PECC Victoria Seminar

Energy transition: Making the most out of available resources
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Storage for electricity
An overview of storage technologies
an innovation challenge

Henri Boyé

French Ministry of Ecology, Sustainable Development and Energy

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RÉPUBLIQUE FRANÇAISE
Ministère
de l'Écologie,
du Développement
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ENERGY STORAGE TECHNOLOGIES FOR INTERMITTENT RENEWABLE ENERGY SYSTEMS

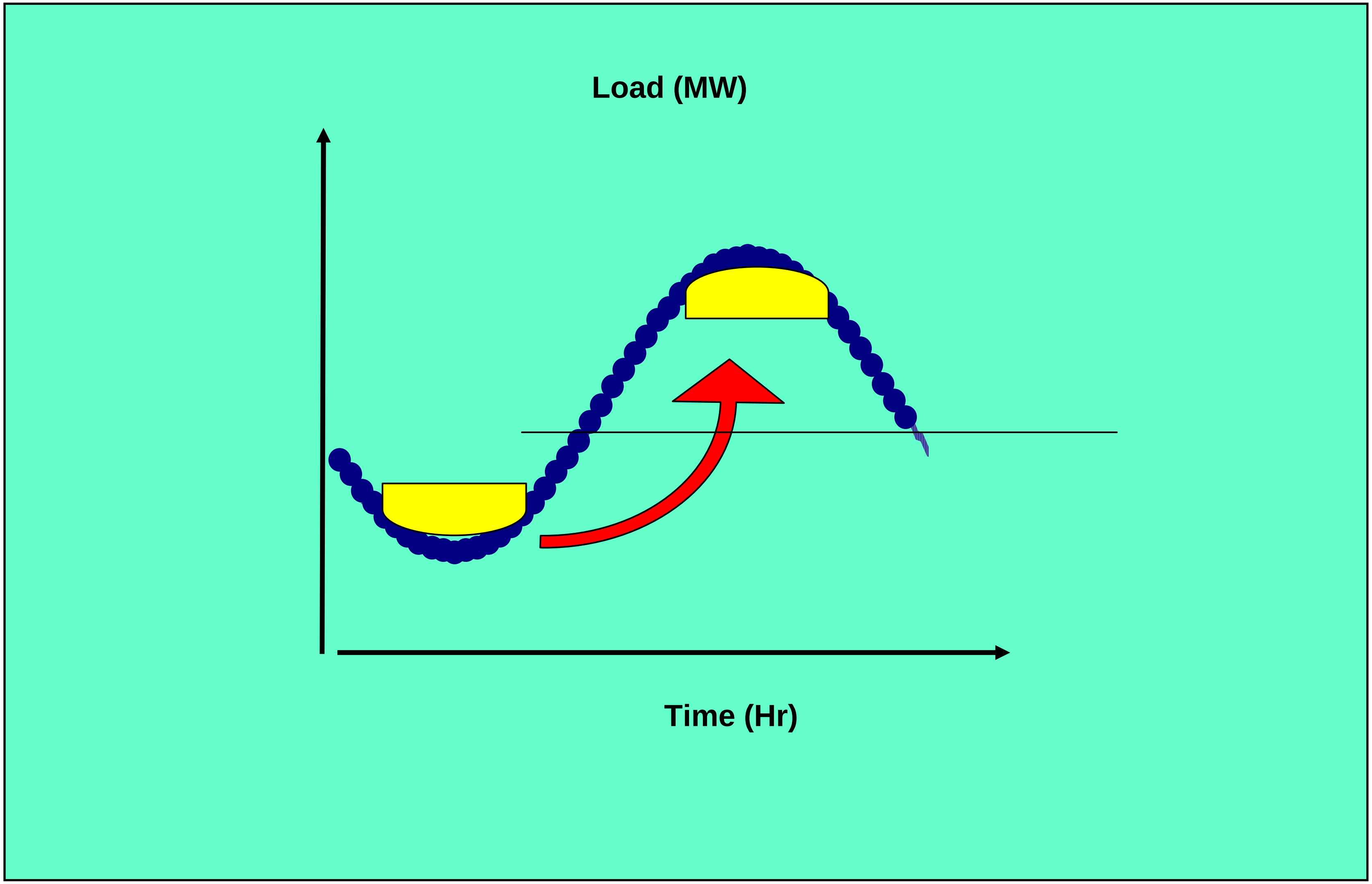
- The development of renewable energy, mostly intermittent, (photovoltaic, wind) optimizing power generation and the development of portability require breakthrough innovations in storage systems.
- It is an indispensable element of any successful energy transition.
- The storage of energy is a necessity for a better use of intermittent energy and facilitate the mobility of tomorrow.

Background of storage system

- In any electrical system, energy exchanges are just in real time, thanks to a continuous real-time management of production that are aligned with the energy demand to maintain the network equilibrium flows. Storage is one of the techniques used to achieve this balance.
- Electric Energy Storage is mostly used to transfer energy from off-peak time, to peak-time, with a valorization.
  For renewable energy, It can store unstable electric energy during wind and photovoltaic power generation, and supply this energy to the electric power system again, in necessary moment

Background of storage system

Energy Storage is mostly used to transfer energy from off-peak time, to peak-time, with a valorization.



Energy storage a challenging and costly process

- Electricity can only be stored by conversion into other forms of energy (e.g. potential, thermal, chemical or magnetic energy).

- The grids must be balanced exactly in real time, and we must ensure that the cost of electricity is the lowest possible.

- Storage of electricity has many advantages,
- in centralized mass storage used for the management of the transmission network,
- or decentralized storage of smaller dimension.

An overview of storage technologies

- We present : mechanical storage in hydroelectric and pumped storage power stations, compressed air energy storage (CAES), flywheels accumulating kinetic energy,
- electrochemical batteries with various technologies, traditional lead acid batteries, lithium ion, sodium sulfur (NaS) and others, including vehicle to grid, sensible heat thermal storage,
- superconducting magnetic energy storage (SMES),
- super capacitors,
- conversion into hydrogen...

DIFFERENT ENERGY STORAGE TECHNOLOGIES

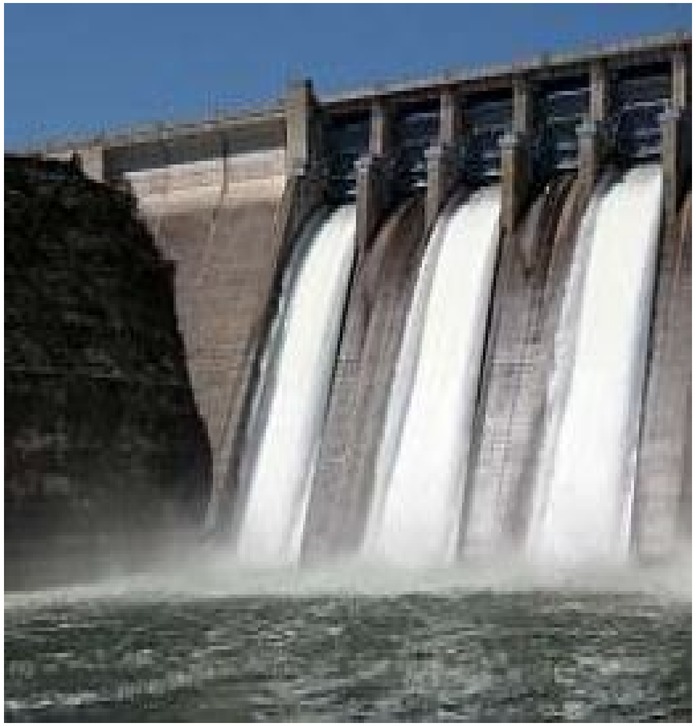
- Pumped storage
- Batteries
- Superconducting magnet energy storage
- Flywheel energy storage
- Regenerative fuel cell storage
- Compressed air energy storage

Hydropower Pumped storage

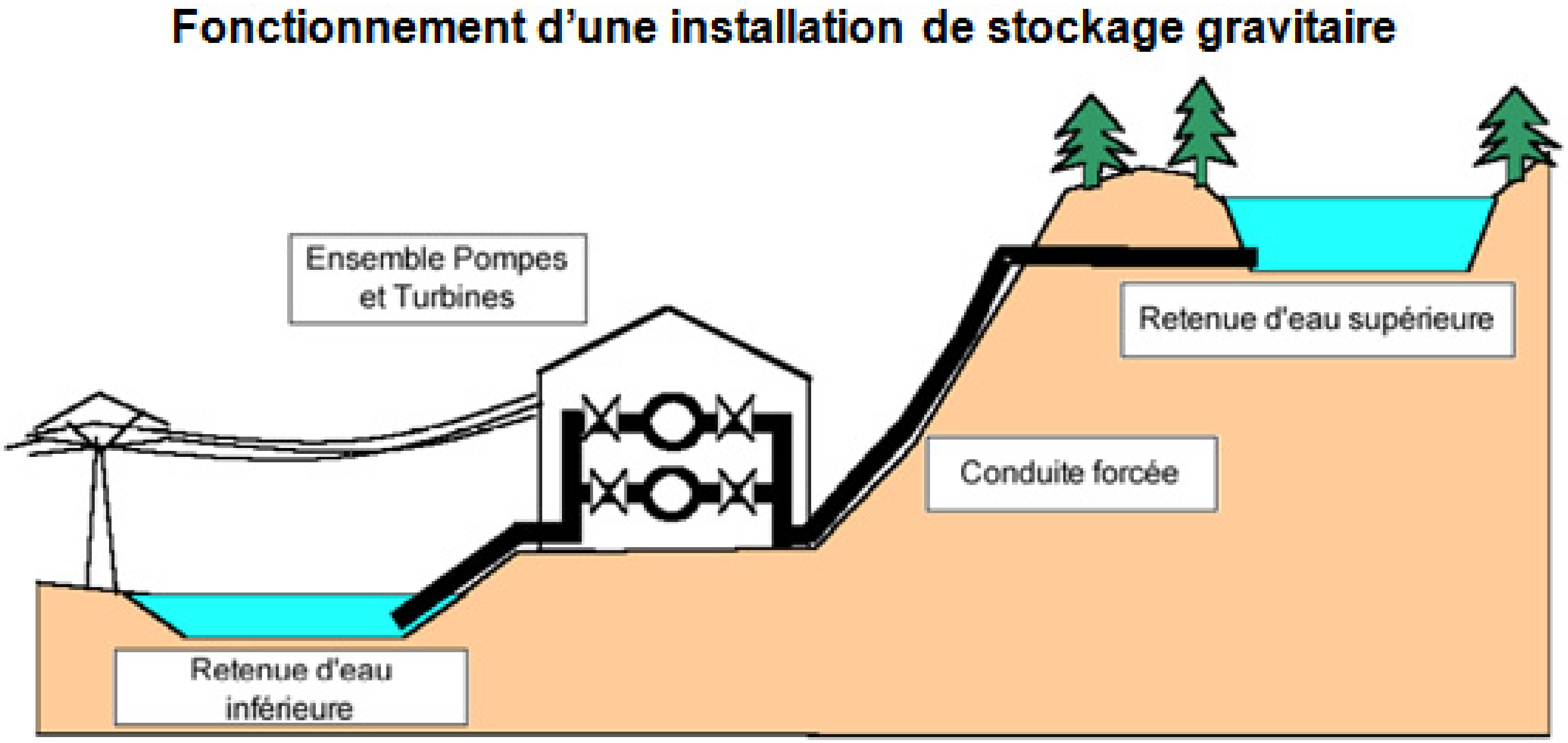
- The pumped storage is a proven technology of hydropower, known since the late 19th century.

