Classification of Electrical Energy Storage.

Electrical energy storage

Directly electricity storage in devices such as capacitors or super-conducting magnetic devices. Those storage methods have the advantage of quickly discharging the energy stored.

Mechanical energy storage

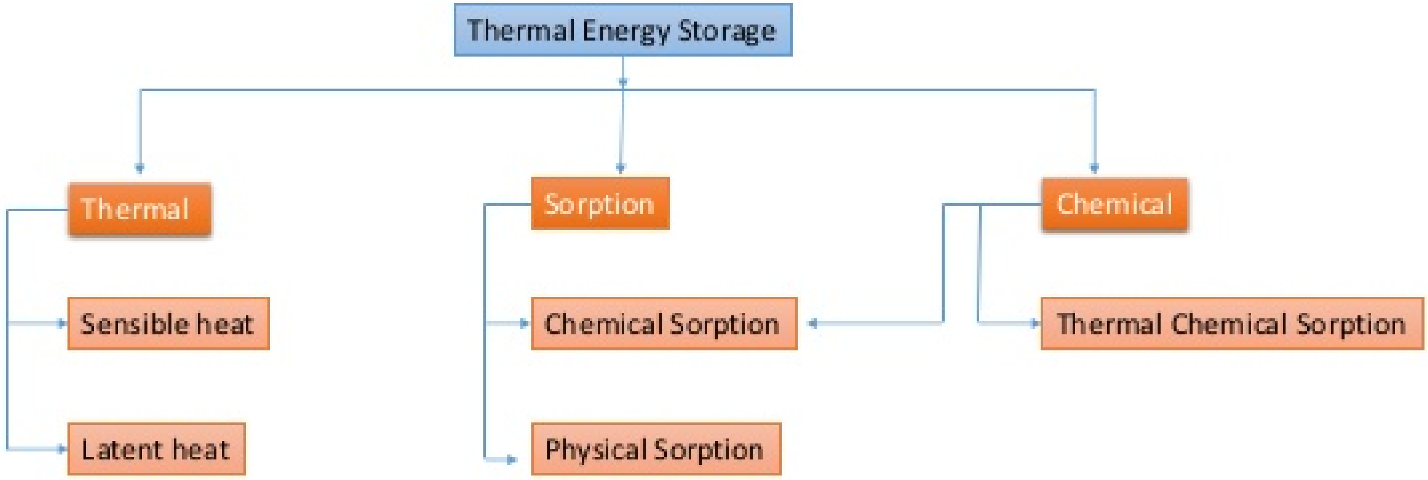
Storage of electrical energy in the form of kinetic energy such as flywheel or potential energy such as pumped hydroelectric storage (PHS) or compressed air energy storage .

Chemical energy storage

Storage in chemical energy form as in batteries, fuel cells and flow batteries. Chemical energy storage usually has small losses during storage.

