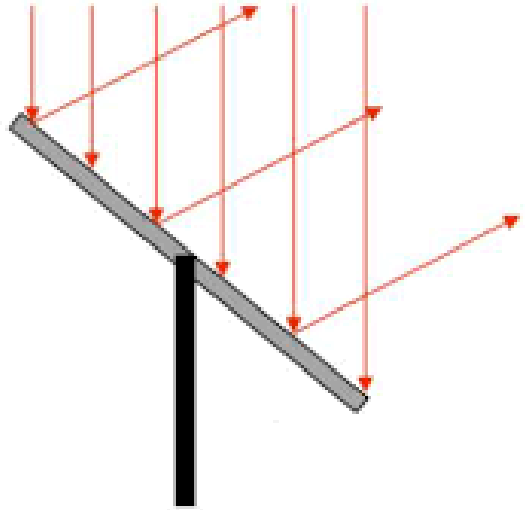
Thermal solar energy

- **Indirect thermal solar energy:**

In this case, we use the principle of geometric concentration of solar radiation, to obtain a maximum of energy power of the radiation collected on a reduced area (surface).

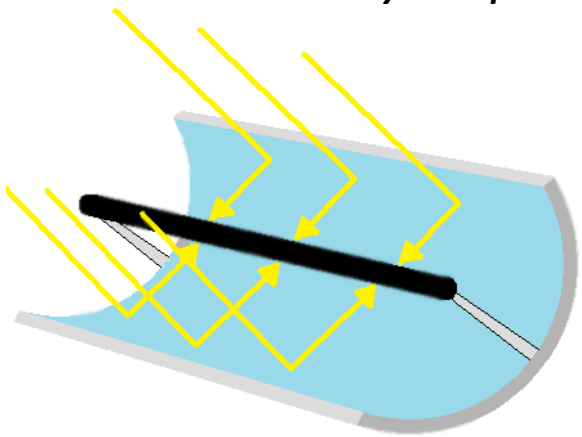


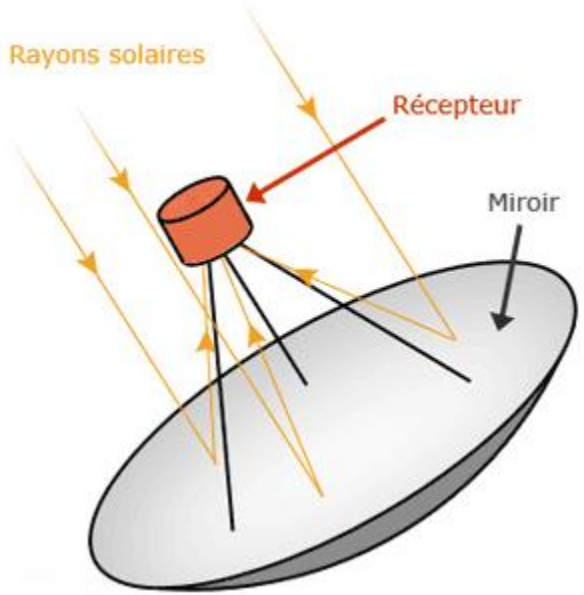
Different types of solar concentrator are used, according to their geometry and use.



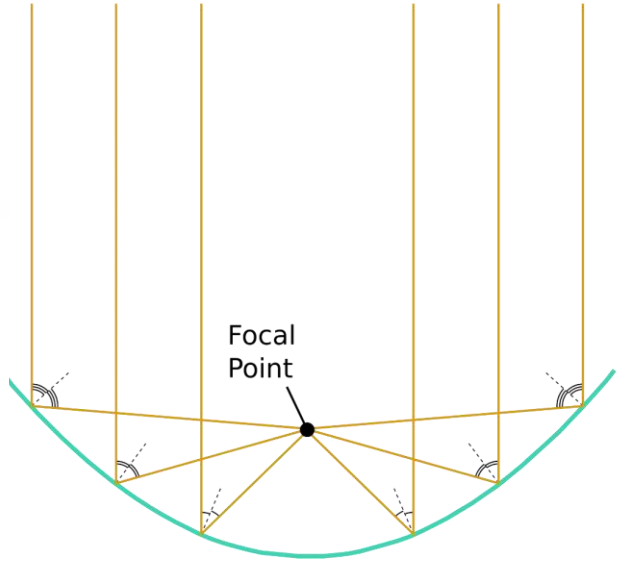
Héliostat(concentrateur plan/miroir)

Concentrateur cylindrique





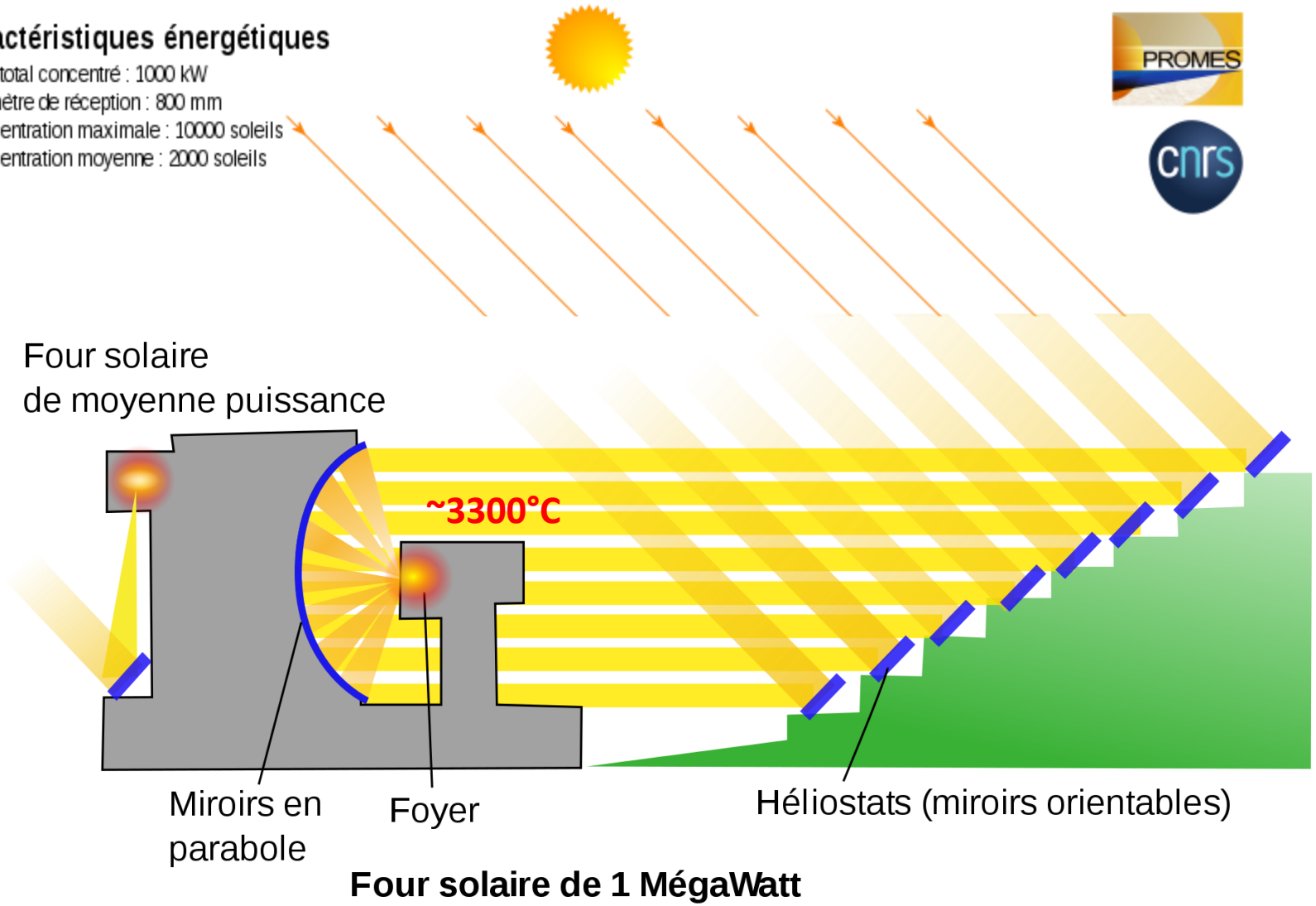
Concentrateur parabolique



Thermal solar energy

- **Indirect thermal solar energy:**

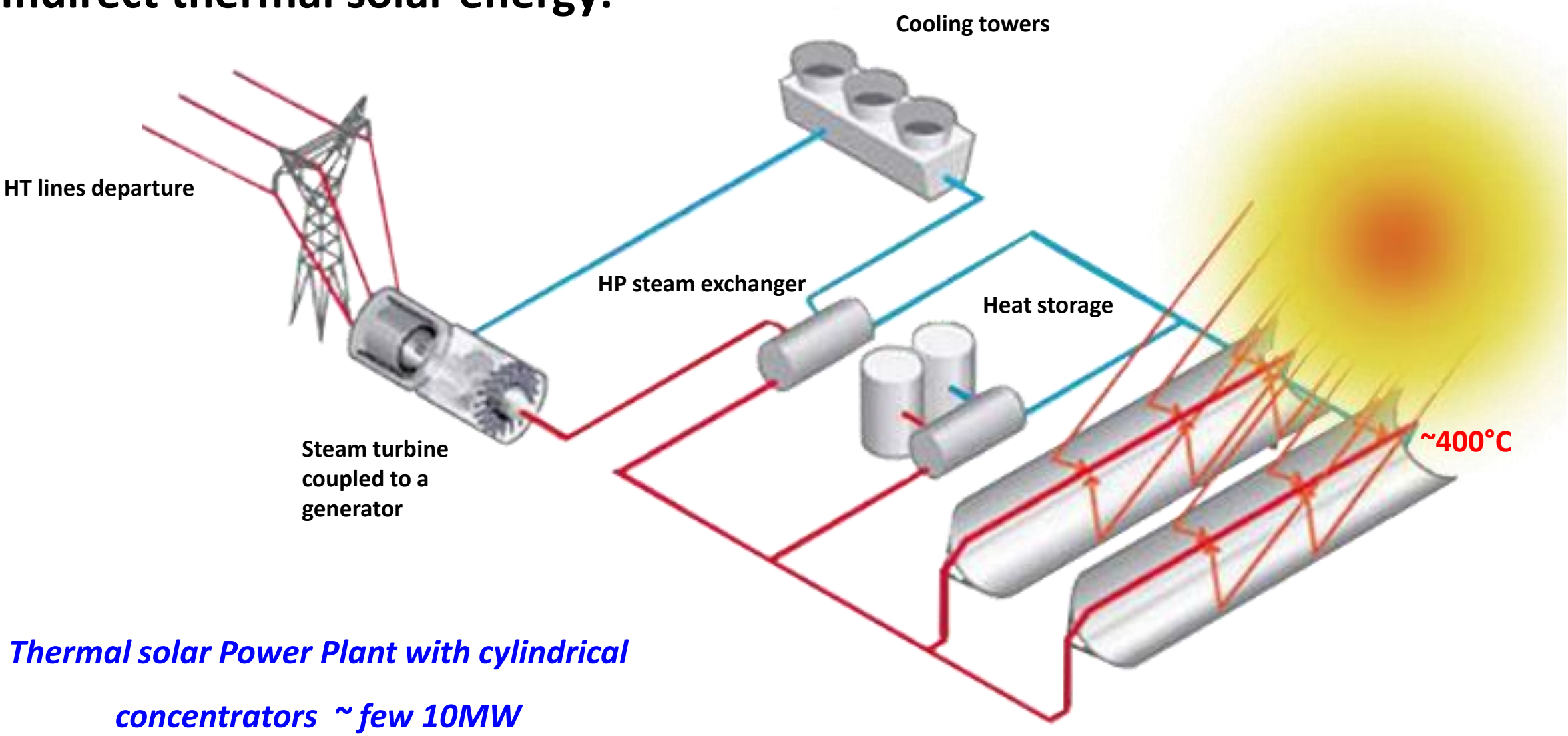
Solar oven - d'Odeillo (France)
1962-2017