- A pumped storage hydro power plant may store huge energy by pumping water from a lower reservoir to a higher pond.

- In a pumped storage hydro plant, Water is pumped during off-peak times and may be utilized to generate electricity. Other innovations may store electricity in small quantity but pumped storage hydro power plant may store electricity in Megawatts (MW) or even) Gigawatts(GW.

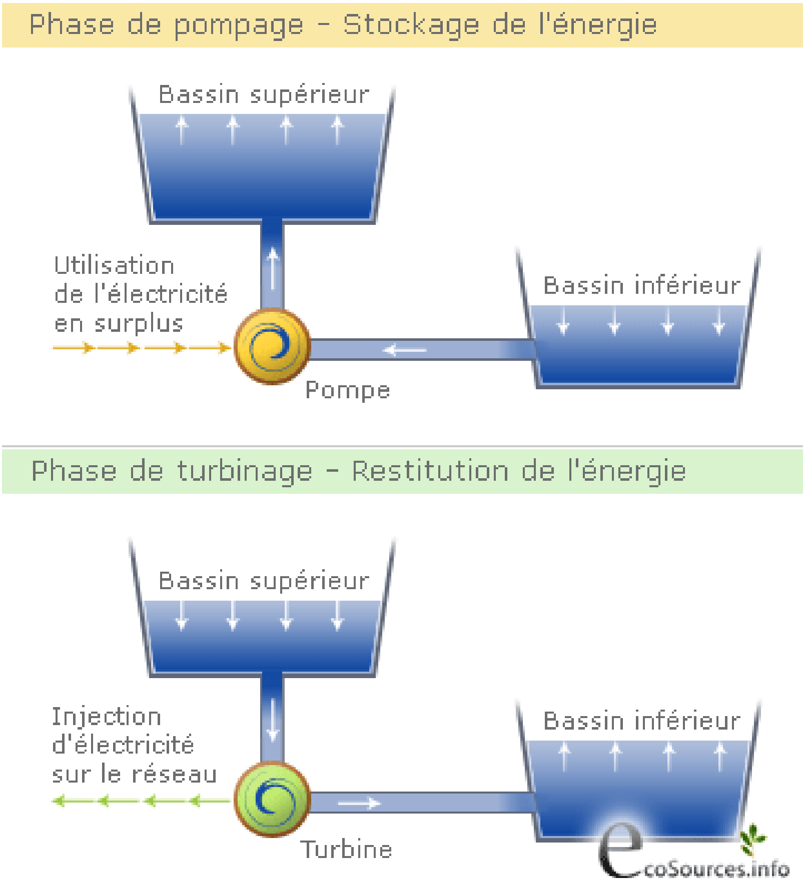


Gravity and Pumping storage



Reservoirs and dams

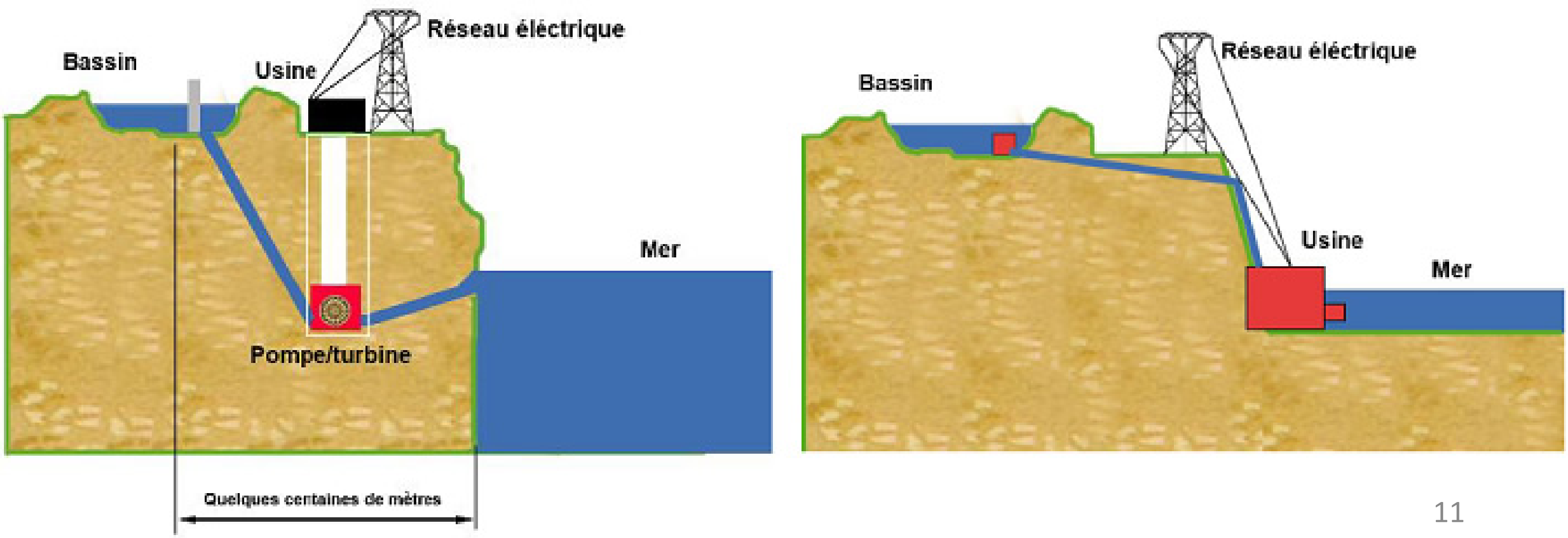
A pumped storage hydro power plant may store huge energy by pumping water from a lower reservoir to a higher pond.



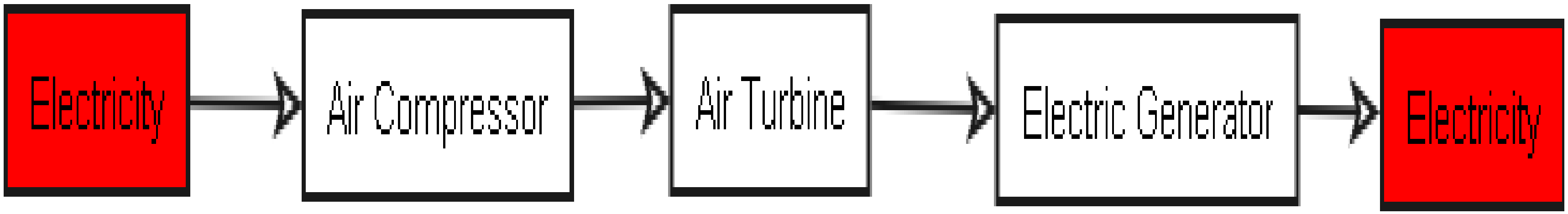
Marine Pumping Storage

Pumped Storage Plants can also be installed coastline, with the sea as bottom reservoirt and an upstream resrvoir on top of a cliff or formed by a dam. There is now a marine STEP in Okinawa, Japan, and projects n France Reunion, Guadeloupe and Martinique islands, and in Morrocco.