Thermal Energy Storage

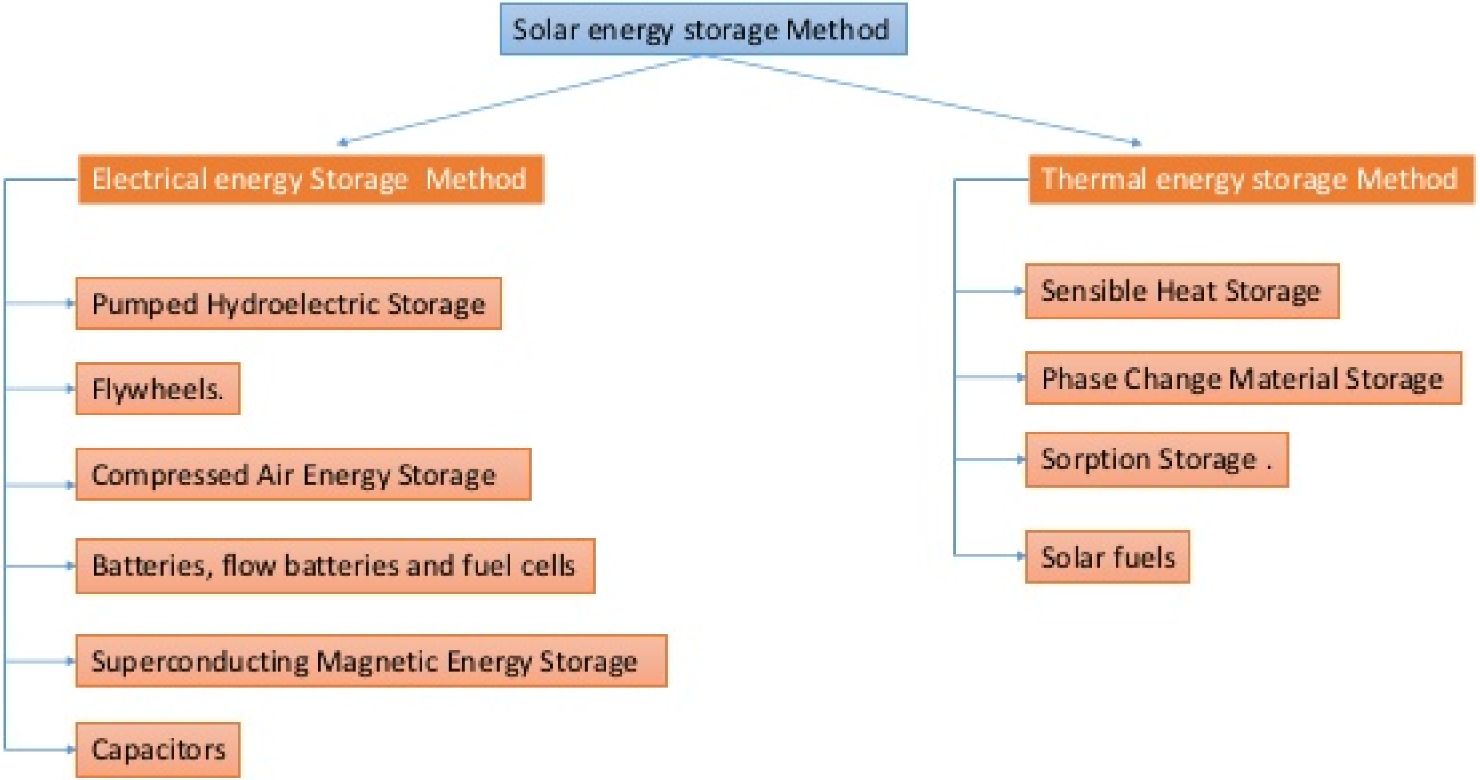
Thermal energy is typically stored in a thermal reservoir for later usage.Thermal energy storage can also be classified according to usage. Thermal energy harvested from a solar source can be stored via thermal physical reaction, i.e. using the temperature difference of materials (or phase changes) to store energy.



- THERMAL ENERGY STORAGE:- thermal energy can be stored directly. In sensible heat storage, such as steam or hot water, by changing the temperature of materials (liquid or solid) during peak hour energy, the energy is stored by temperature difference of the material. In latent heat storage, such as phase change materials, by changing the phase of materials.

- SORPTION STORAGE:- in sorption storage, two chemicals, which are bonded together under standard conditions, are separated using peak hour energy. Energy is released when the two chemicals are mixed and exposed to standard conditions. The choice of materials has great impact on the performance of the storage system.

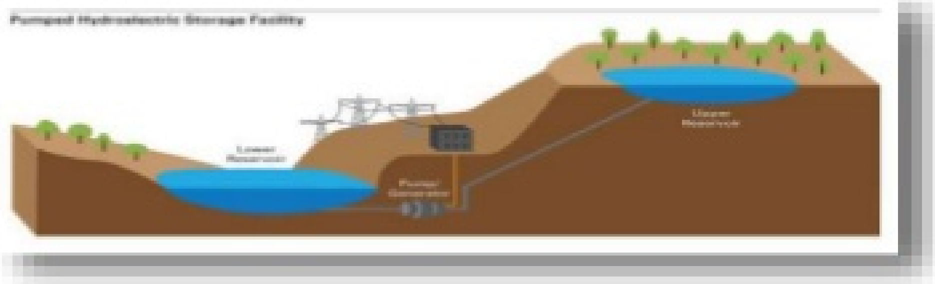
- CHEMICAL ENERGY STORAGE:-heat generated from concentrated solar power is used to carry out endothermic chemical transformation and produce storable and transportable fuel. Examples are solar hydrogen, solar metal and the solar chemical heat pipe.


Solar energy storage Method
Electrical energy Storage Method
Thermal energy storage Method
Pumped Hydroelectric Storage
Flywheels.
Compressed Air Energy Storage
Batteries, flow batteries and fuel cells
Superconducting Magnetic Energy Storage
Capacitors
Sensible Heat Storage
Phase Change Material Storage
Sorption Storage .
Solar fuels

Electrical Energy Storage Methods

1. Pumped Hydroelectric Storage

- Pumped hydroelectric storage has the largest storage capacity that is commercially available.
- The basic idea is simple: use the excess electrical energy generated at off peak hours to pump water from a lower reservoir to a higher reservoir. The electrical energy is converted into gravitational potential energy.
- When the peak hour comes, the water then will be discharged from the higher reservoir to the lower reservoir. The potential energy of water converts into electrical energy as normal hydroelectric power plants do.
- Typically, a turbine will be used to generate electricity. maximum power output, for a PHS system is typically about 1000 MW.