Four solaire de 1 MégaWatt

Thermal solar energy

- **Indirect thermal solar energy:**

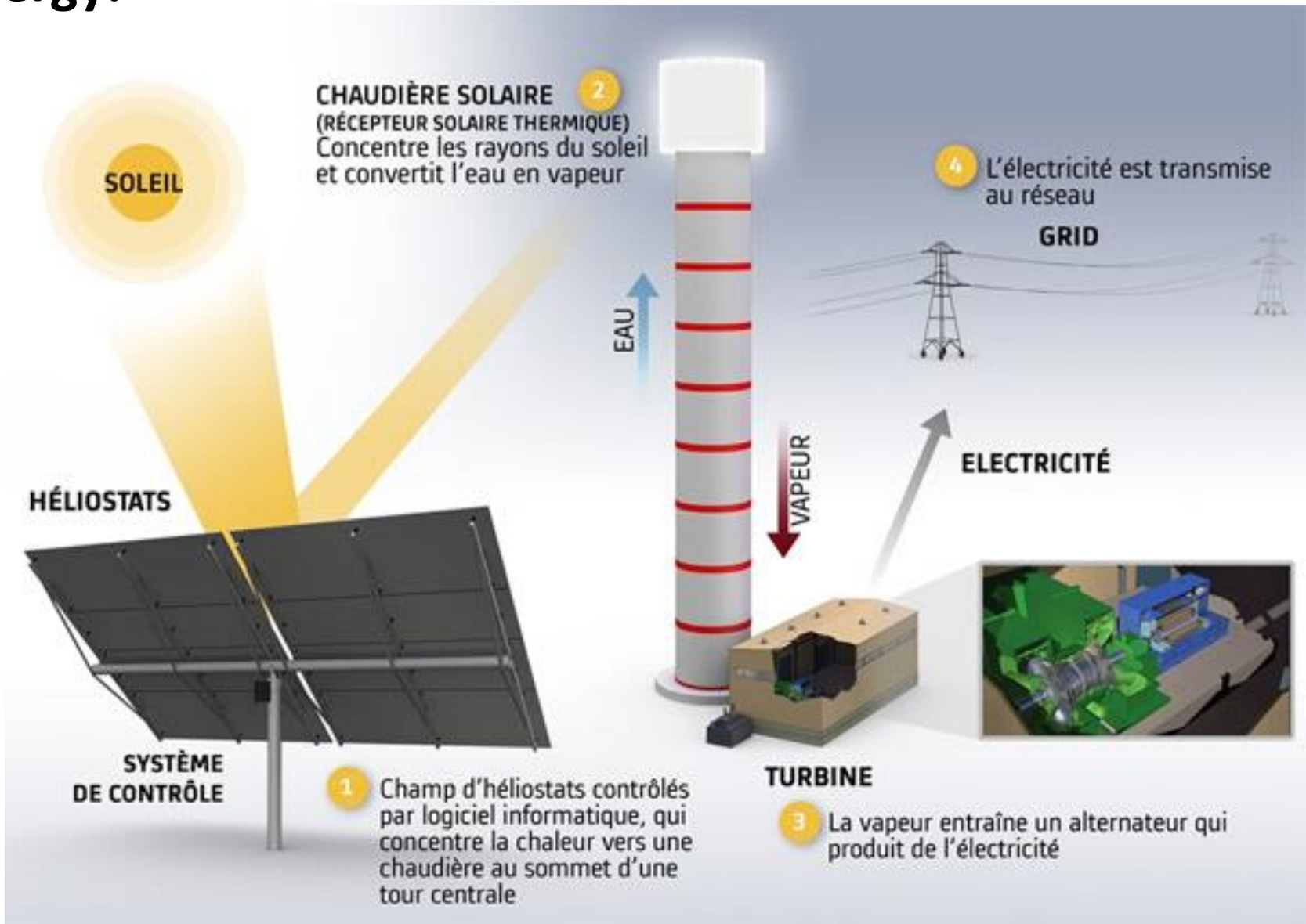


Thermal solar Power Plant with cylindrical concentrators ~ few 10MW

Thermal solar energy

- **Indirect thermal solar energy:**

Thermal Solar Power Plant with tower ~ few 100MW



Thermal solar energy

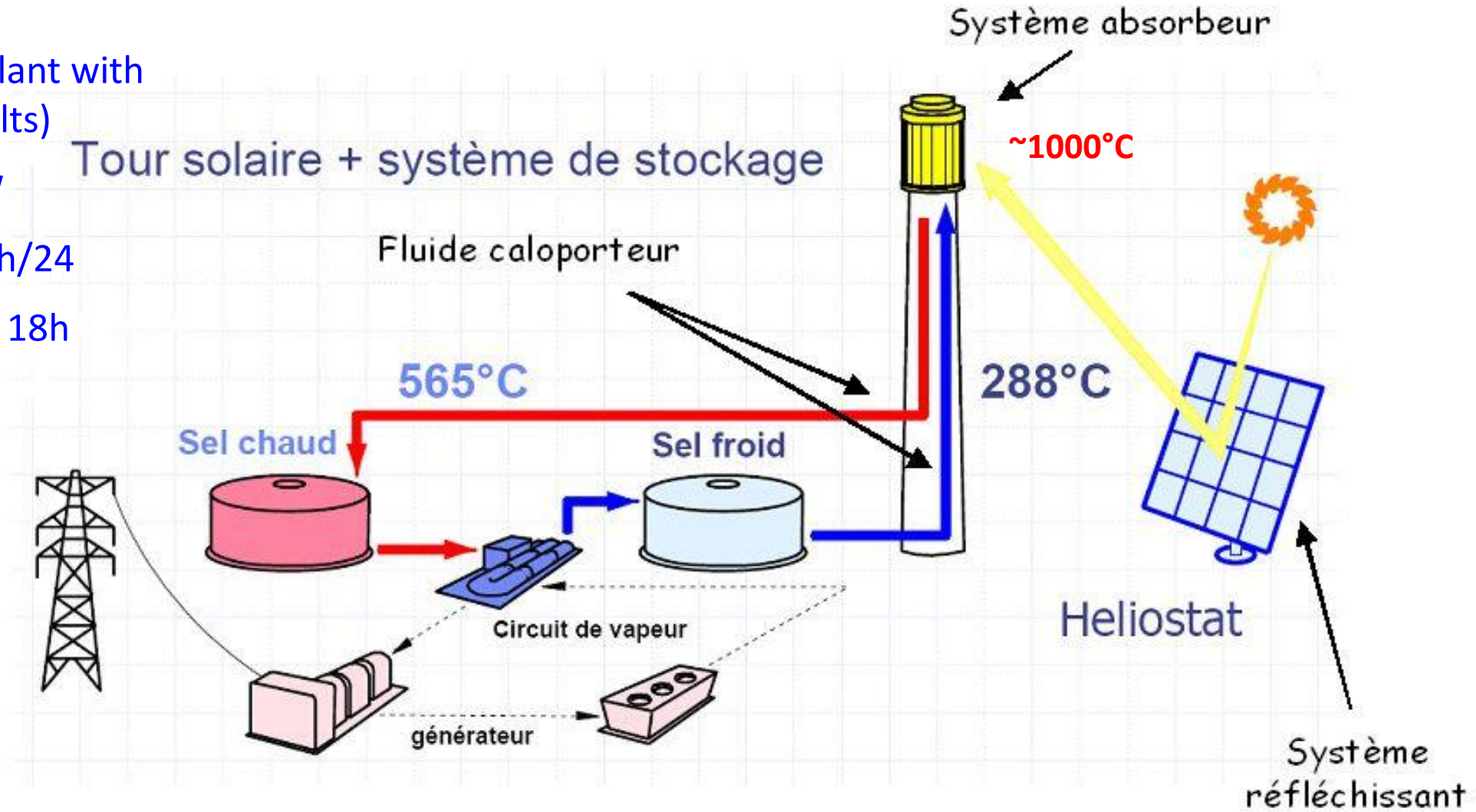
- **Indirect thermal solar energy:**

Thermal Solar Power Plant with tower (Molten salts)

~ few 100MW

Daily operation 24h/24

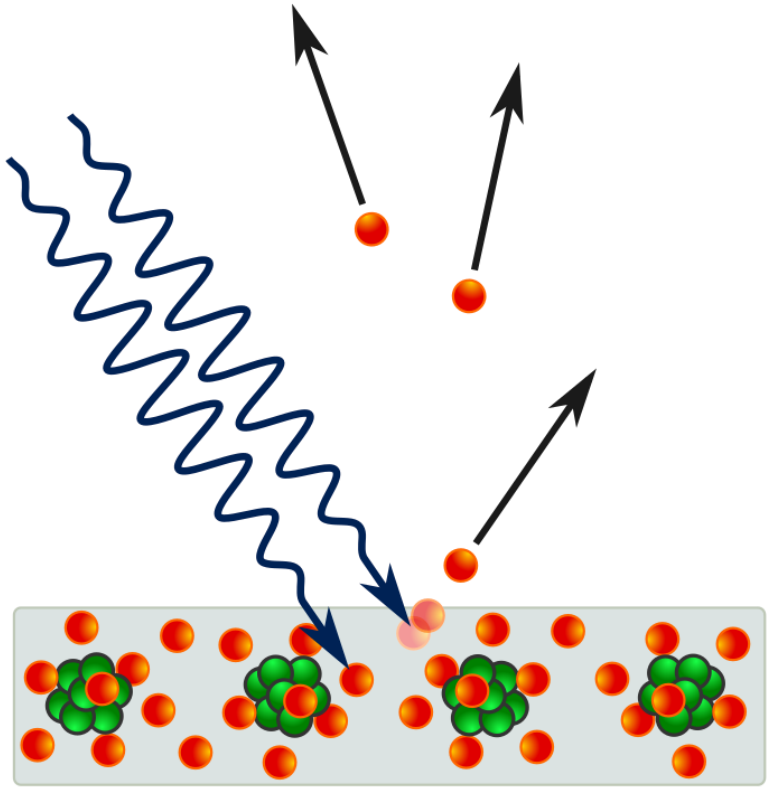
Storage capacity ~ 18h



Photovoltaic solar energy

- **Photovoltaic solar energy:**

Photovoltaic solar is based on the photo-electric effect (discovered in 1839 by Becquerel, understood in 1887 by Hertz and explained in 1905 by Einstein). It is the absorption of a photon (in the visible domain) by a weakly bound electron (conductive or semiconductor material) that will allow the latter to escape and become a conduction-free electron (electric current).



This phenomenon is reflected in Einstein's famous law on the photoelectric effect:

$$\boldsymbol{E_{ph} = h\nu = W_{ext} + T_{e-}}$$

$h = 6{,}626 \times 10^{-34} J.s$

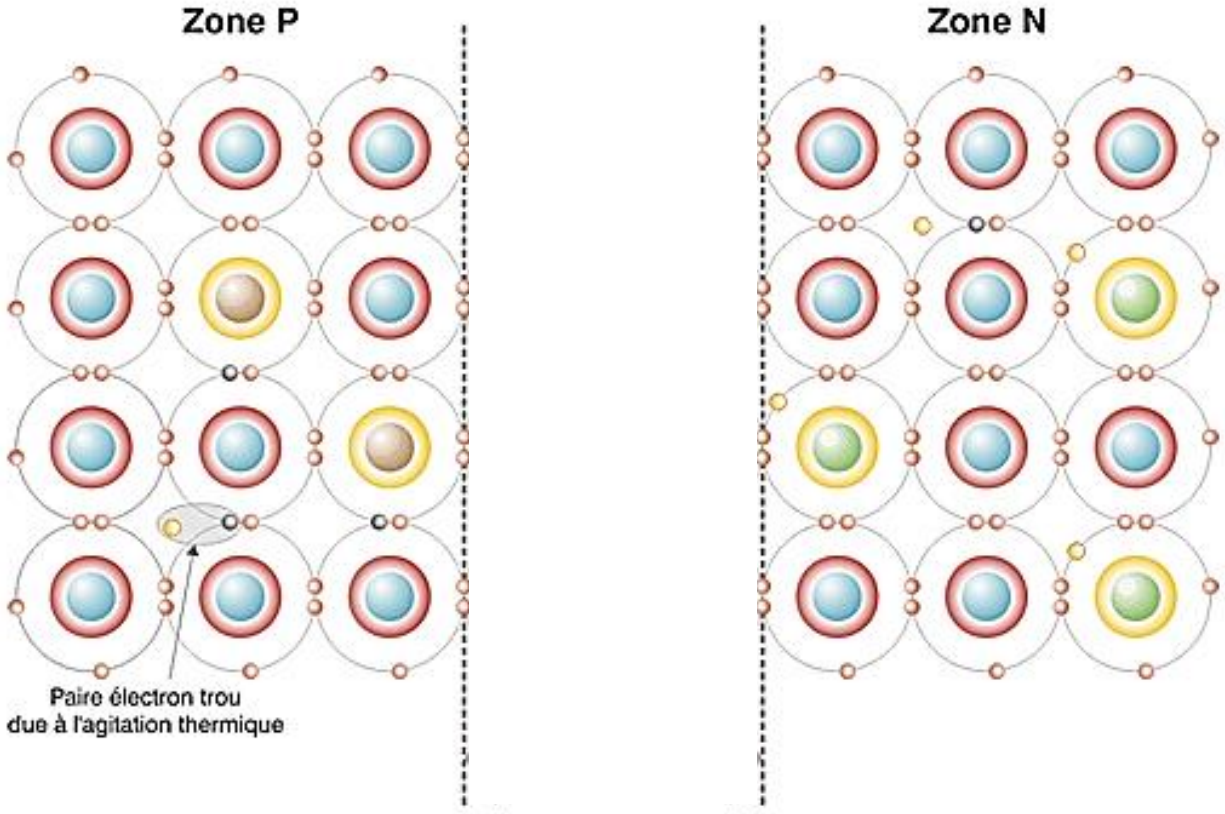
W_{ext}: Electron extraction work (binding energy) ~ few eV

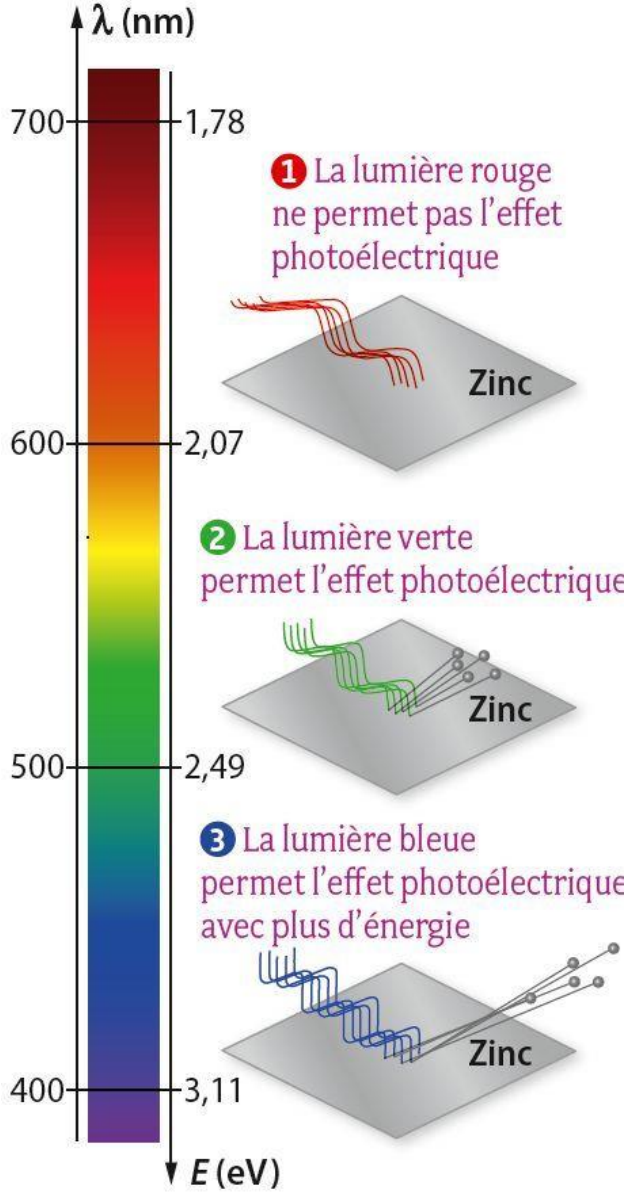
T_{e-}: kinetic energy of extracted electron

Photovoltaic solar energy

- **Photovoltaic solar energy:**

The photoelectric effect depends on the energy of the radiation and the irradiated material. For better control of the effect, semiconductor materials such as silicon are used.