Schéma de principe d'une STEP marine

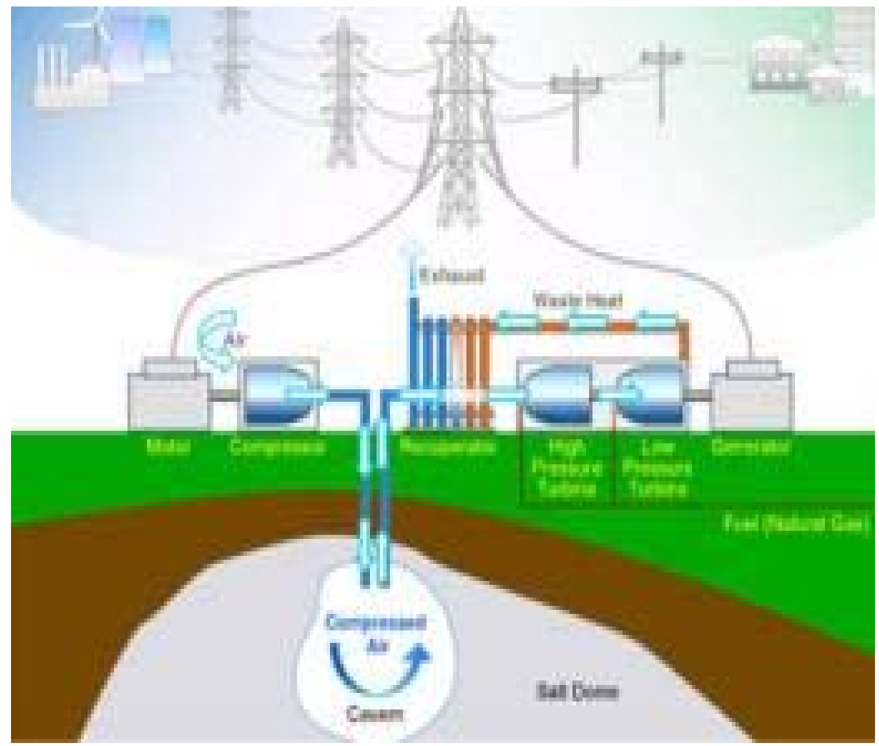


CAES Compressed air energy storage



•In CAES Air is compressed offpeak by a turbocharger coupled to a gas turbine and is stored in underground cavities

•Energy from solar or wind and even electricity from thermal power plant during off-peak period may be utilized to compress air by compressor and same air may be utilized to produce electricity during peak-hour.

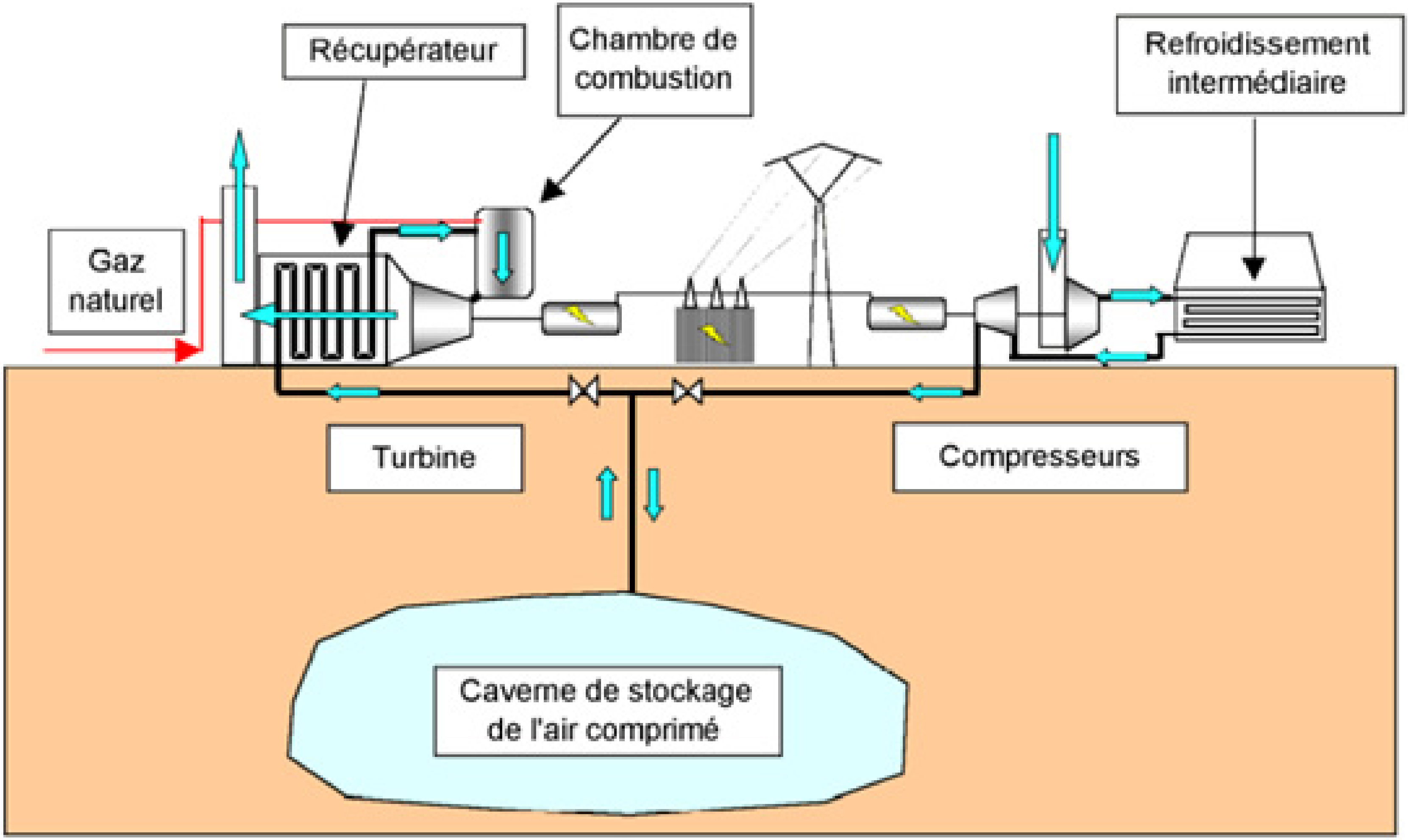


CAES in operation

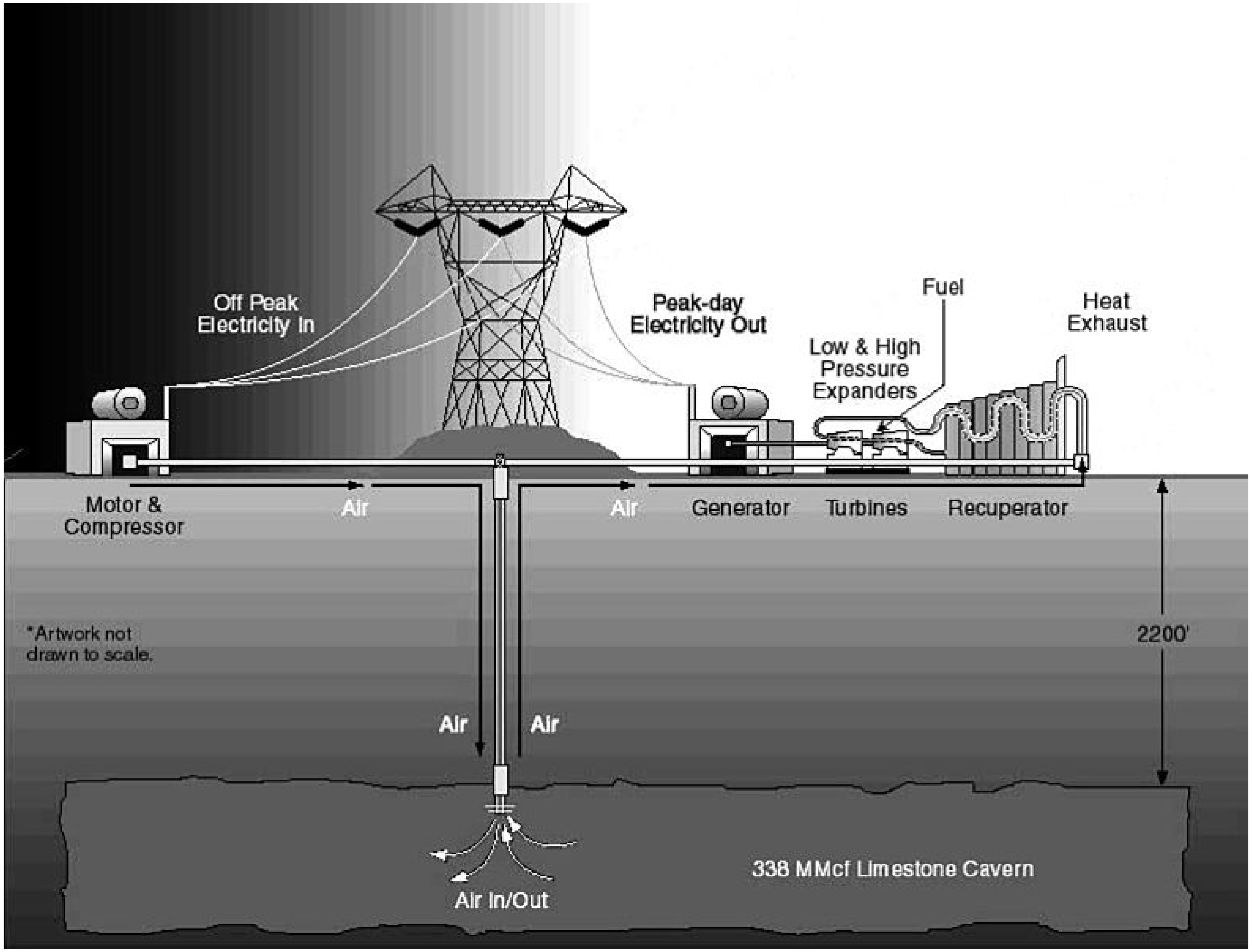
- The CAES are experienced since 1979 in Germany and the USA
- - In Germany near Bremen the CAES plant at Huntorf delivers 290 MW with a range of two hours, with air stored at 70 bars in two salt caverns of 310,000 m3 within 500 m of depth.
- A second application from the development of wind power in Northern Germany is used to compensate for variations of this resource in order to provide a more stable power.
- - In the USA, the largest project of CAES in the world is at Norton (near Cleveland, Ohio). Its power is about 2700 MW, with nine production units (compressors - turbine) operating with compressed air at 110 bar. The storage tank is a cave in limestone quarries at 570 m depth.