2. Flywheels

- A flywheel energy storage system stores energy in the form of angular momentum.
- During peak time, energy is used to spin a mass via a motor.
- At discharge, the motor becomes a generator that produces electricity.
- The system is usually kept in a vacuum containment at pressures around 10-6-10-8 atm.
- The energy storage capacity depends on the speed, the mass of the spinning object and the size of the flywheel.

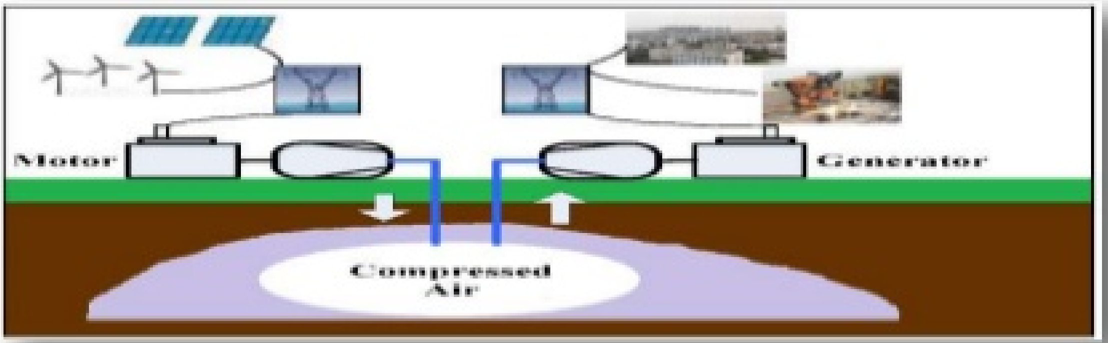
$$E \equiv \frac{1}{2} m V^2$$

where E is the energy stored, and m and V are the mass and velocity of the spinning object, respectively.

Some flywheels can store 25 kWh of energy

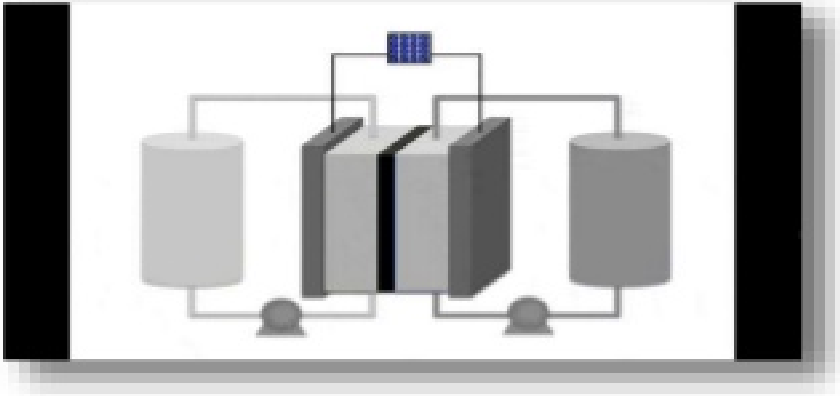
Compressed Air Energy Storage

- The basic idea of a CAES system is to use the off peak excess electricity to compress air.
- During off peak hours, excess electricity can be used to run an air compressor to compress air into underground caverns.
- During discharge, the compressed air is released and a conventional gas turbine is used to generate electricity. The pressure for the compressed air is typically from 4.0 to 8.0 MPa.
- The storage capacity of CAES system depends on the size of the underground cavern. A cavern size of 700,000 m3 corresponds to a capacity of 1500 MWh.



Batteries, flow batteries and fuel cells

- A battery is an electrochemical cell that converts stored chemical energy into electrical energy.
- Rechargeable batteries can have their chemical reaction reversed by supplying electrical energy to the cell; therefore, they can be used to store electricity generated by solar panels.
- Battery Performance is evaluated by the following characteristics: energy and power capacity, efficiency, life span, operating temperature, depth of discharge, self-discharge (loss during storage) and energy density.



Superconducting Magnetic Energy Storage

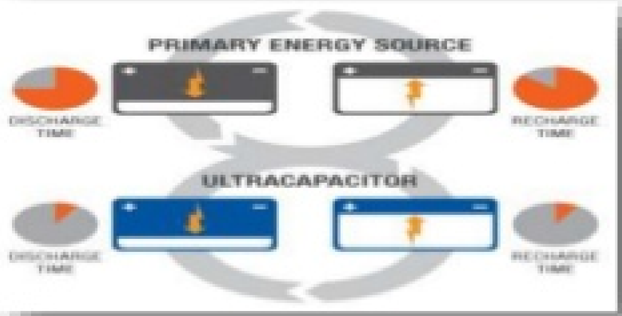
- The superconducting magnetic energy storage method stores electrical energy in magnetic field generated by direct current.
- Direct electrical current passes through a coil made of superconducting materials.
- The device is kept at low temperature, 50 – 77 K to maximize the efficiency.
- The low temperature keeps the coil at superconducting state, the resistance becomes small or zero, thus, the energy can be stored in a persistent mode.
- The energy stored in the magnetic field is calculated from:

$$E = \frac{1}{2} L I^2$$

where E is the energy stored, L is the inductance of the coil and I is the current passing through it.