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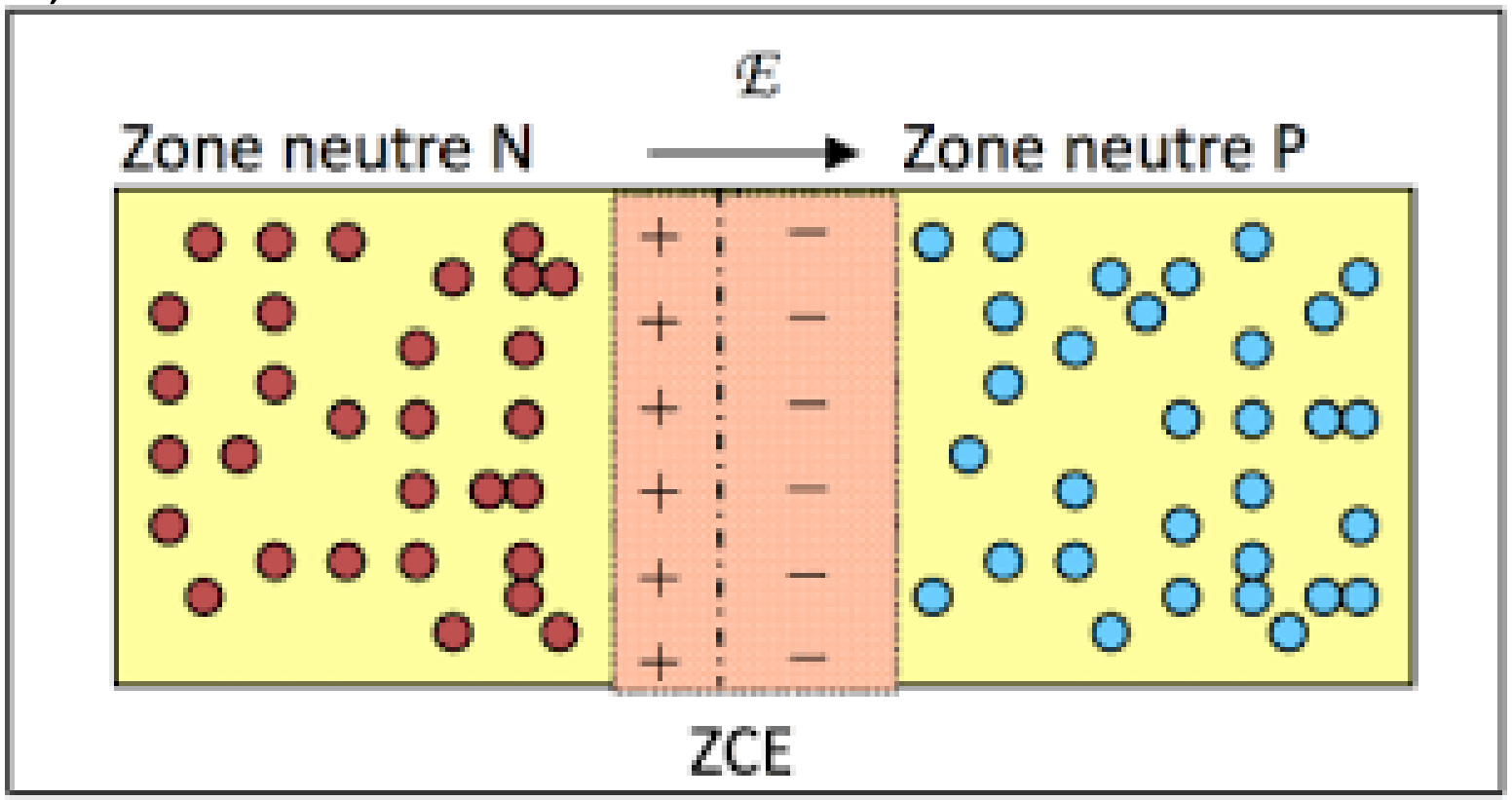
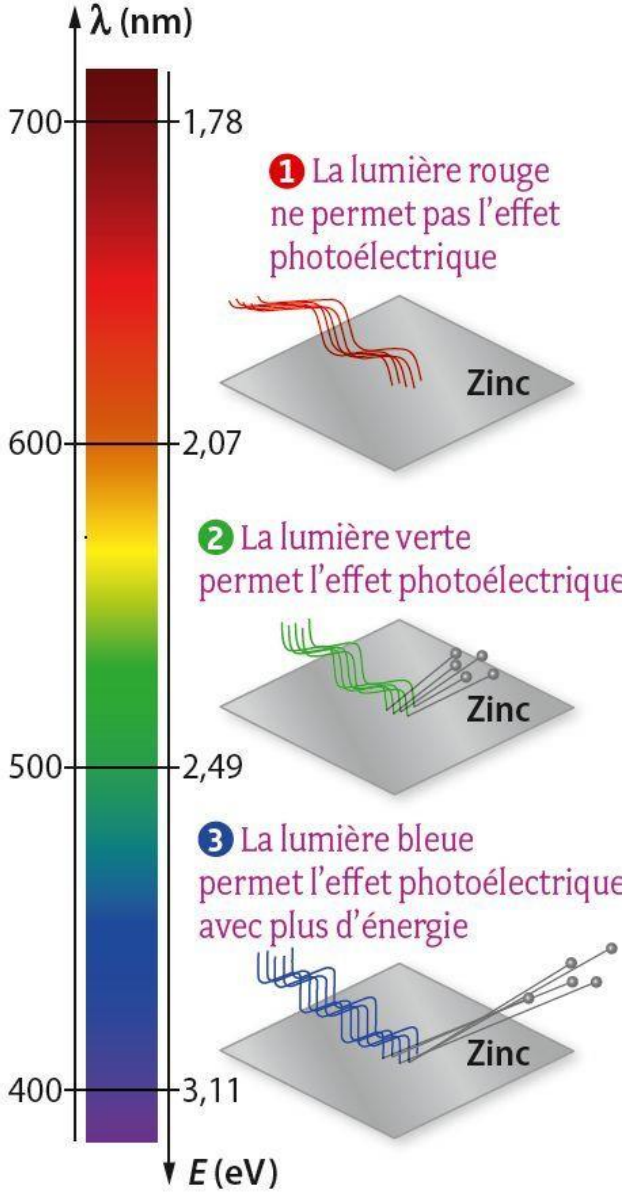


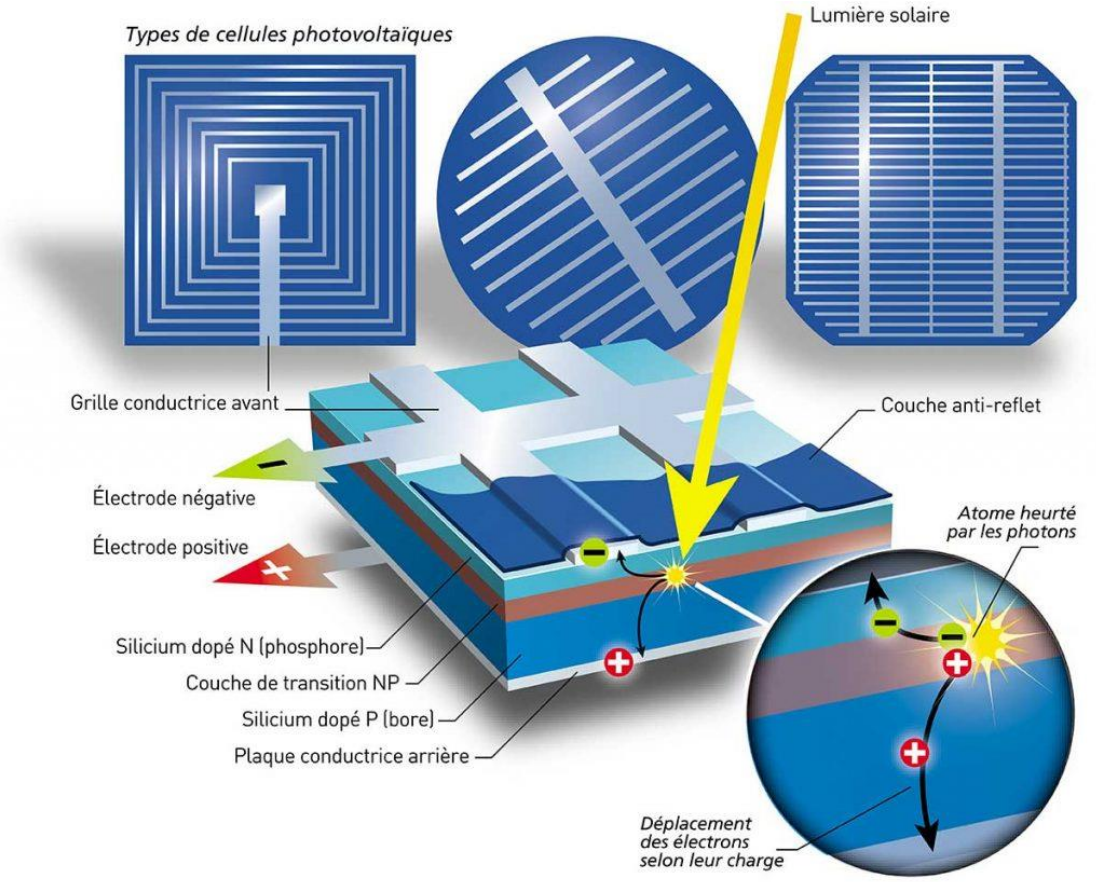


Photovoltaic solar energy

- **Photovoltaic solar energy:**

Silicon is used for its semiconductor character and its very low cost (abundance in nature: sand) to manufacture the elements of a photovoltaic cell made of a succession of semiconductor layers N-P.

The whole is covered by glazing and a coating to reduce the reflection of radiation towards the outside of the cell.



A PV cell is characterized by:

- Performance (transformation of solar energy in electric energy): $8 \leq \eta \leq 25\%$
- Produced output power in Watts per m^2

Photovoltaic solar energy

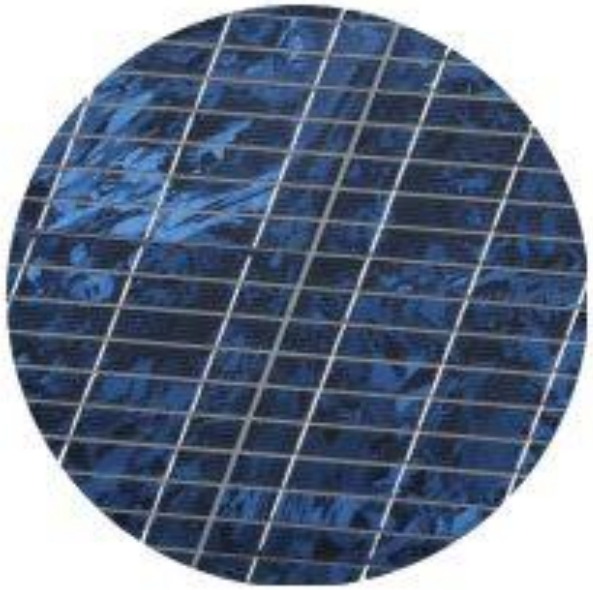
- **Photovoltaic solar energy:**

The performance of PV cells depends on the technology used in the manufacture of the main element, namely the semiconductor material (Silicon).

Two main types of relatively high performance will be noted.

Monocristallin

$\eta \sim 25\%$

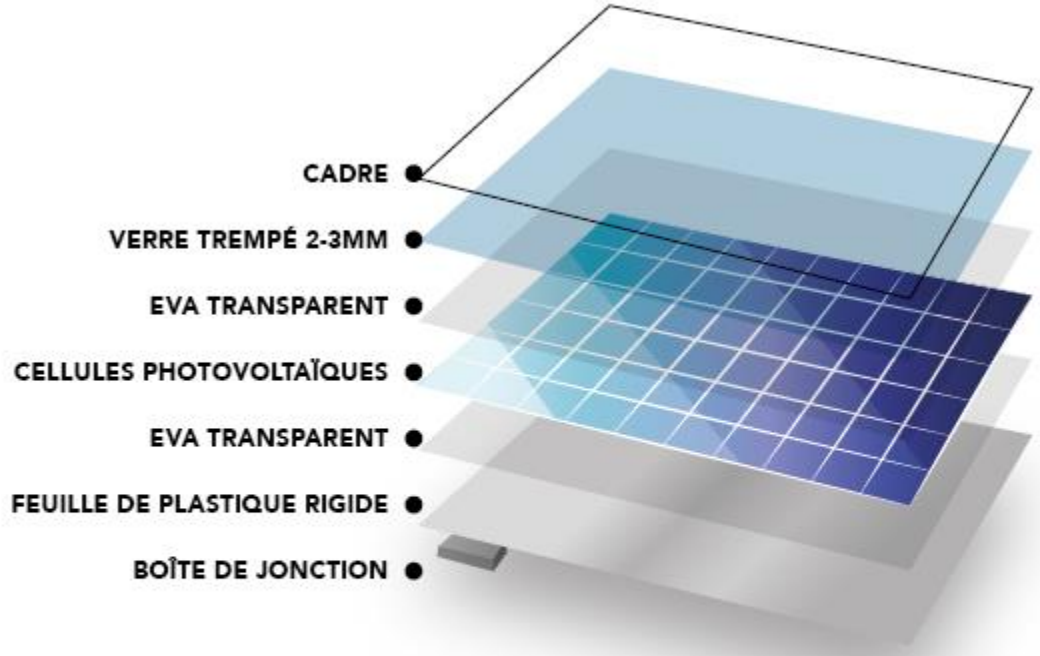


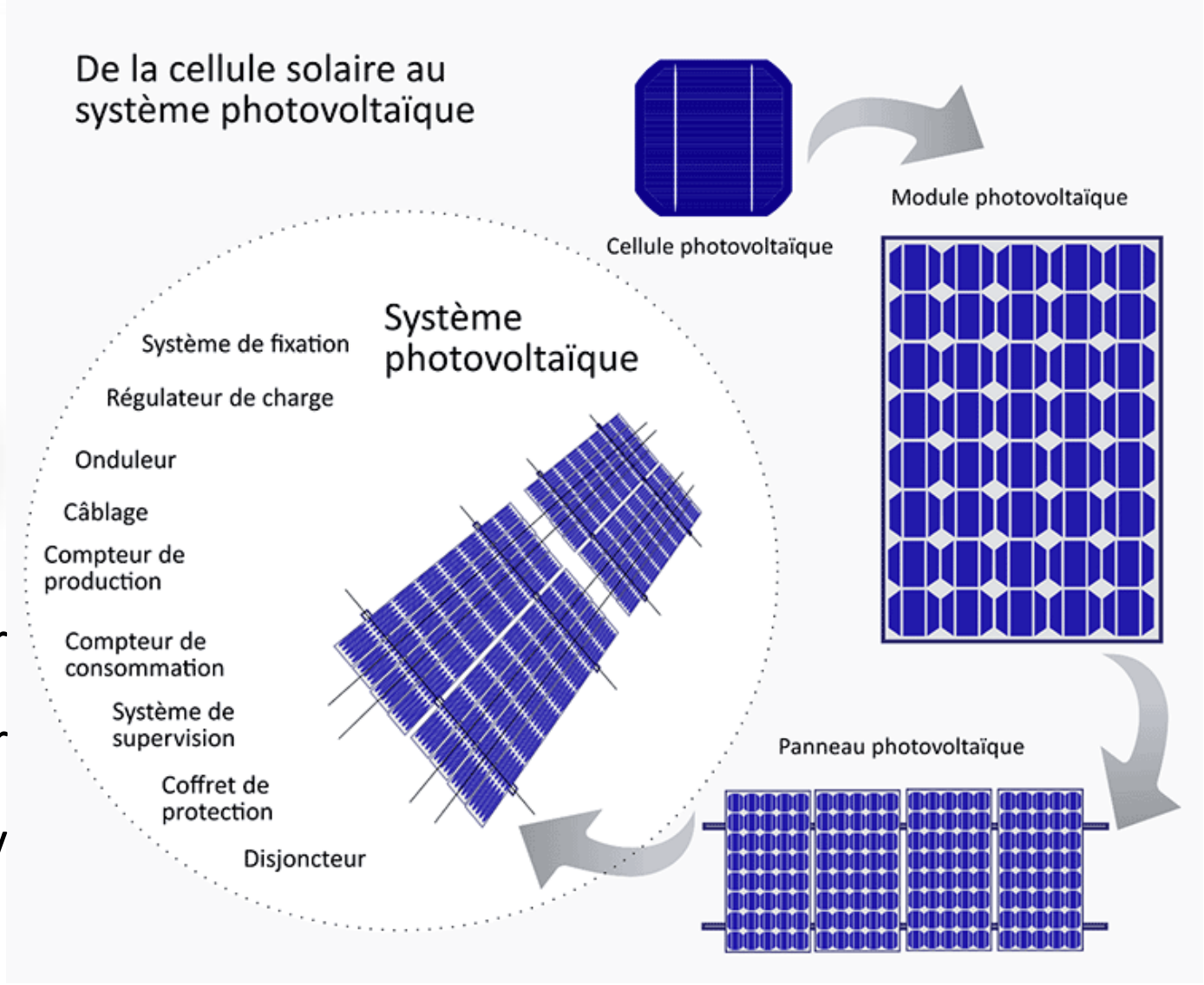
Polycristallin

$14 \leq \eta \leq 18\%$

Photovoltaic solar energy

- **Photovoltaic solar energy:**





The nominal (theoretical maximum) power of a photovoltaic panel is estimated for 1m² as a reference surface. It is usually around $200W/m^2$