CAES : Compressed Air Energy storage

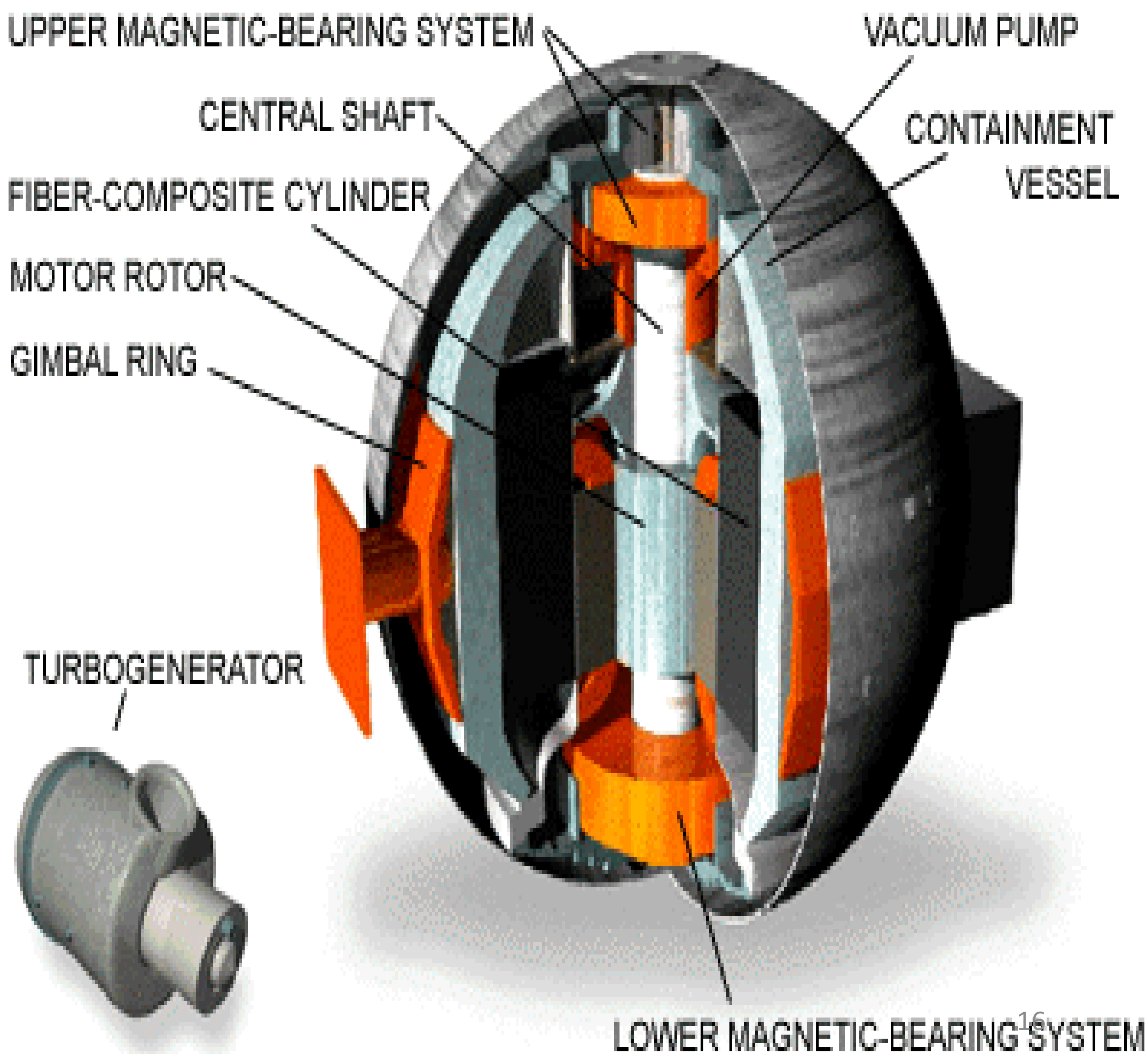
Schéma de principe d'une installation de stockage à air comprimé



CAES *Compressed Air Energy storage*



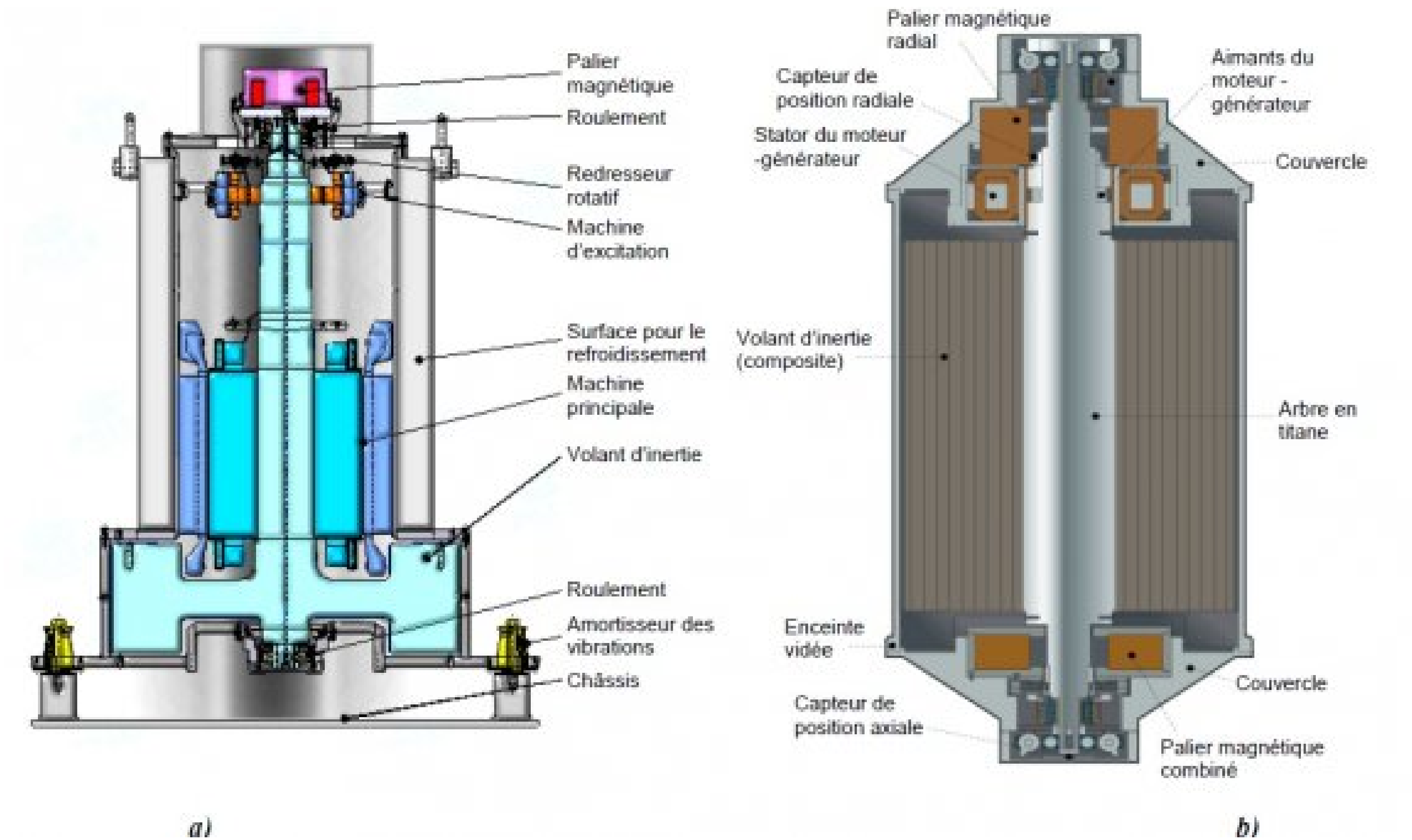
Spinning flywheel



Flywheel energy storage

- A flywheel stores electrical energy as kinetic energy through the rotation of a heavy mass, to reach very high speeds (> 8000 rev / min) in some minutes. To store energy , an electric motor accelerates a Disk ; To use the stored energy in the rotor, a generator converts mechanical energy to electrical energy. The system performance is optimized through the magnetic bearings and vacuum containment . We distinguish flywheels slow (hard steel) and rapi(composite discs)
- The flywheel system is a very efficient energy storage device, it can be used for various applications. Systems storage flywheel have a very high reactivity and durability . They can absorb very high power variations on very large numbers of cycles. Flywheel systems can store more energy per system weight compared to chemical batteries