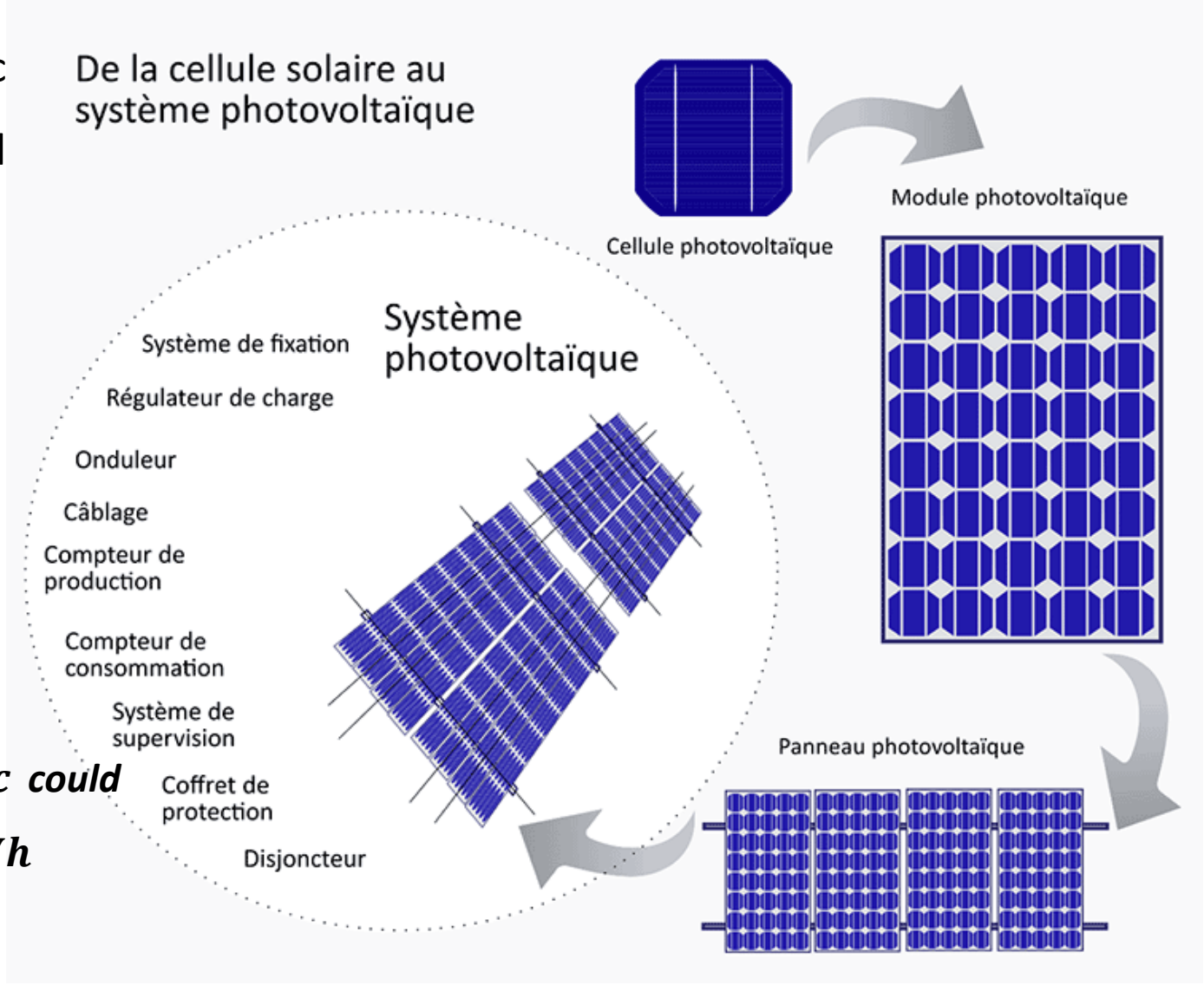
Photovoltaic solar energy

- **Photovoltaic solar energy:**

Also used is the power in Watt-peak (Wc) or kW-c which represents the maximum power obtained under laboratory conditions:

- Sunshine of $1000W/m^2$
- Ambient temperature around $25°C$
- Orientation to south (north hemisphere)
- Tilt of 30°
- Lack of shading

According to the installation zone (sunshine), $1kWc$ could produce an output power between 900 and $1400kWh$

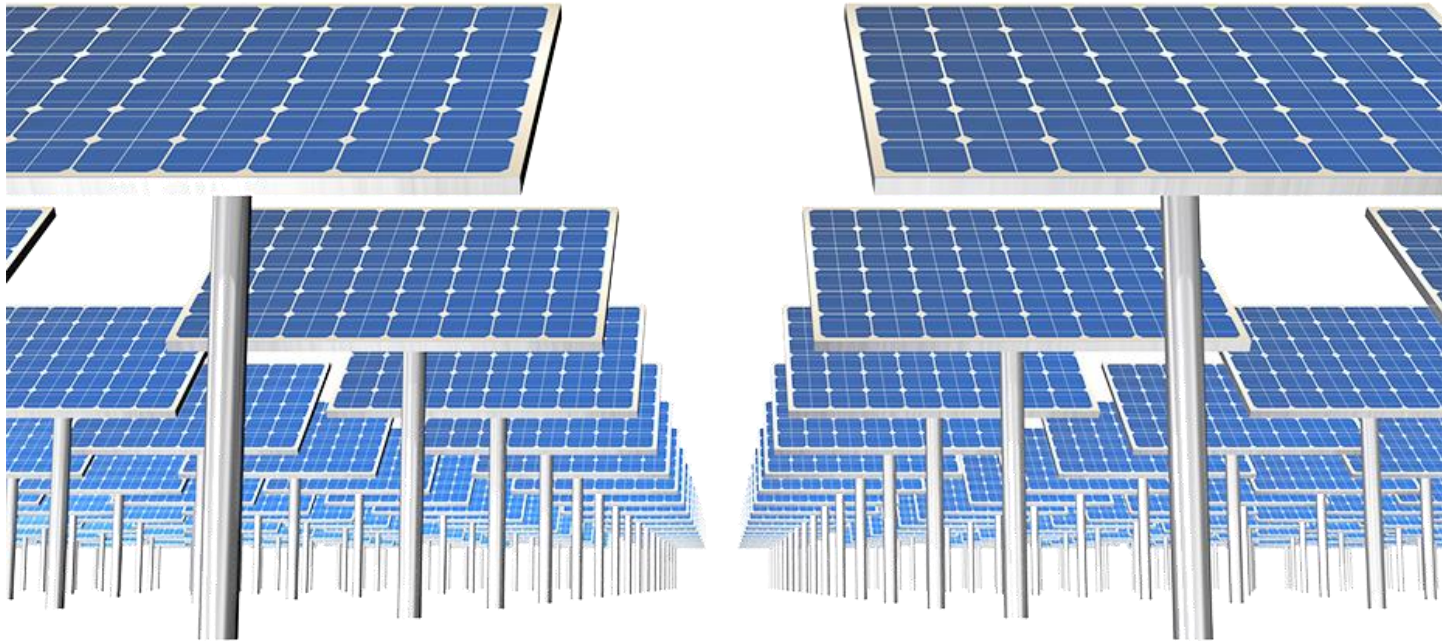


Photovoltaic solar energy

- **Photovoltaic solar energy:**

P(kWc)	Panneaux	S(m²)	Min(kWh)	Max(kWh)
3	8	15,2	2700	4200
6	16	30,5	5400	8400
9	24	45,6	8100	12600

PV Plants can produce peak power ranging from $5MWc$ $(\sim 6ha)$ to $1200MWc$ $(8km^2)$



Wind energy

It is the energy that consists in transforming the natural dynamic energy of the air (wind) into mechanics to turn an electric generator and produce renewable electric energy.

$$E_c = \frac{1}{2}mv^2 = \frac{1}{2}(Avt\rho_{air})v^2 = \frac{1}{2}At\rho_{air}v^3$$

$$P_{éol.} = \frac{E_c}{t} = \frac{1}{2}A\rho_{air}v^3$$

A: *Area of the sufrace striked by wind*

t: *the time during which the wind act on the surface A*

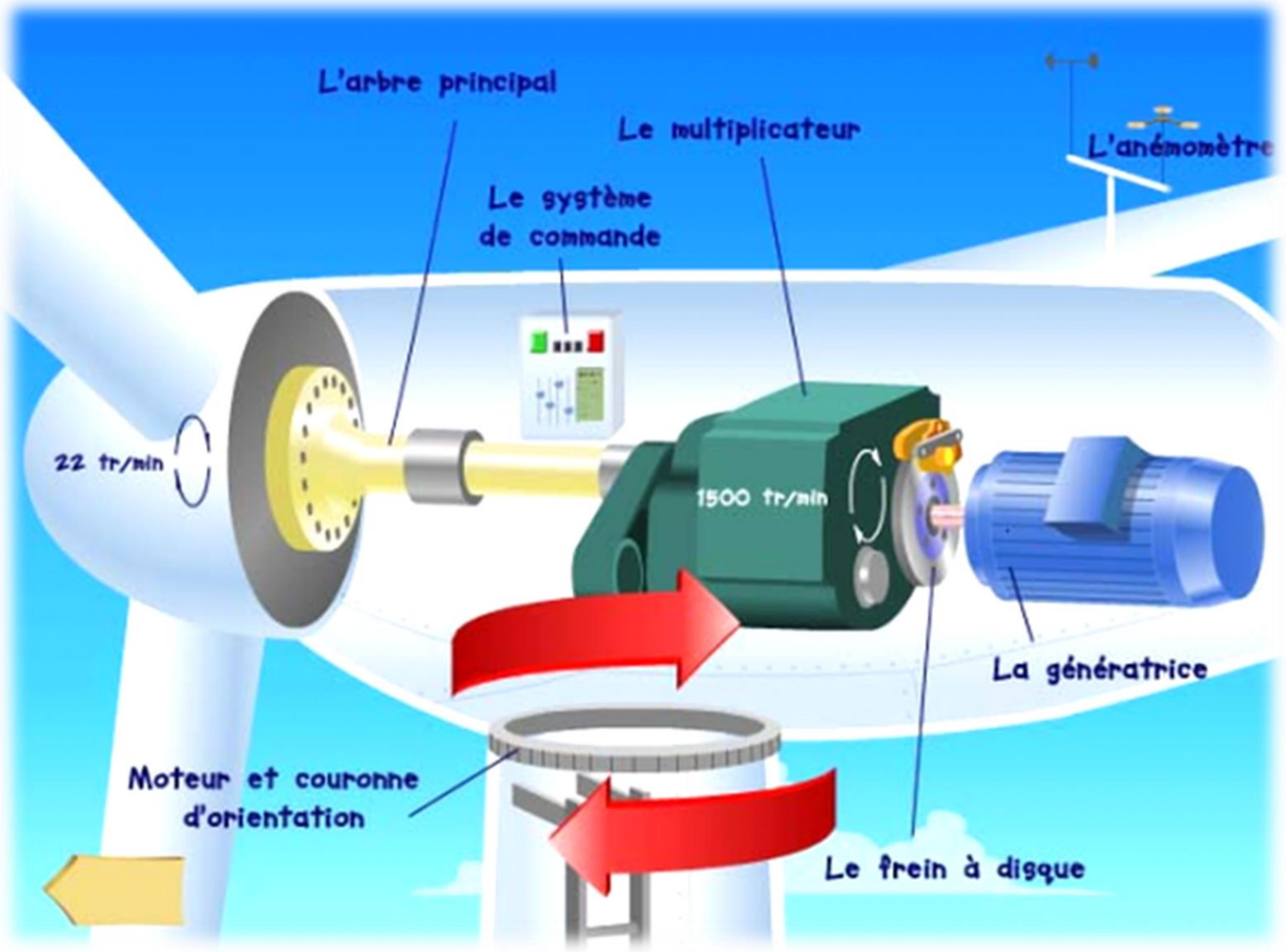
ρ_{air}: *Air density*

v: *wind speed*

Wind energy

The principle of operation of a wind turbine is to make the most of the wind force (azimuth orientation) to produce electrical energy via a generator installed in the body of the wind turbine lifted at an optimal height.

A speed multiplier (mechanical) is also used to regulate the rotation of the electric generator.



Wind energy

Middle to large wind turbine
$P \sim 36kW - 2MW$
$36 \leq h \leq 120m$

Domestic wind turbine
$P \sim 0,1 - 36kW$
$h \leq 36m$

But !!!

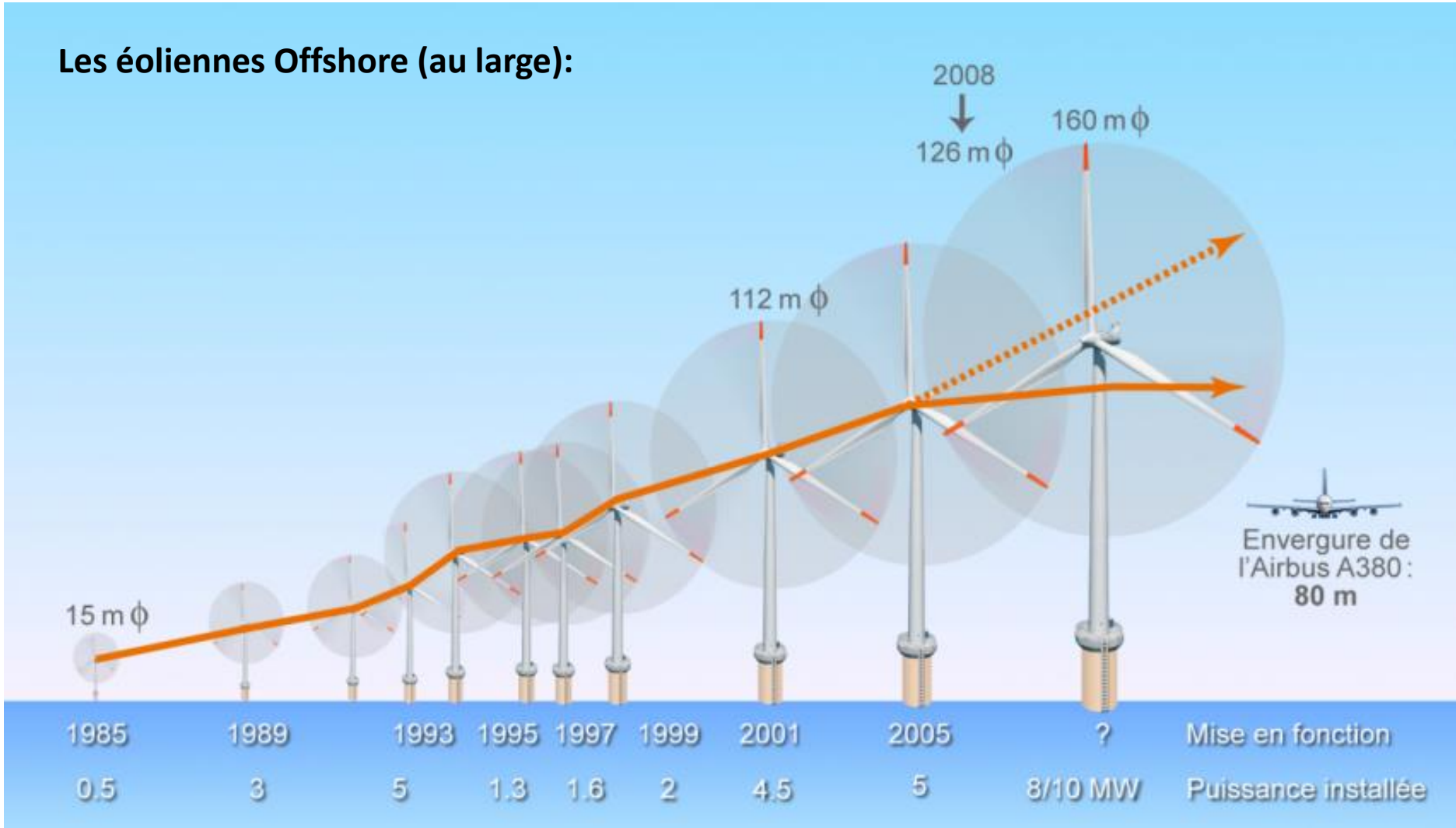
Wind energy

The major problem of wind turbines and that their production is intermittent, because of the random nature of weather conditions.

For this reason, it is often necessary to install the wind turbines with a second regular (conventional) energy source or provide an energy storage system to prevent periods of low ventilation.