Spinning flywheel



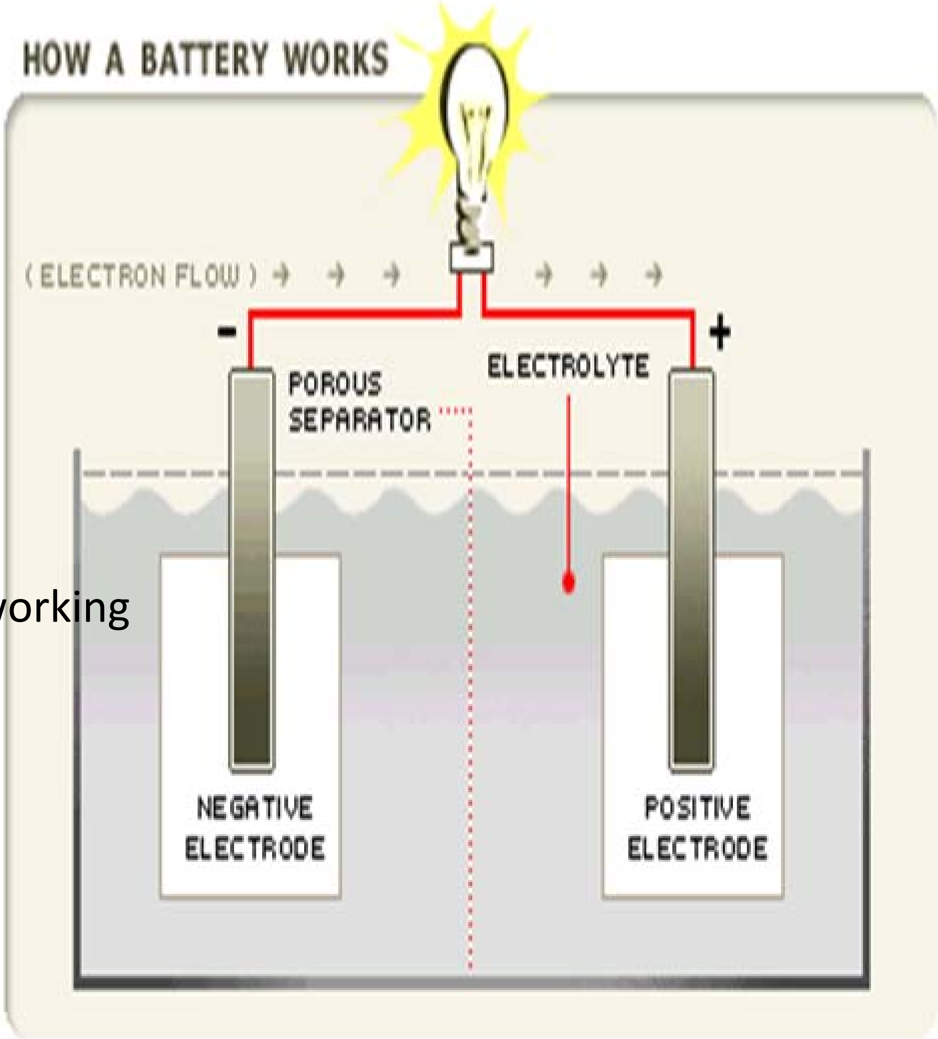
a) b)

Electrochemical batteries

An early solution to the problem of storing energy for electrical purposes was the development of the battery as an electrochemical storage device. Batteries have previously been of limited use in electric power systems due to their relatively small capacity and high cost.

electrochemical batteries with various technologies, traditional lead acid batteries, lithium ion, sodium sulfur (NaS) and others

Batteries



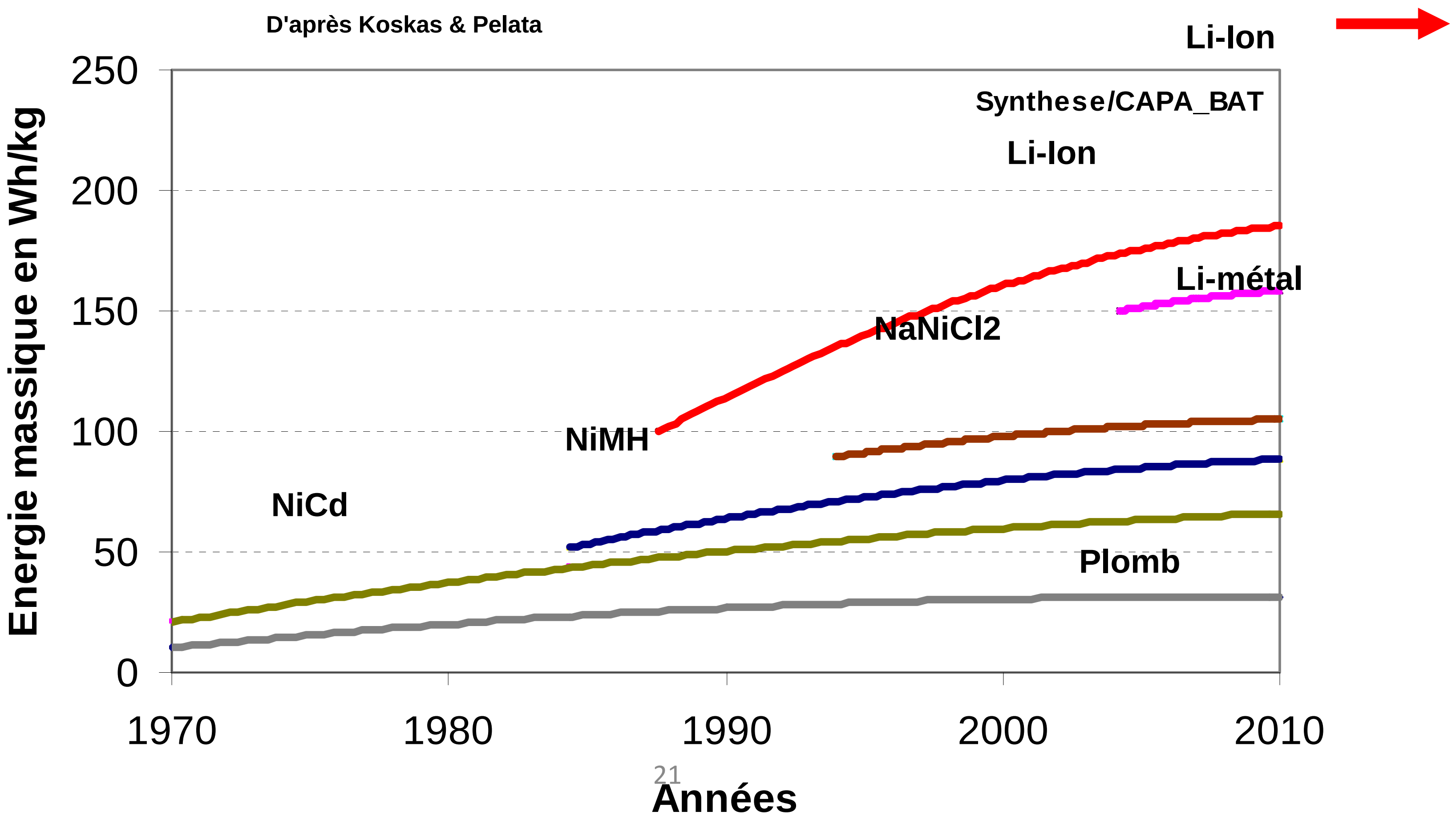
tery working

Battery

Battery Bank

Problem of battery energy density

- Newer battery technologies have been developed that can now provide significant utility scale load-leveling capabilities