Wind energy

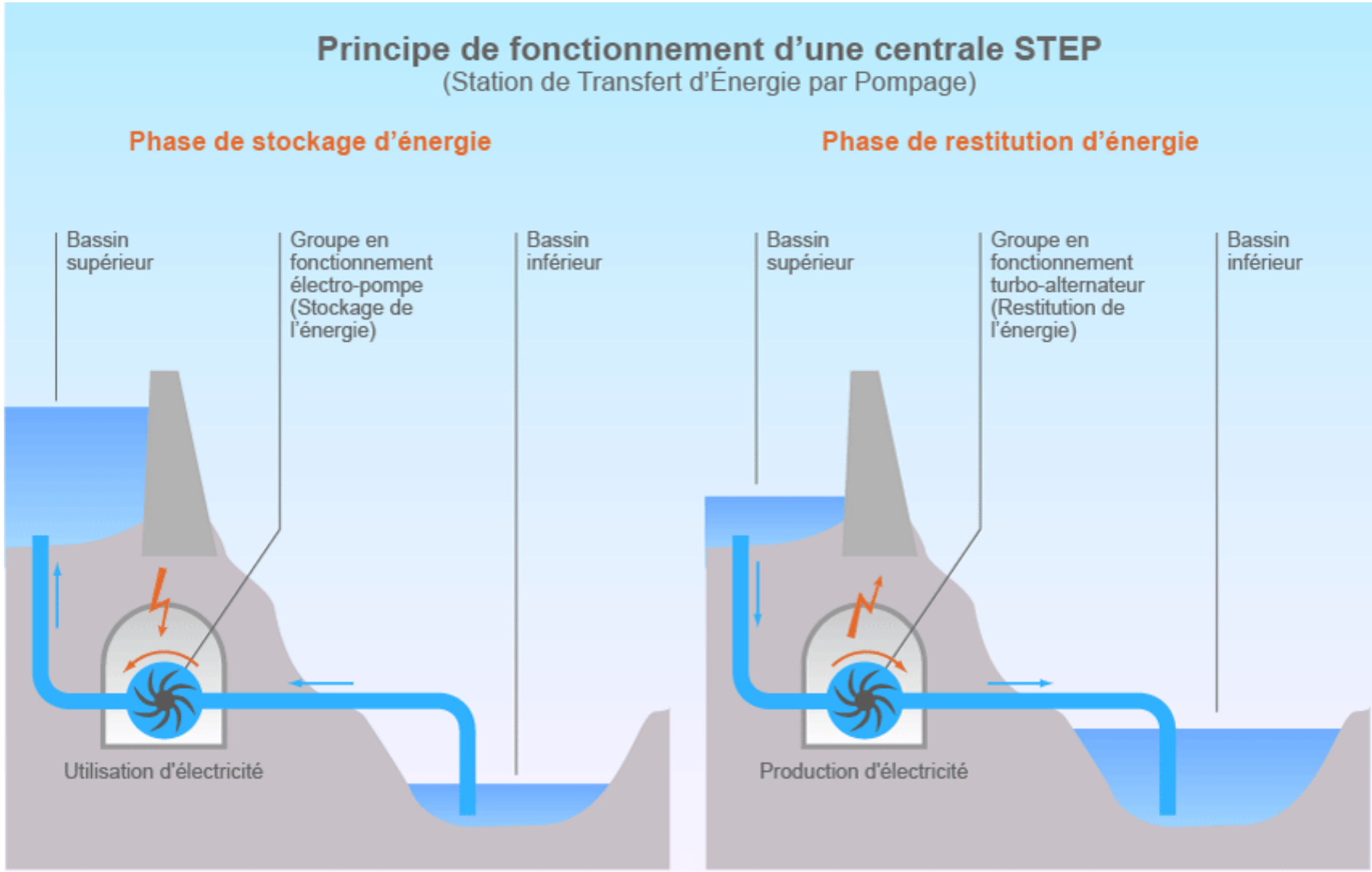
- Built at sea
- More than 10km from the coast
- A more regular and powerful wind
- More power than on the ground
- Connected via a submarine cable
- Production : wind $\geq 10km/h$



Wind energy

Energy storage of wind turbines

Storage by pumping and turbinage, which consists of using the surplus of electricity production to pump water from a lower basin to a higher basin (potential energy), then use it for turbinage during the period of low production of wind turbines, as a hydro-electric energy

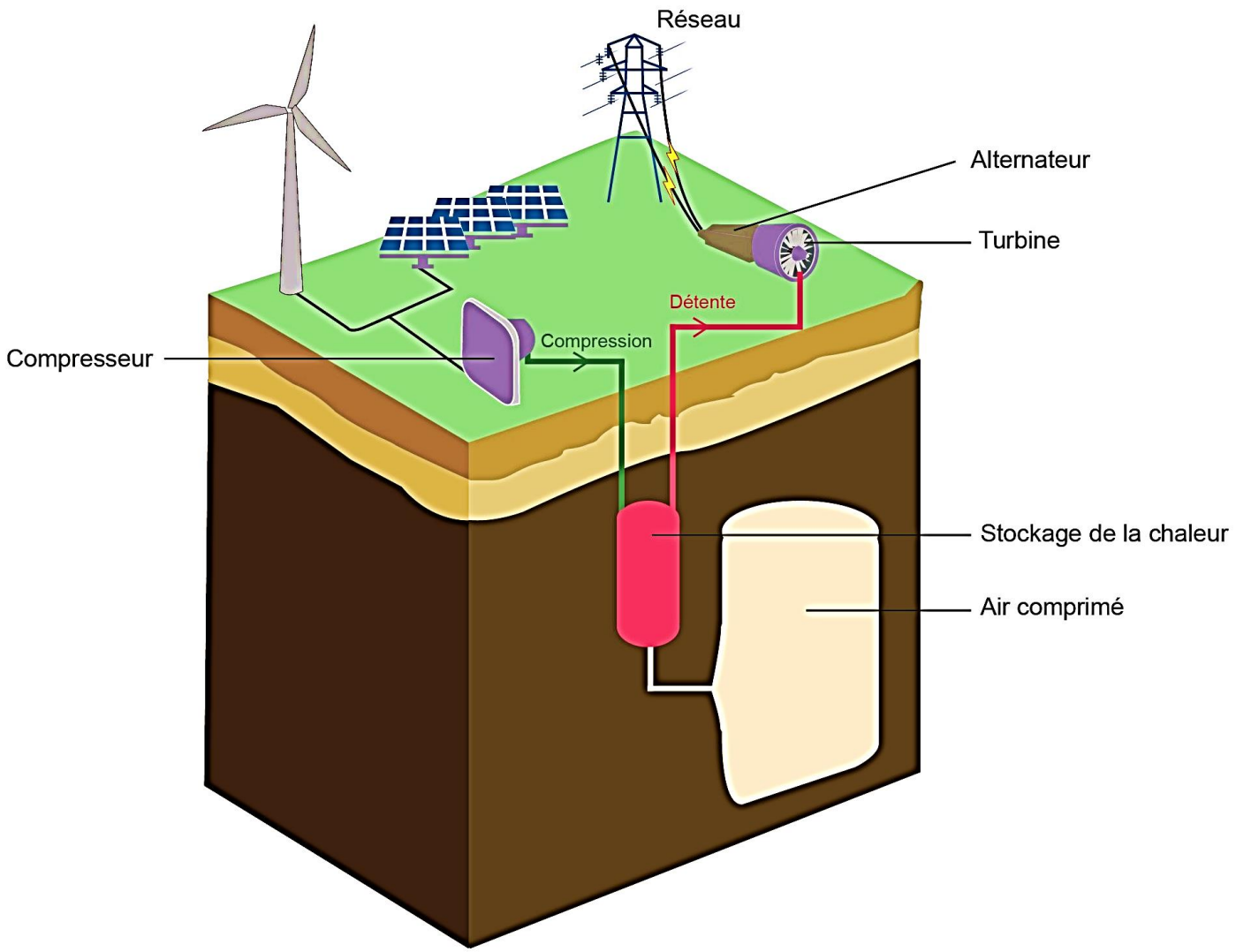


Wind energy

Energy storage of wind turbines

Compressed air storage, which consists of using excess electricity production to compress air in geological or artificial cavities at very high pressure, this pressure will be restored in dynamic flow during the period of low production of wind turbines, applied on steam/gas turbines

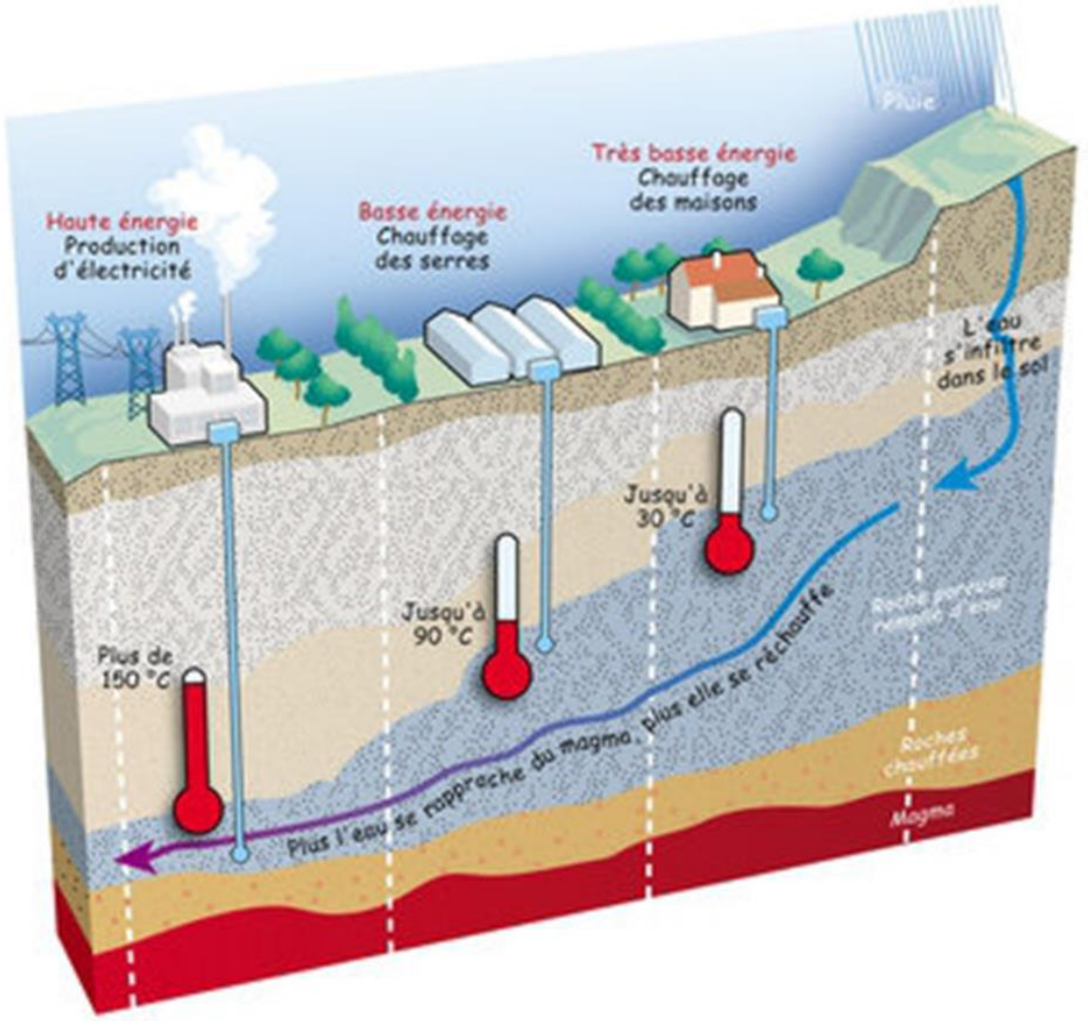
Compressed air storage



Geothermal energy

The heat stored in the subsoil (Enthalpie) of planet Earth is estimated around $10^{31}\ joules$. This heat naturally migrates to the surface by conduction at a flow rate of $44{,}2\ TW$. Much of this heat is produced by the energy deposited from radioactive decay radiation (U, K, Th, …) at the level of $30\ TW$.

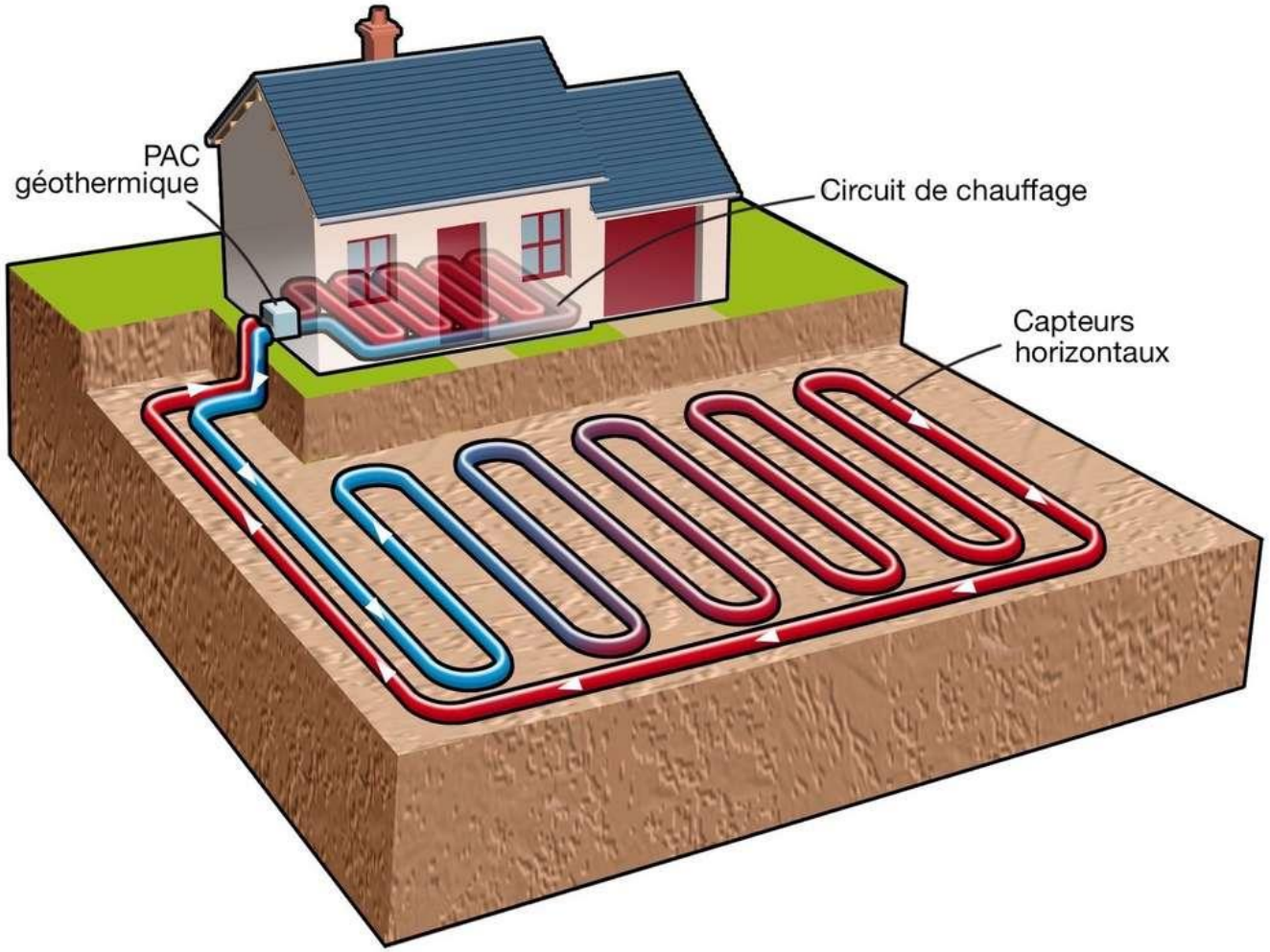
Most of this heat is diffuse and represents a low heat flux $\sim 0{,}1 \mathrm{W/m^2}$, with a thermal gradient between 25 and 30 $°C/km$ (Away from hot springs and tectonic limits)



Geothermal energy

For special purposes (mainly heating) a horizontal geothermal network is installed at a depth of about 1m. A small power heat pump (PAC) is required in this case.

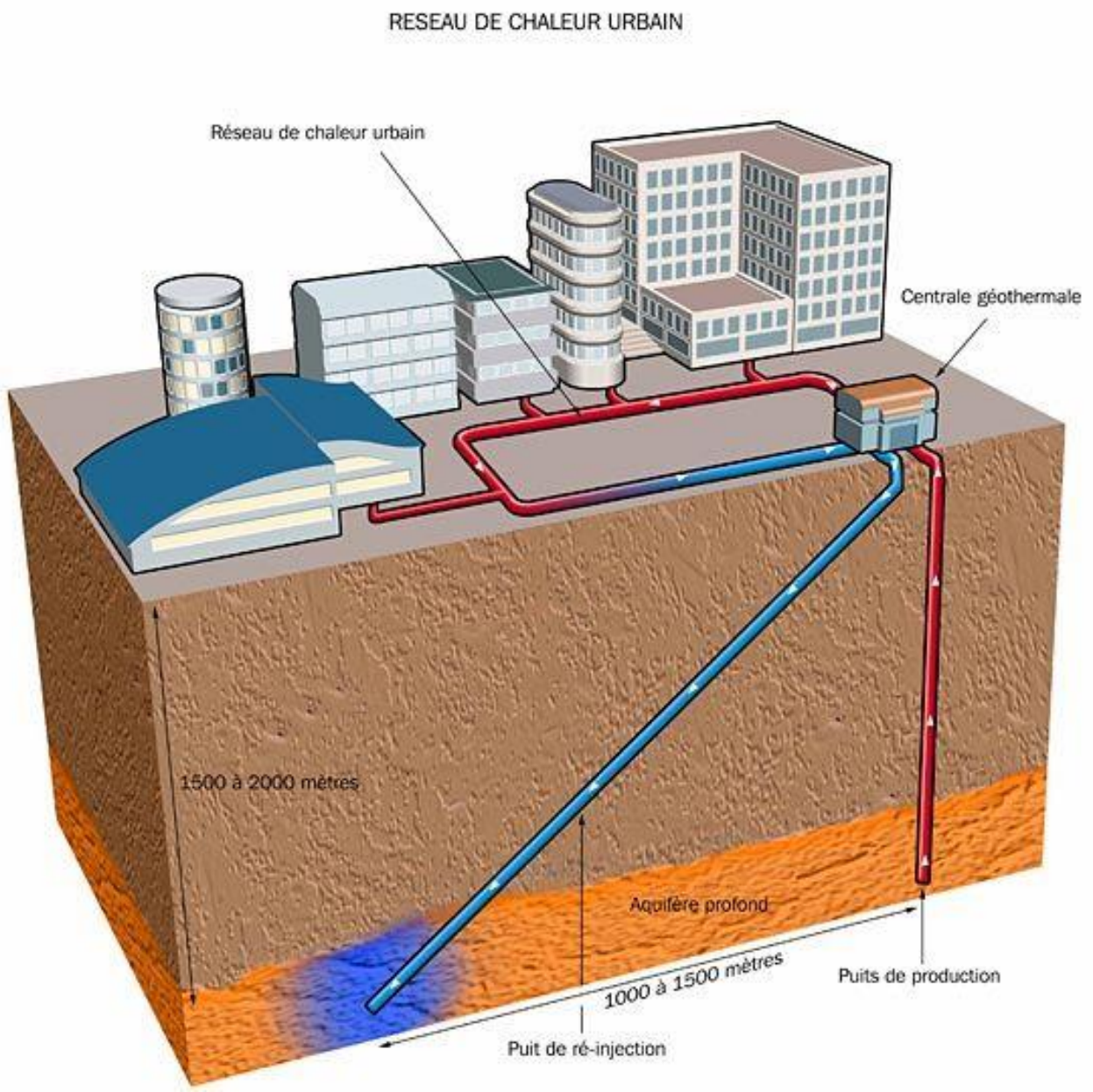
It thus makes it possible to exploit the thermal gradient from the deep subsoil to maintain a constant ambient temperature in private localities (around 18°)



Geothermal energy

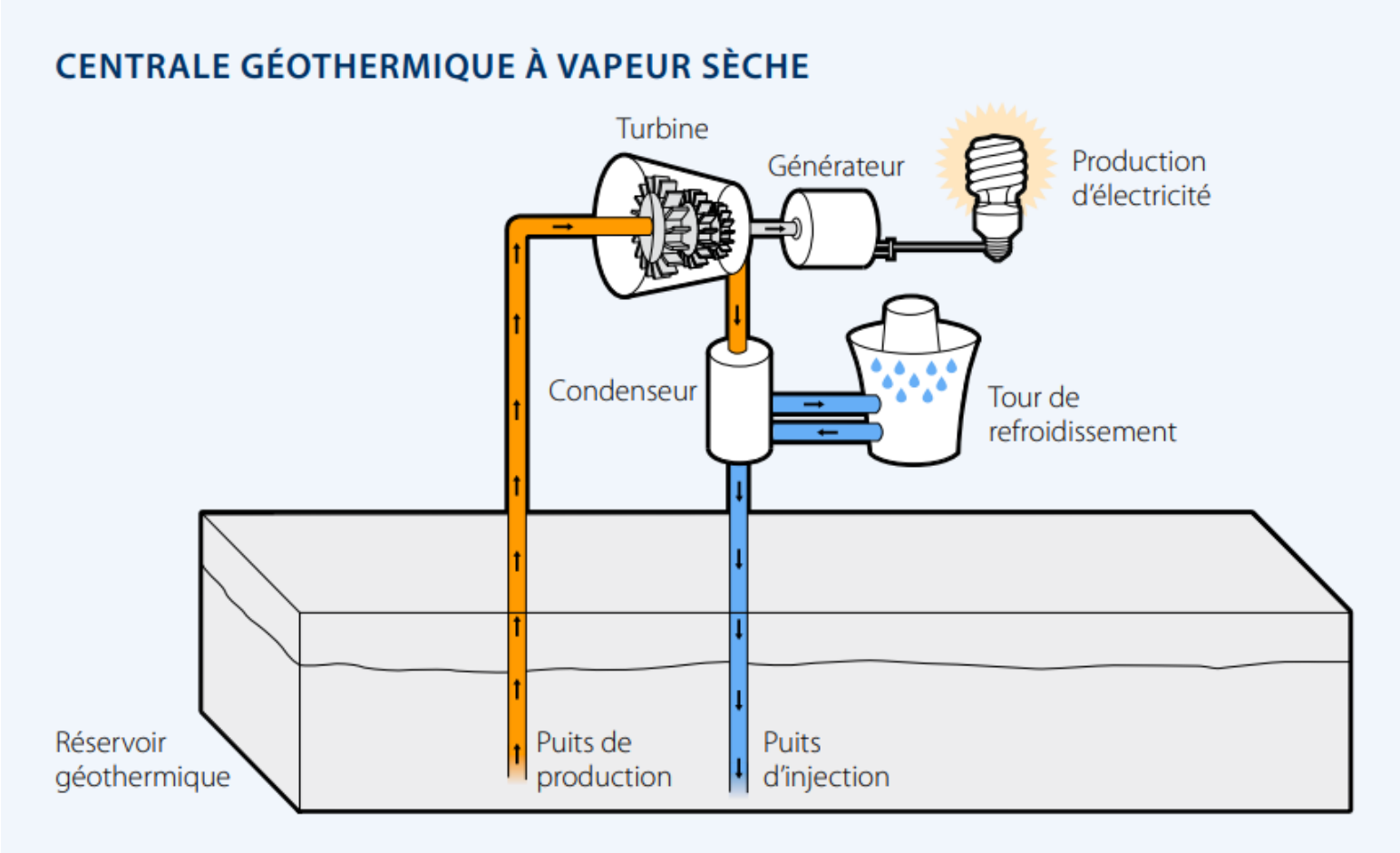
For greater use, it is possible to install a vertical geothermal network at a depth of about 100m. In this case, a geothermal power plant of medium to large power is needed.

In this case it is possible to provide heating for a set of premises (administrative, buildings, common structures)



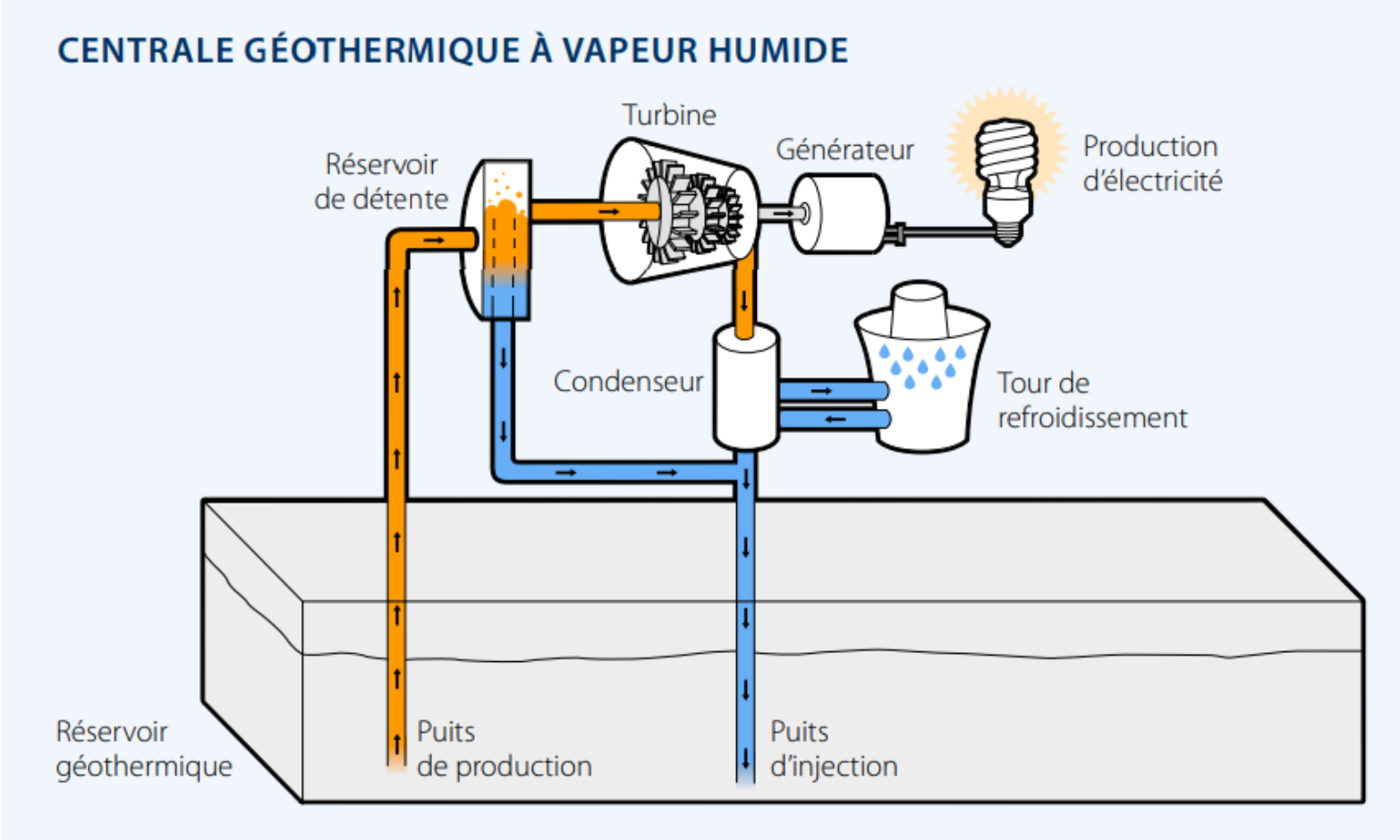
Geothermal energy

The geothermal fluid is pressurized and superheated dry steam at a temperature ranging from 180°C to more than 350°C. It rotates the turbine of a plant operating according to the Rankine cycle, while the resulting cooled water is injected into the geothermal reservoir.



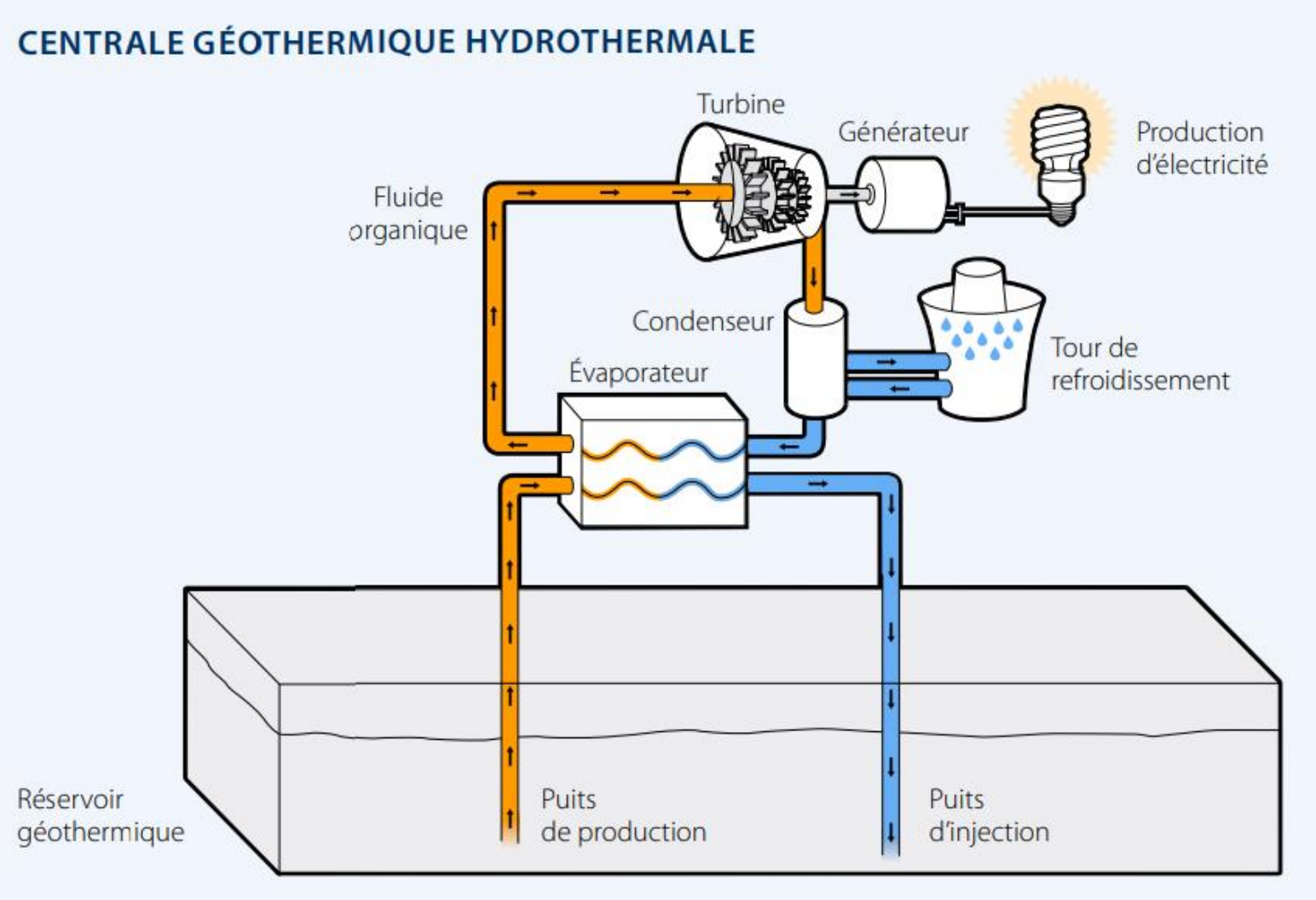
Geothermal energy

The geothermal fluid is in the form of wet steam (mixture of water and steam) pressurized at a temperature greater than 180°C. Dry saturated steam, separated from wet steam in one or two expansion tanks, rotates the turbine of a plant operating according to the Rankine cycle. The resulting cooled water is injected into the geothermal reservoir. It is a single or double expansion geothermal plant.