Saft Energy Storage Lithium-ion

Eléments → Modules → Systèmes

SYNERION 48E

SYNERION 48M

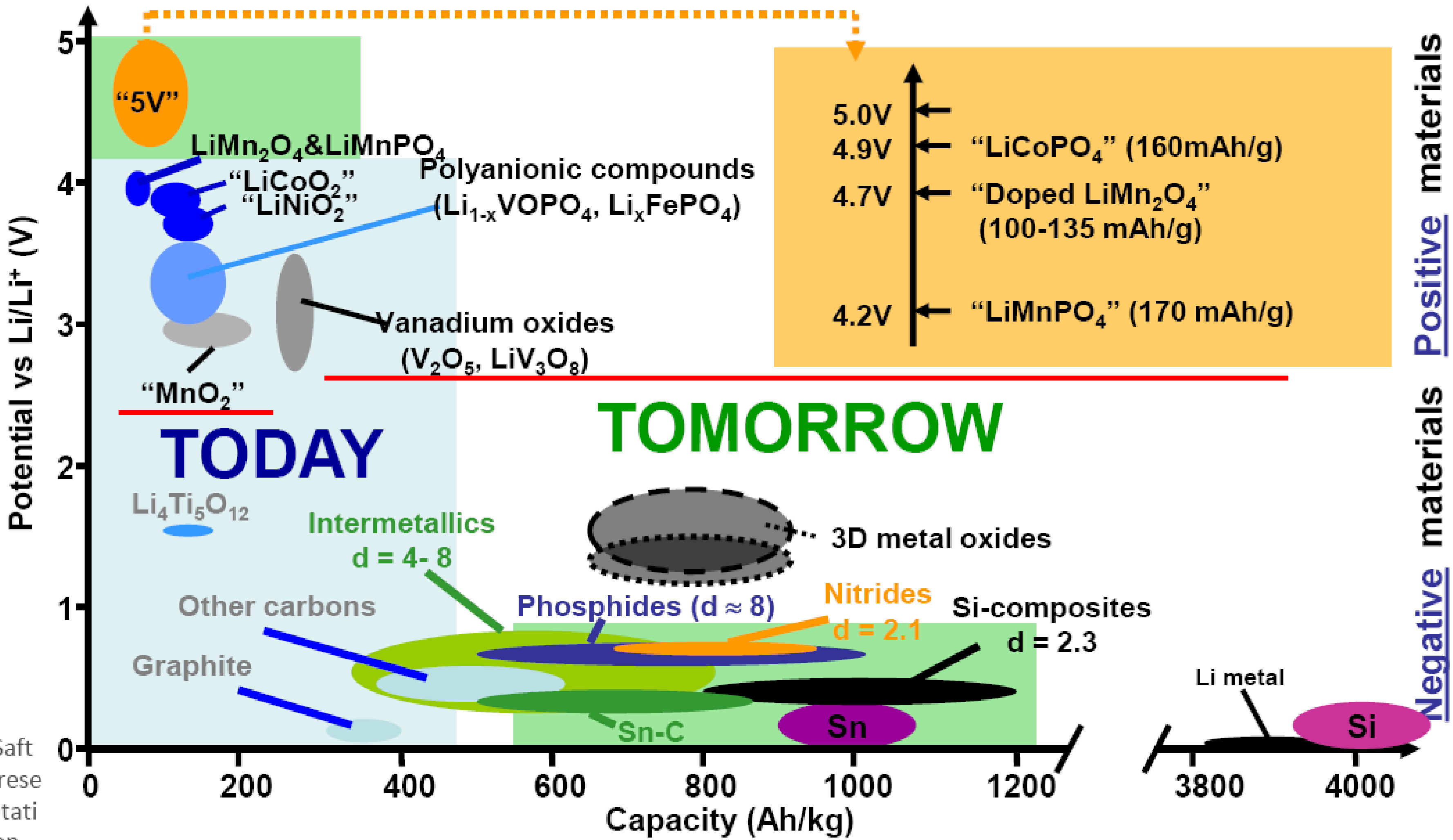
SYNERION 24E

SYNERION 24M

Exemple système résidentiel 5kW

Conteneur 560 kWh / 1MW

Future developments of lithiums



Saft presentati
on

Sodium Sulfur Battery

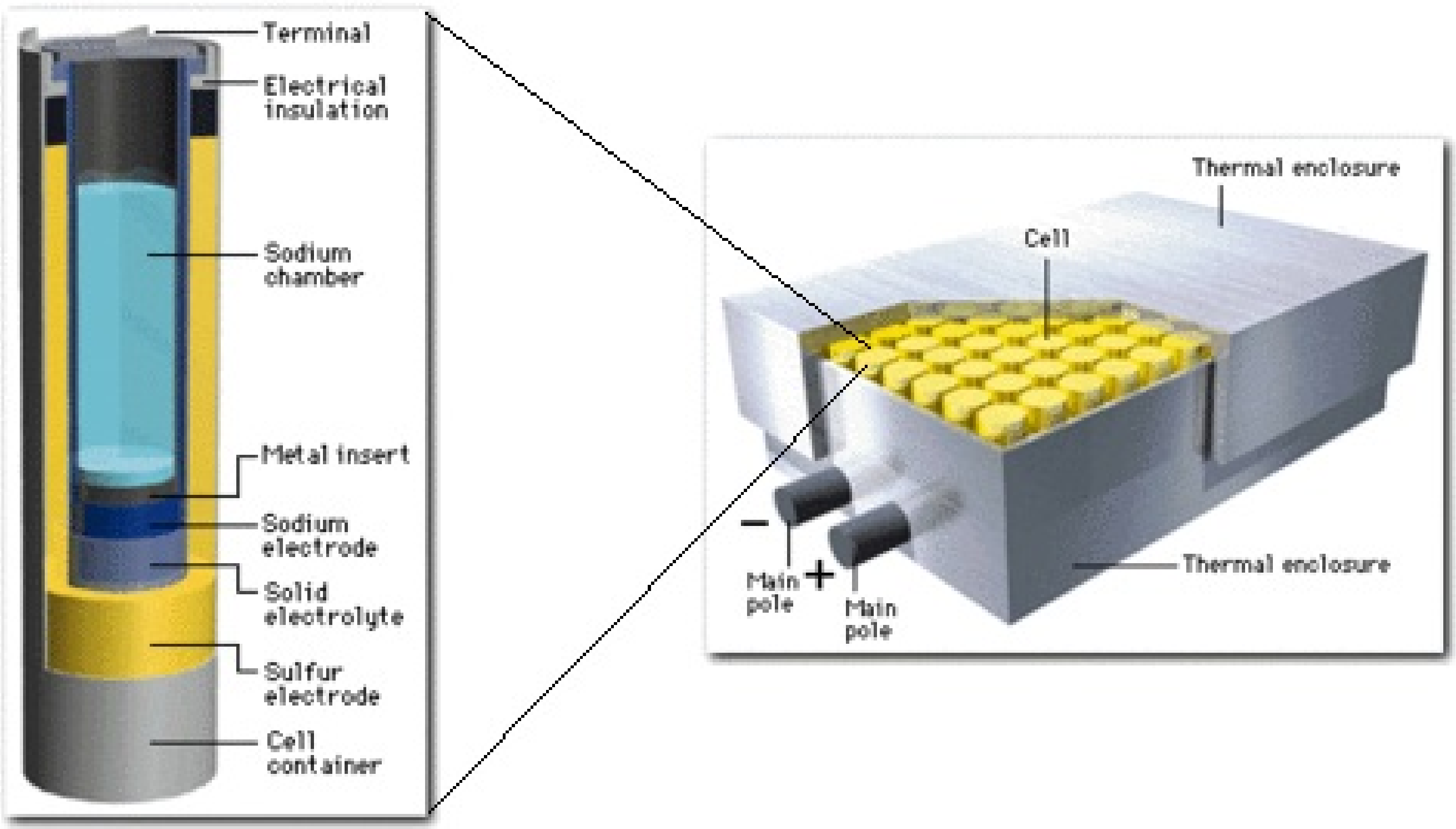


Diagram of the sodium-sulfur components and their assembly into battery. Source: NGK Insulator

The battery sodium - sulfur (NaS) works with liquid electrodes and must be maintained at a temperature between 290°C and 350° C. The rankings of various types of batteries in terms of cost and availability of basic materials frequently classify the couple sodium-sulfur No. 1 in all categories.

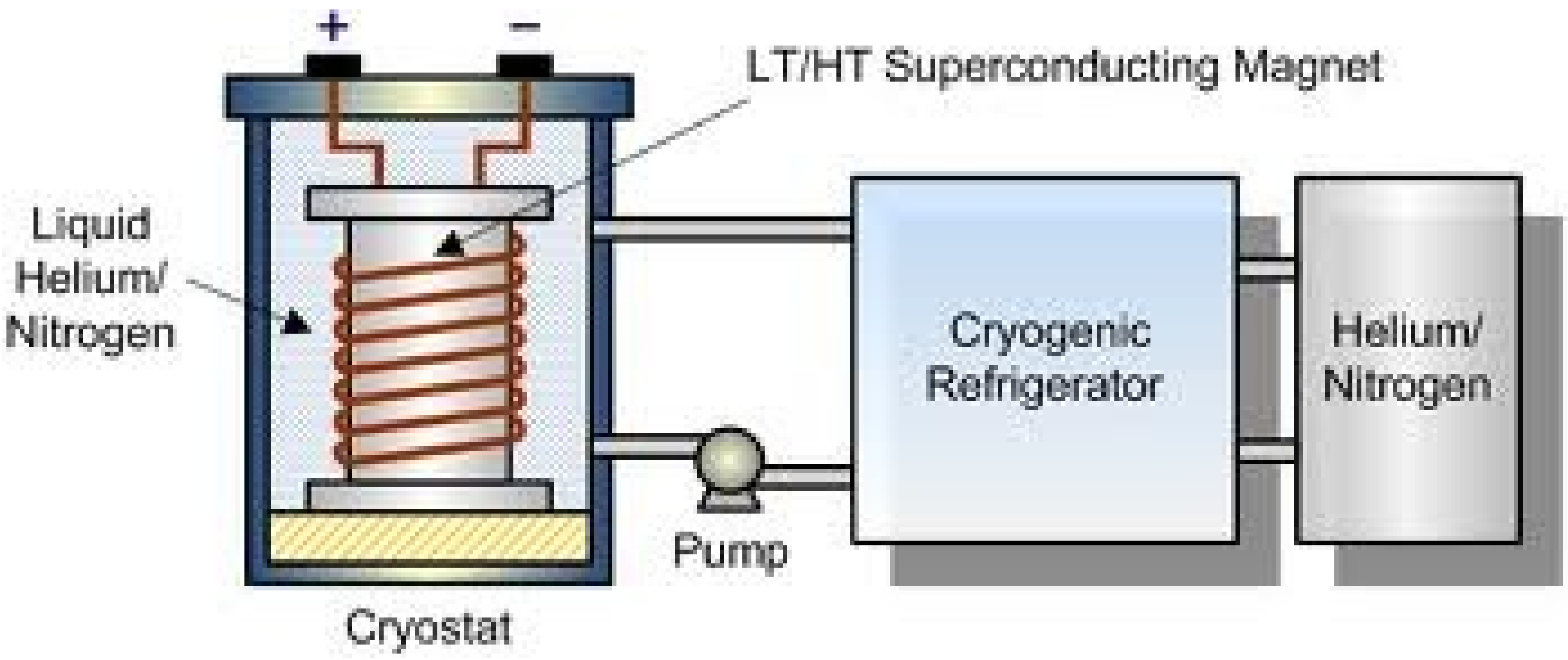
SMES
Superconducting magnet energy storage

Superconducting magnetic energy storage systems (or SMES) store energy in the magnetic field created by the flow of direct current in a superconducting coil.

This advanced systems store energy within a magnet and release it within a fraction of a cycle.

The facilities are mainly pilot demonstration, with the beginning of industrialization.

Superconducting Magnet

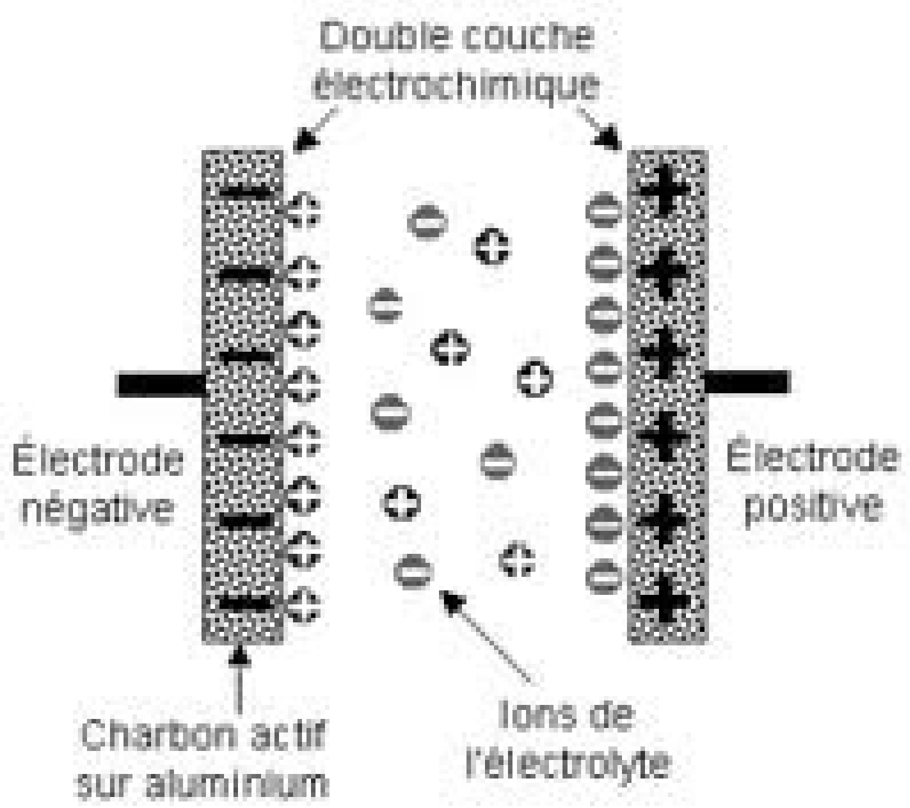


S M E S Superconducting Magnetic Energy Storage

with cryogenic refrigerator

Super Capacitor

Appeared in the 2000s , super- capacitors are dedicated components to power storage rather than the energy .



Maxwell Products super capacitors

Super condensators

Thermal Energy Storage

Example of sensible heat storage at Krems in Austria, 50,000 m3 of water, 2 GWh.
(district heating of the city of Krems on the Danube)

High Temperature Thermal Storage

CSP concentrated Solar Power Storage by Molten Salts

- # CSP Energy Storage

- Concentrated Solar Power (CSP) uses molten salt to store solar power and then dispatch that power as needed. The system pumps molten salt through a tower heated by the sun's rays. Insulated containers store the hot salt solution, and when needed water is then used to create steam that is fed to turbines to generate electricity.

Hydrogen Energy Storage

- Hydrogen is also being developed as an electrical power storage medium. Hydrogen is not a primary energy source, but a portable energy storage method, because it must first be manufactured by other energy sources in order to be used. However, as a storage medium, it may be a significant factor in using renewable energies, with a very high energy density.
- These technologies are very promising. But for now , they suffer from several drawbacks : low efficiency of the process is at best about 30 % , a high price , limited power and low life of electrochemical generators . R & D works are still in progres

Hydrogen storage 2800 Nm^3 (250 kg) – 35 bars

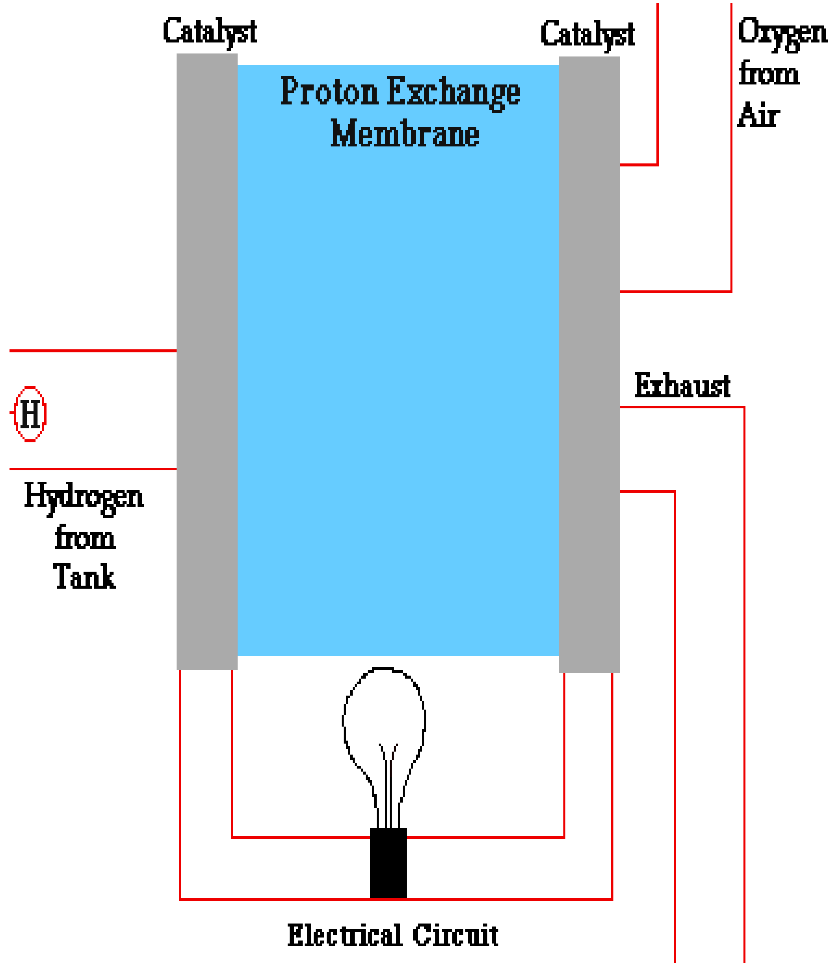
Oxygen Storage 1400 Nm^3 (2000 kg) – 35 bars

Regenerative fuel cell storage

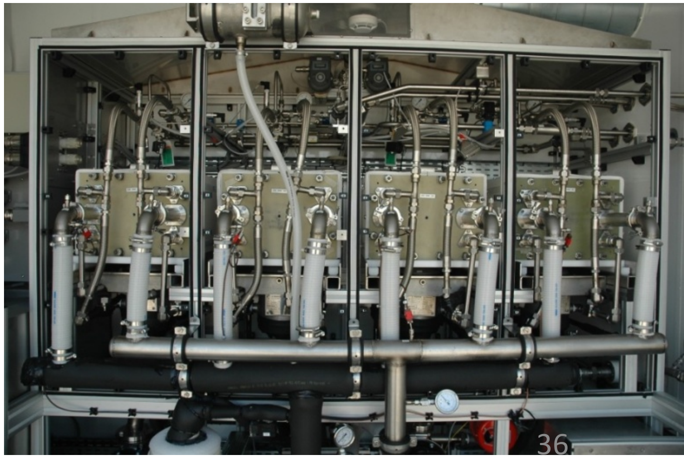
- A fuel cell is a device that generates electricity by a chemical reaction (from combustible substances such as hydrogen, methane, propane, and methanol) into an electric current.

- Every fuel cell has two electrodes, one positive and one negative, called, respectively the anode and cathode.

- Hydrogen is the basic fuel, but fuel cells also require oxygen.
- Fuel cells generate electricity with very little pollution.