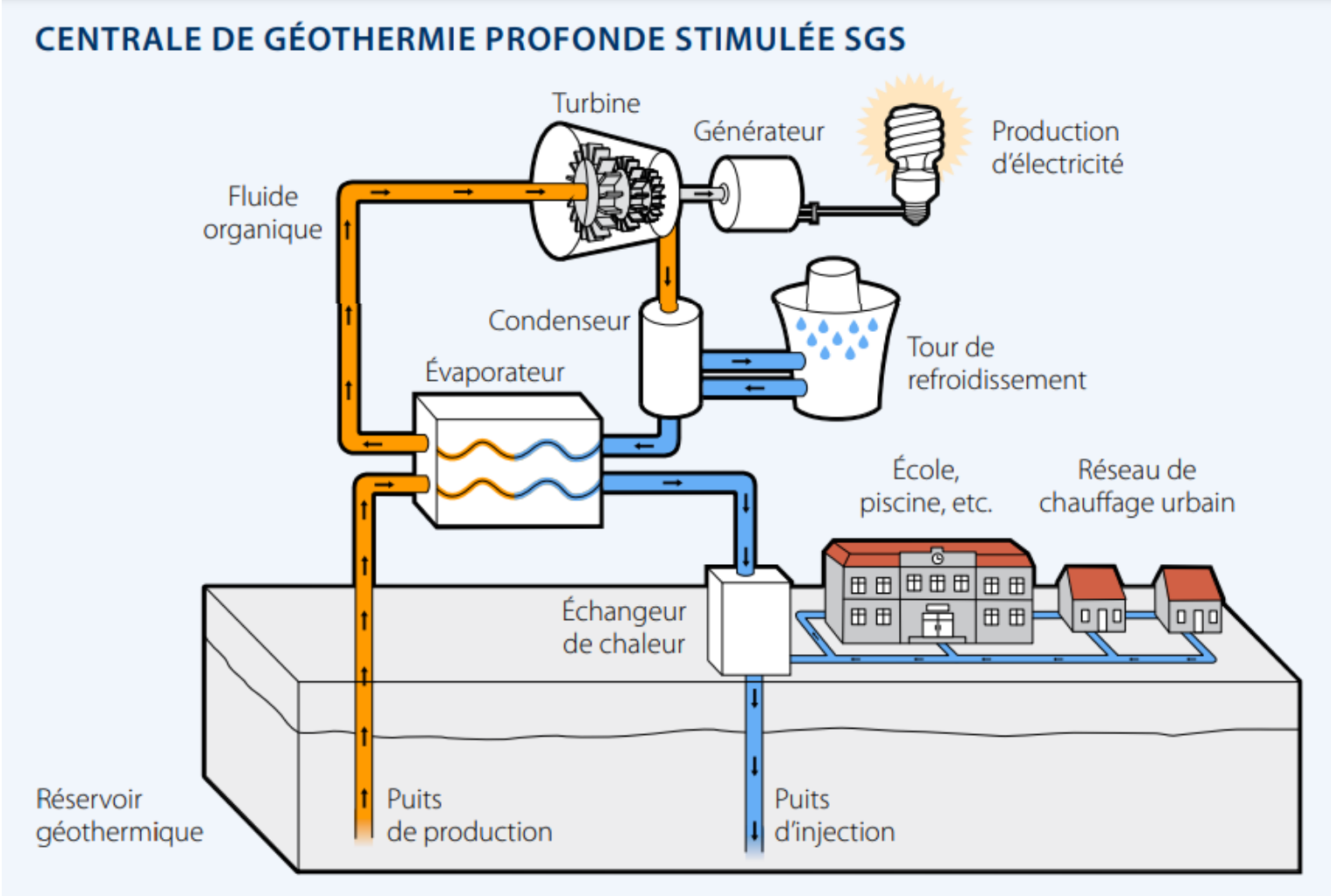
Geothermal energy

The geothermal fluid comes in the form of pressurized hot water at a temperature of 125 to 180°C. To efficiently convert the heat recovered at this temperature level into electricity, the geothermal plant must be a binary cycle.



Geothermal energy

The geothermal fluid is a liquid heated in contact with hot rocks above 150°C. To access the thermal energy of hot rocks, hydraulic fracturing is required. create cracks in the rock by injecting water under high pressure to allow the fluid to flow through the geothermal reservoir. Part of the geothermal fluid could be used as a heat source in geothermal district or industrial heating systems.



Geothermal energy

Pays	Production (TWh)	Part prod. mondiale	Part prod. élec.du pays
	2019		
États-Unis	18,36	20,2 %	0,42 %
Indonésie	14,10	15,5 %	4,8 %
Philippines	10,69	11,7 %	10,1 %
Turquie	8,95	9,8 %	2,9 %
Nouvelle-Zélande	8,04	8,8 %	17,9 %
Italie	6,07	6,7 %	2,1 %
Islande	6,02	6,6 %	30,9 %
Mexique	5,35	5,9 %	1,6 %
Kenya	4,88	5,4 %	45,5 %
Japon	2,83	3,1 %	0,27 %
Costa Rica	1,51	1,7 %	13,2 %
Salvador	1,47	1,6 %	24,3 %
Nicaragua	0,78	0,9 %	17,0 %
Russie	0,43	0,5 %	0,04 %
Guatemala	0,31	0,3 %	2,3 %
Honduras	0,30	0,3 %	2,8 %
Chili	0,20	0,2 %	0,2 %
Allemagne	0,20	0,2 %	0,03 %
France	0,13	0,14 %	0,02 %
Chine	0,12	0,14 %	0,002 %
Total mondial	**91,09**	**100 %**	**0,34 %**

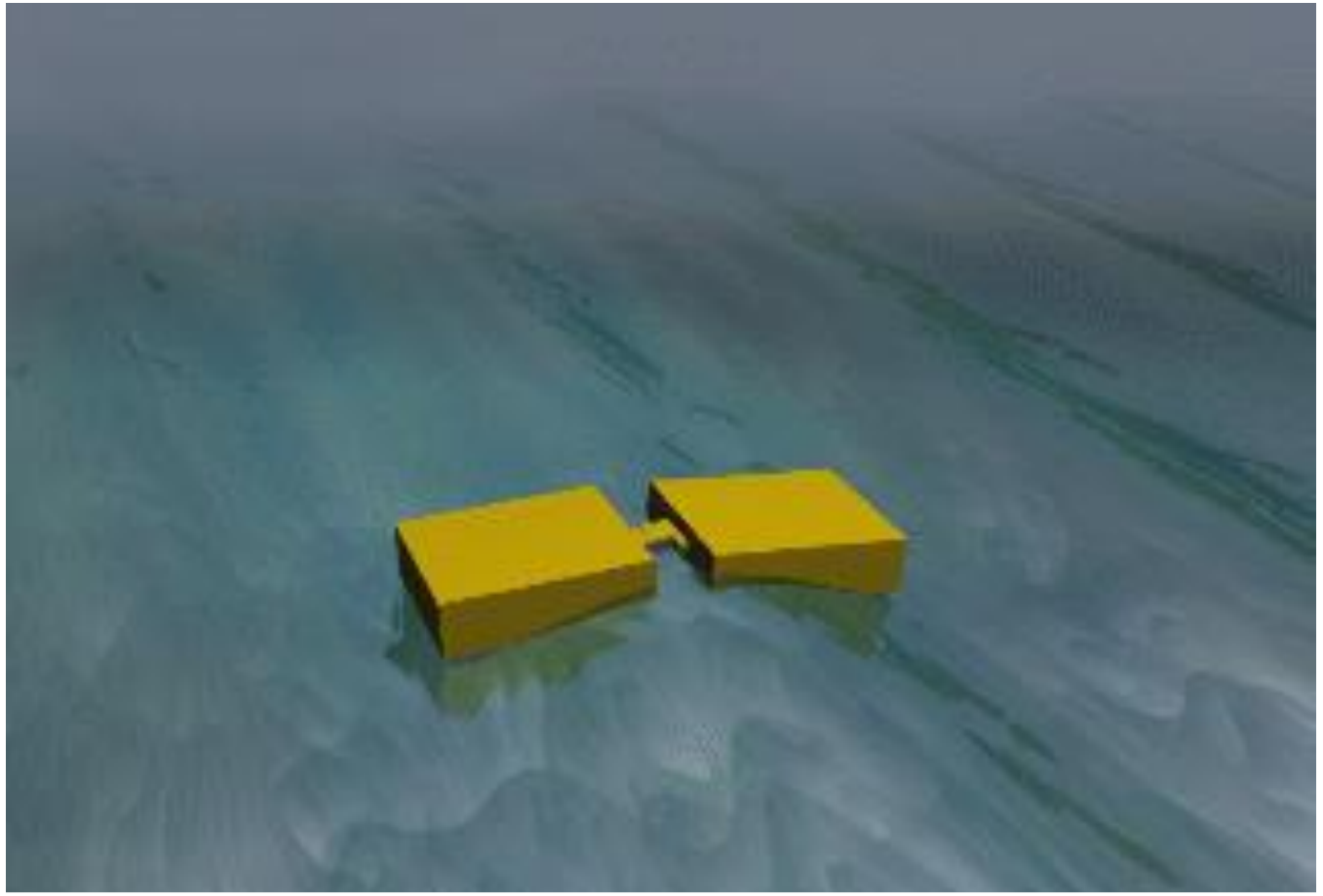
Source : Agence internationale de l'énergie[21].

Sea wave energy

It consists in exploiting the movement of the water mass at sea (near the coast) either on the surface (waves) or in depth (swell), to transfer it via hydraulic systems to electricity generators.

Sea wave energy

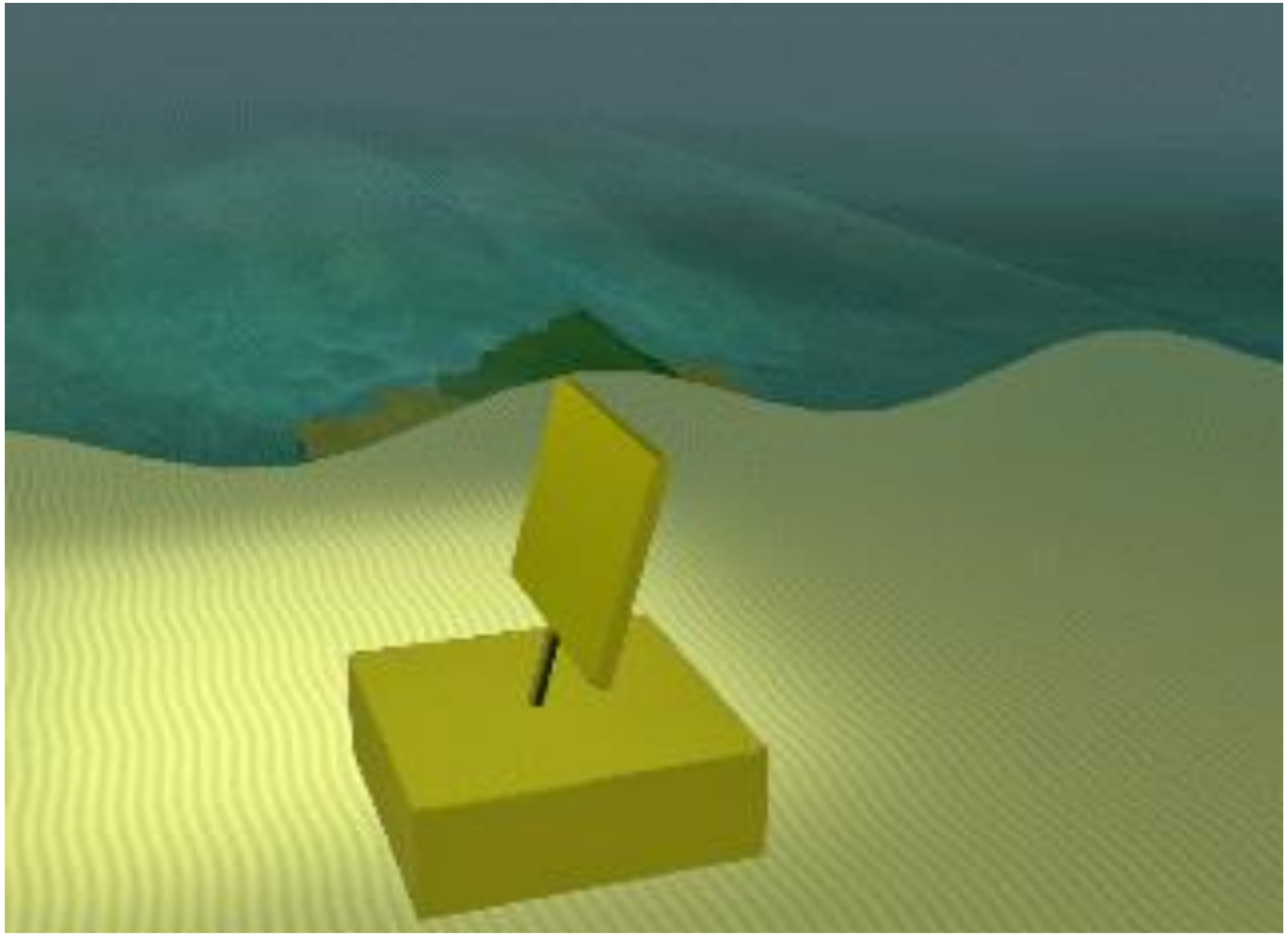
System consisting of a series of long floats that line up in the direction of the wind perpendicular to the waves and whose head is anchored to the seabed by a cable. The waves create an oscillation of the chain. This oscillation is exploited at the joints to compress a hydraulic fluid that in turn drives a turbine. It is the best known process exploiting wave energy.