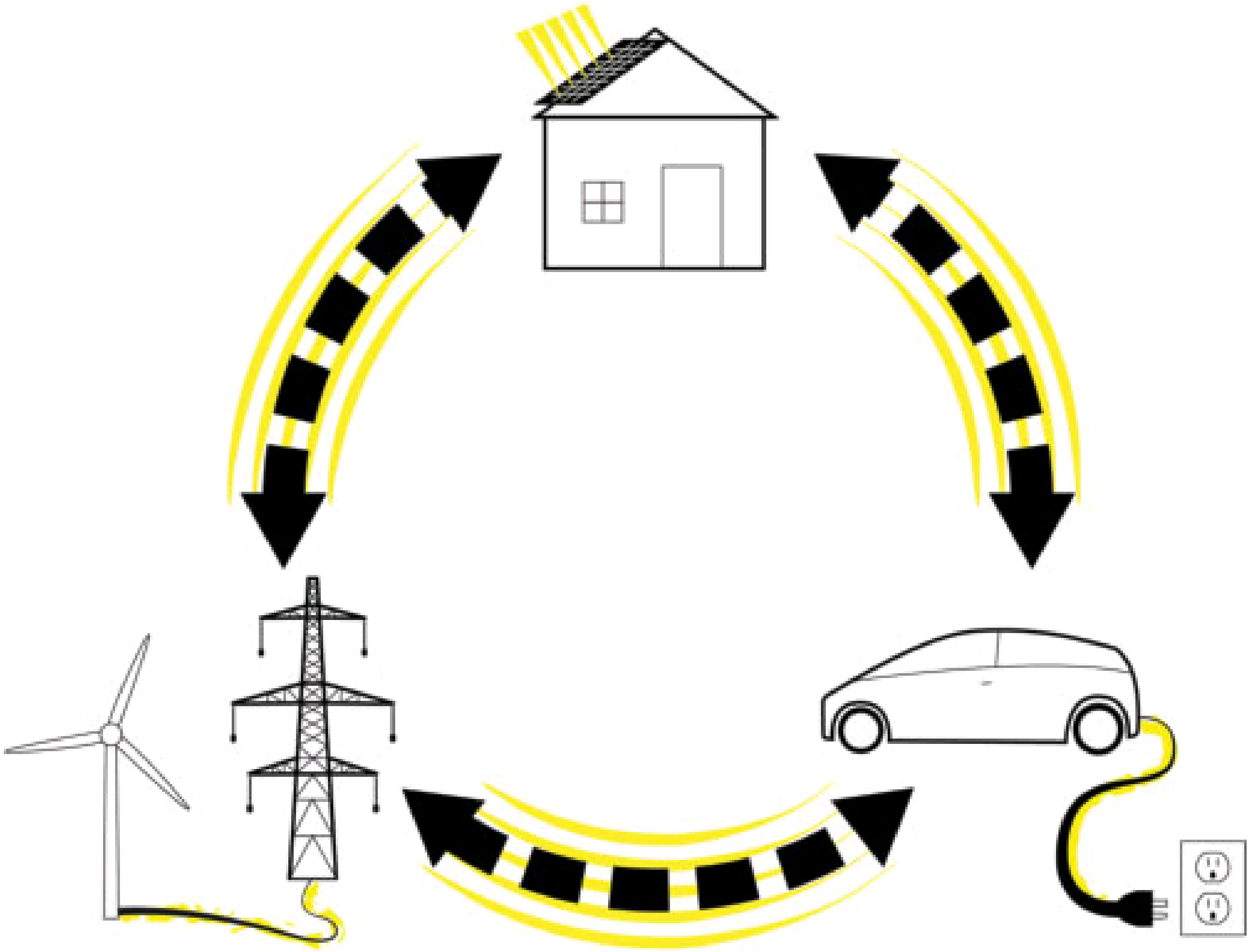


Fuel Cell PEM 200 kW



Vehicle to Grid scheme

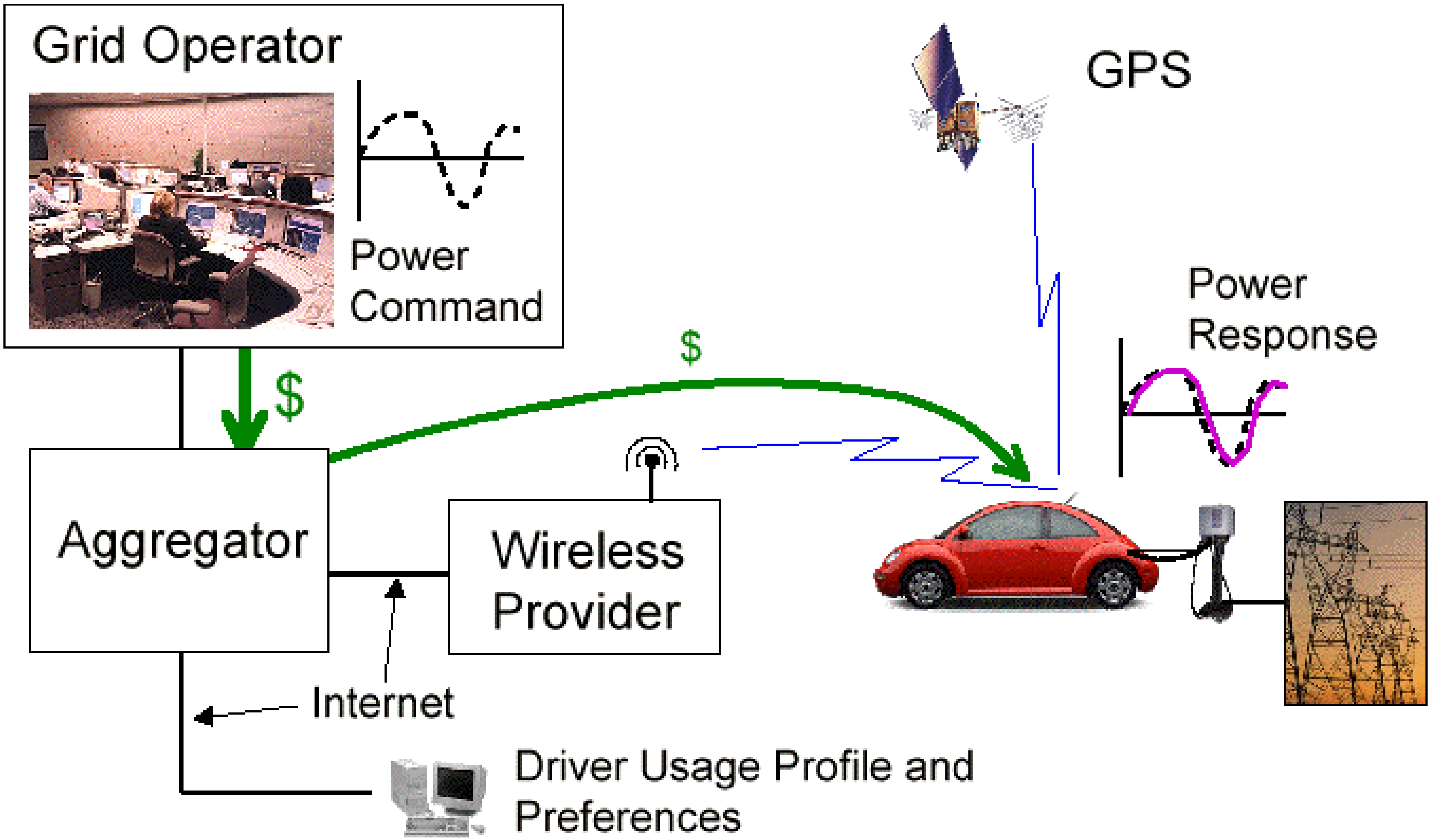
integration of electric vehicles with renewables and the future ‘intelligent’ grid



Vehicle to Grid scheme

- By using their batteries, the arrival of electric vehicles (EV) is a new element in the management of the electricity grid as a possible means of storage. A car is idle 95% of its lifetime and the average use of electric vehicles will require less than 80 % of the battery capacity for commuting .
- It therefore appears possible to use the stored energy to inject in the electric grid during periods when the vehicle is connected to the grid in order to meet peak demand , or conversely to charge the vehicle battery off-peak . This is the concept of " vehicle-to -grid " or V2G , which is to use the batteries of electric vehicles as mobile storage capacity .

Vehicle to grid



Electric bikes & scooters

An example of electric bike, at Paris La Défense

Henri Boyé

Electric scooter

- Some conclusions on energy storage
- The different technologies for energy storage are compared in terms of their cost and level of maturity. The technologies are not all at the same level today of technological maturity.
- We reproduce a summary table of the maturity of key technologies for stationary electricity storage (source ENEA Consulting) .
- The investment costs are provided for information only, with still significant uncertainties , given the still emerging nature of the sector and the lack of feedback

Energy storage Technological readiness level

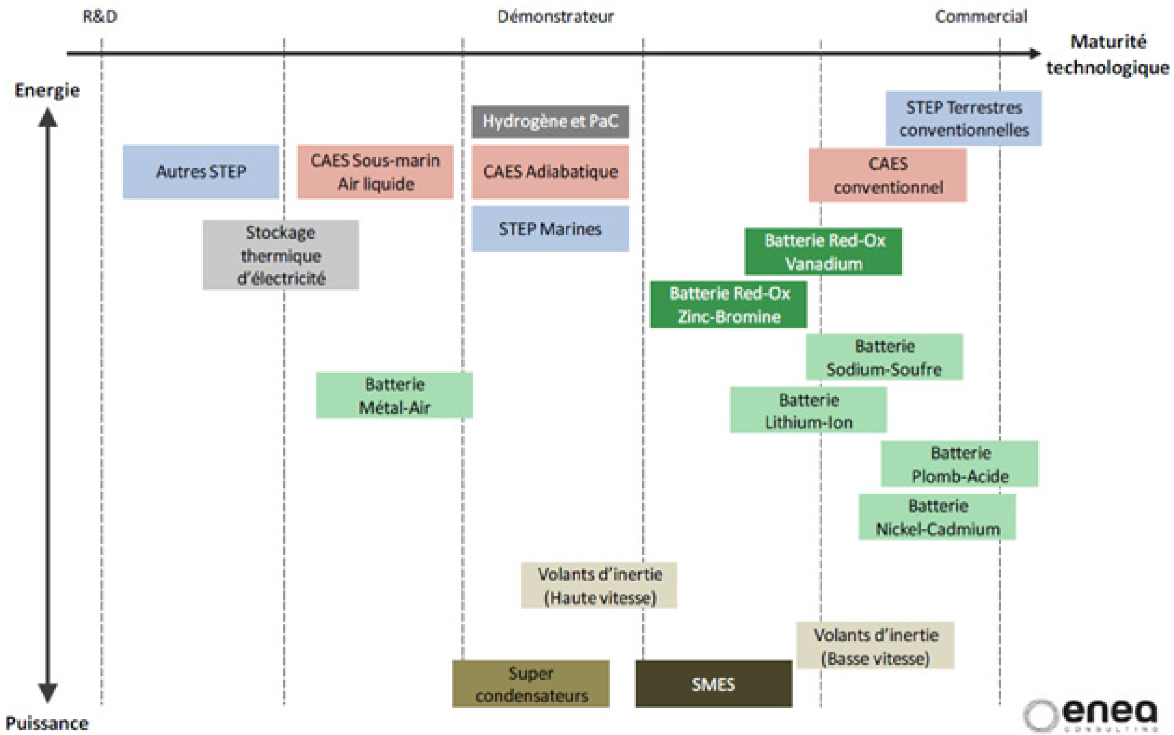


Figure 4 : Niveau de maturité technologique des différents moyens de stockage d'électricité

Typologie des moyens de stockage d'électricité

Stockage gravitaire	Stockage chimique	Stockage inertiel
Stockage à air comprimé	Stockage électrochimique	Stockage électrostatique
Stockage thermique	Stockage électrochimique à circulation	Stockage électromagnétique

[6] *DoE : Department of Energy*

[7] *NEDO : New Energy and Industrial Technology Development Organization*

The different technologies for energy storage are compared in terms of their cost and level of maturity We reproduce a summary table of the maturity of key technologies for stationary electricity storage (source ENEA Consulting) .

Some conclusions on energy storage

- There are a large number of storage technologies for electricity. Each has its own characteristics in terms of size, power output , cost, number of cycles and therefore life , energy density , technological maturity and many questions arise as to the choice of the most appropriate technology to needs.
- Most industrial electricity storage technologies are large and centralized. Decentralized storage (at the consumer level) is also of great interest.
- **We have to r**educe the cost of storage options and develop integrated value propositions.

Which storage technology can make the transition happen? How much will it cost ?

The comparative study of different storage solutions also involves an economic analysis , with each technology assessment of their investment costs declined in terms of power and energy and their operating costs. Cost structures are significantly different depending on the technology . Pumping storage are capital intensive while batteries have high replacement costs. To compare the actual costs of the various alternatives , it is also necessary to integrate the use of parameters (life , stress frequency)

We must of course take into account the still experimental nature of many industrial sectors storage , facing the issues of extension of networks, peaking and even erasing.

The development of intermittent renewable energy will bring a growing need for mechanisms to regulate energy flow, and innovative energy storage solutions seem well positioned to penetrate.