The articulated floating chain (or «sea snake»)

Sea wave energy

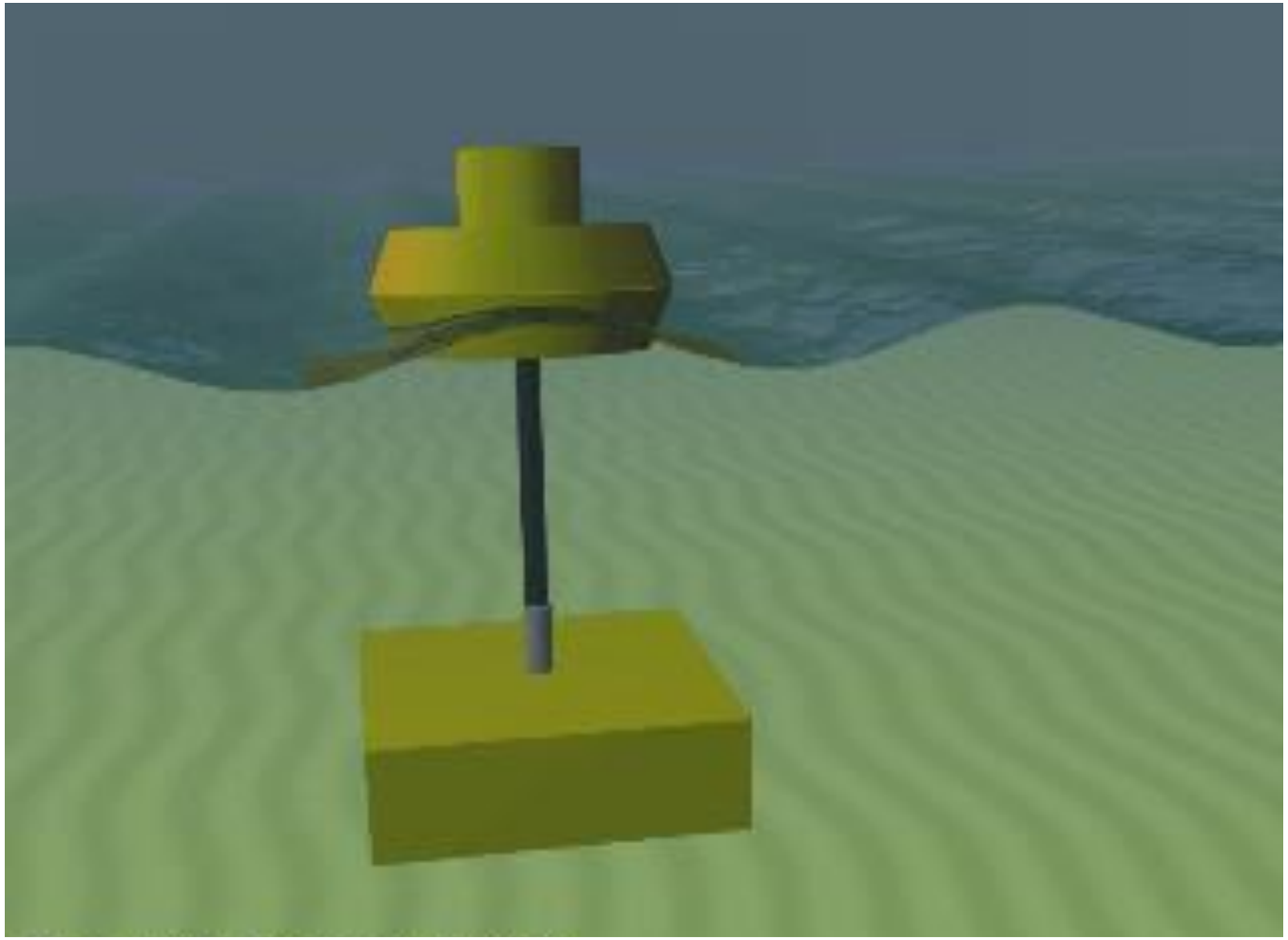
Pivoting system driven by the orbital movement of water at the passage of waves. These oscillations allow to operate pumps to compress and turbinate a hydraulic fluid.



The submerged oscillating wall

Sea wave energy

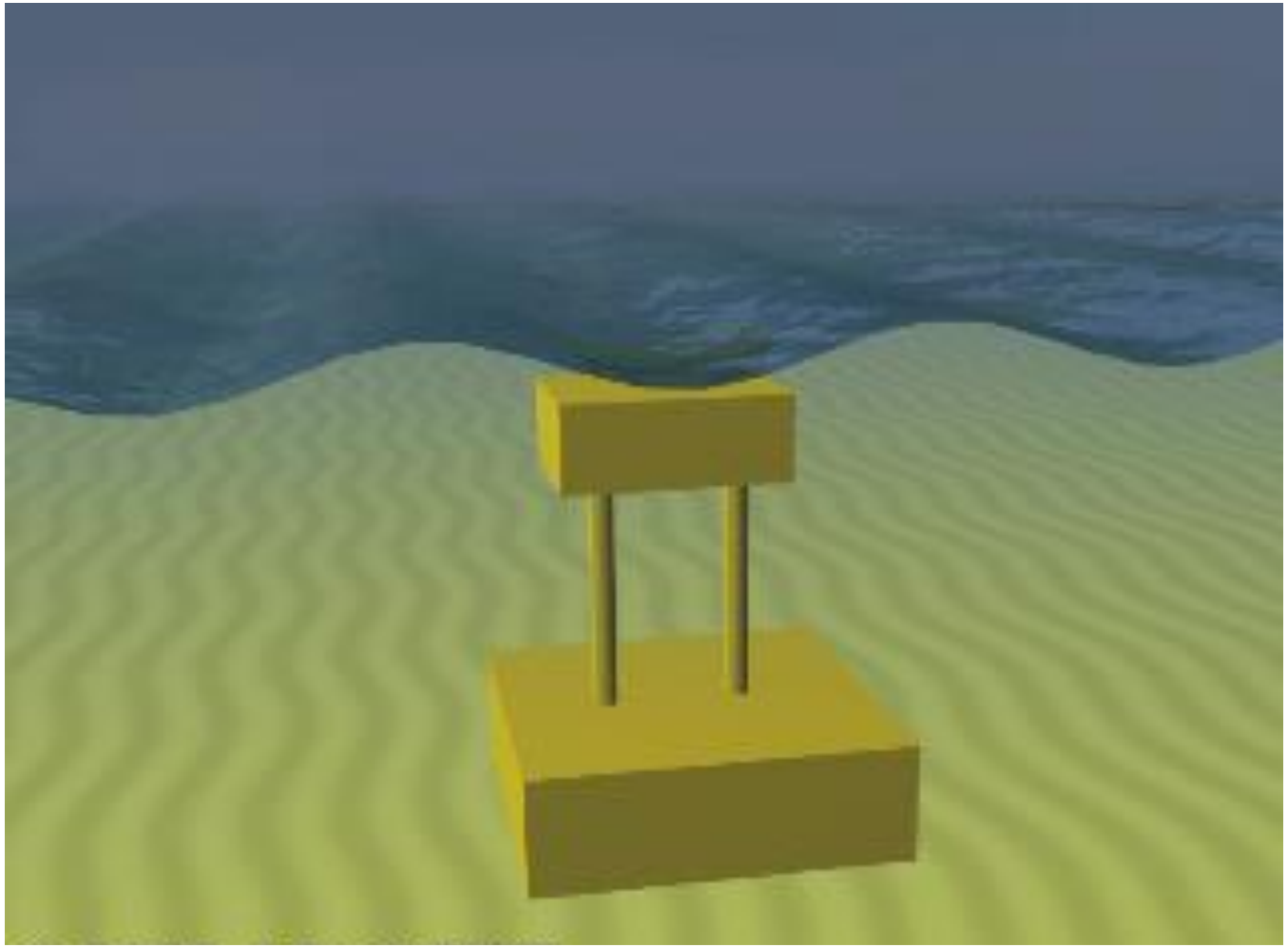
Floating structure set up on the surface of the sea and transforming all horizontal or vertical movements into mass displacements (elements using centrifugal force to create a work). The energy associated with moving weights is used to actuate a pump and pressurize a hydraulic fluid that then makes it possible to turn a turbine driving in turn an alternator. A possible variant is to directly use the displacement to drive the alternator.



The column with vertical oscillation

Sea wave energy

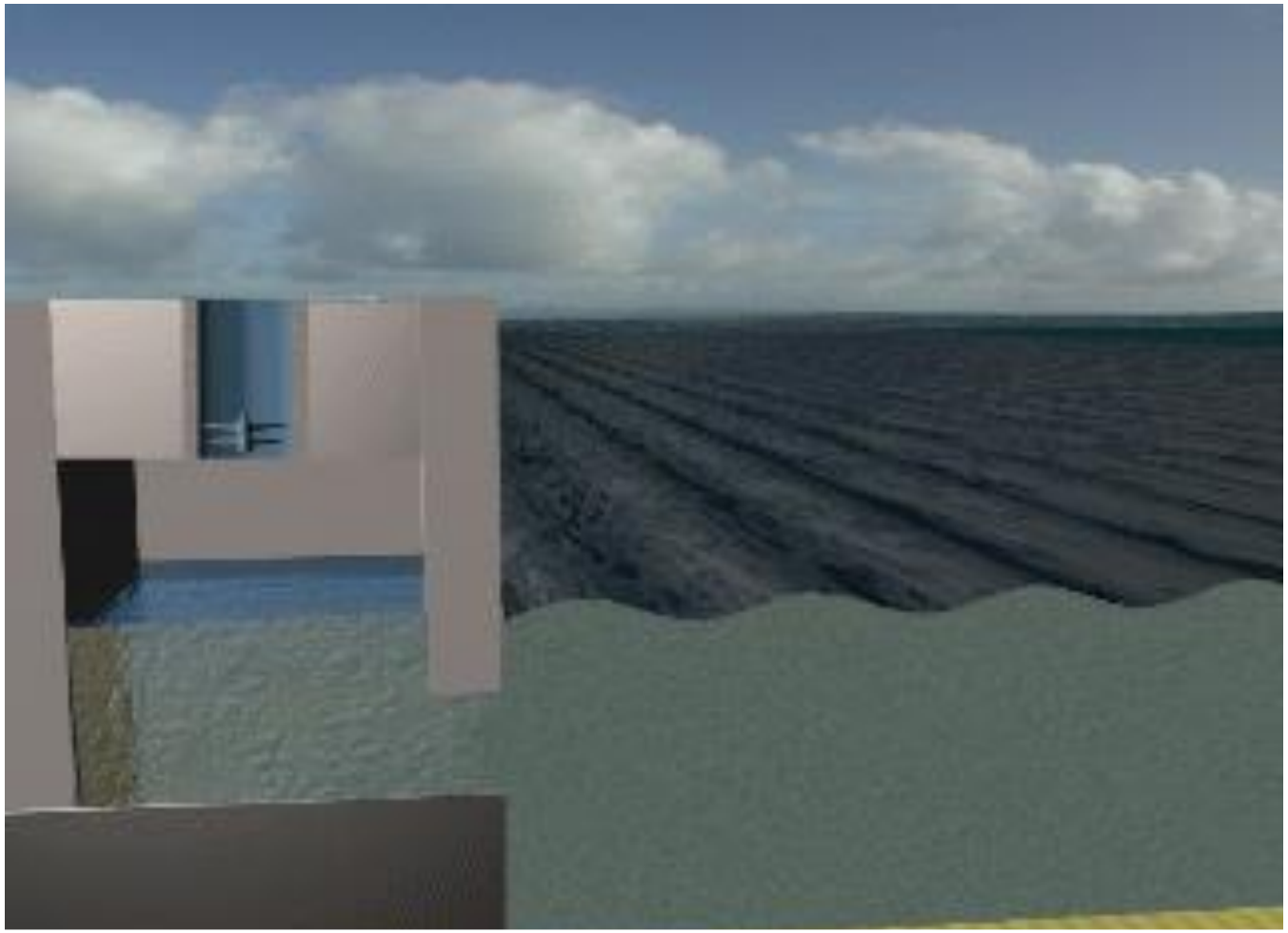
System anchored to the seabed that uses the orbital motion of waves to compress a hydraulic fluid. The easiest sensor to use is a balloon. It is possible to build a network of sensors and collect the compressed fluid on land where it is turbinated to produce electricity.



The immersed pressure sensor

Sea wave energy

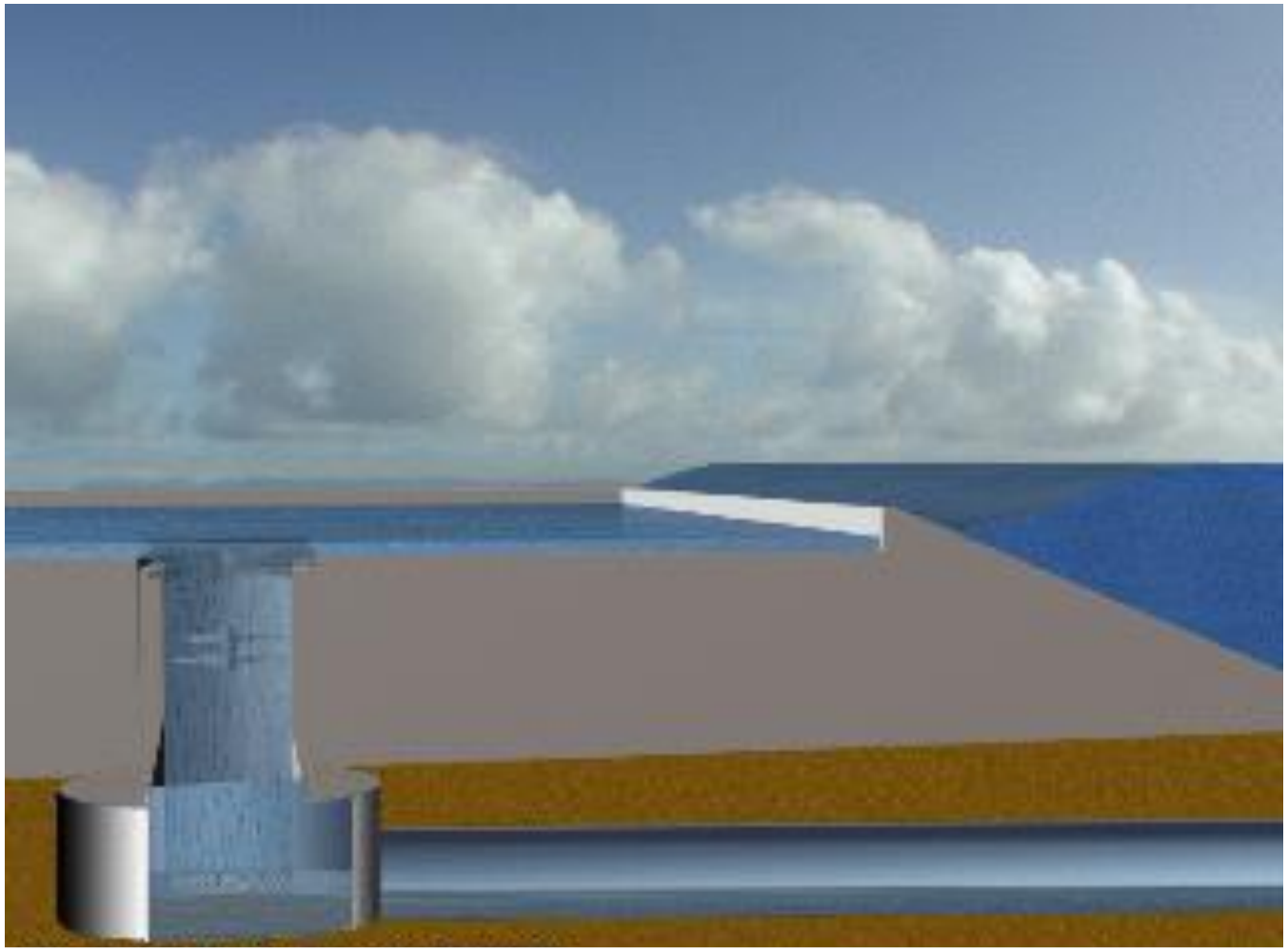
Floating steel or concrete structure, open at the base and closed on top. The waves raise and lower the water level in the column. This has the effect of compressing and decompressing alternately air trapped in the upper part of the column. The air then activates a two-way turbine to produce electricity. This system can be installed offshore or on shore.



water column

Sea wave energy

Crossing system that retains water from wave crests, creating overpressure in the tank. The volume of trapped water is turbinated.



The flood trap

Biomass energy

- **Biofuel:**

Biomass energy is the oldest form of energy used by man since the discovery of fire in prehistory. This energy makes it possible to manufacture electricity thanks to the heat released by the combustion of these materials (wood, plants, agricultural waste, organic household waste) or biogas from the fermentation of these materials, in biomass power plants..

Biomass energy

- **Biofuel:**

Biomass by combustion

The waste is directly burned by producing heat, electricity or both (cogeneration). This concerns wood, waste from wood processing industries and agricultural plant waste (straw, sugar cane, peanut, coconut...).

Biomass energy

- **Biofuel:**

Biomass by methanisation

The waste is first transformed into biogas by fermentation using microorganisms (bacteria). The biogas is then burned. This biogas is close to natural gas and mainly composed of methane. This includes household waste, animal manure and slurry, sewage sludge, paper and paperboard…