Capacitors

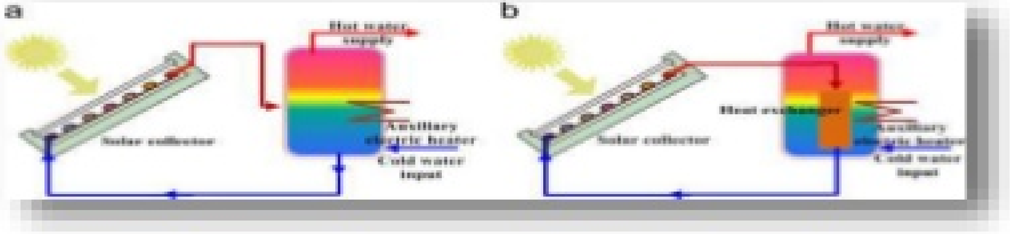
- Super-capacitors, ultra-capacitors or electrochemical double-layer capacitors (EDLCs) are terms for the same high-capacitance electronic component.
- Their capacitance can reach thousands of Farads, making them alternative means of electrical energy storage.
- Those types of capacitors are based on the same principle as a double electric charge layer capacitor. Higher capacitance is achieved by using porous electrodes with large surface area.



Thermal Energy Storage Methods

Sensible Heat Storage

- Changing the temperature of materials (liquid or solid) by using solar energy generated at its peak hour, energy is stored by the temperature difference of the material with the original temperature.
- Some examples include solar water and air heaters, graphite and concrete storage.
- The concept of solar water and air heaters is simple: using the solar radiation to store thermal energy in air and water.
- This storage method is getting popularity due to its relative low cost and simple manufacturing process but the density of thermal storage is low.
- For concrete storage, 20 m3 of concrete storage material can store up to 400 kWh of energy.



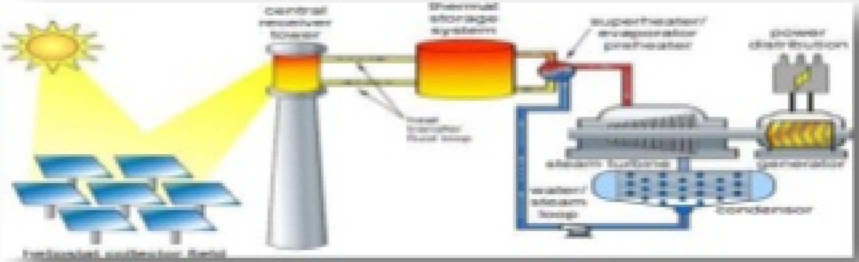
Phase Change Material Storage

- Latent heat refers to the energy associated with phase change of a material. When a material undergoes a phase change, heat is absorbed or released. The latent heat materials store about 5- 14 times more heat per unit volume than sensible heat storage materials. The energy stored during a phase change can be calculated as:

$$E = mL$$

where m is the mass of the material that has a phase change and L is the latent heat associated with the phase change.

- The methods often fail because of poor thermal conductivity of the PCM material. The PCM can turn into two different phases in the same container and effective heat transfer cannot be achieved. PCM materials perform best in small containers such as cells.



Sorption Storage

- Sorption is the fixation or capture of a gas or a vapor (sorbate) by a solid or liquid substance (sorbent).
- The sorption of gas by liquid is called absorption while the sorption of gas by solid is called adsorption.
- Adsorption includes two mechanisms: thermo-physical reaction by Van der Waals forces (physisorption) and thermo-chemical reaction by valence forces (chemisorption).
- Chemisorption processes typically store more heat per unit mass than physisorption but may be irreversible.
- The principle of using sorption (also for thermochemical storage) to store energy is based on a reversible physico-chemical reaction. The A/B is defined as the working sorbate/sorbent couple. When heat is introduced to the system, AB is split into compounds A and B; this is the regeneration or charging phase:

$$\text{AB} + \text{Heat} \Leftrightarrow Sorbate\ A + Sorbent\ B$$

- The compounds A and B have to be stored separately.
- This way, solar thermal energy is stored as the chemical potential of A and B with negligible loss, which gives sorption the potential for long-term storage. When A and B are mixed, A is fixed onto B to form AB, releasing heat; this is the discharging phase. The reversible reaction can be used to store and release energy as needed. Sorption materials have the highest storage density of all repetitive storage media.

Solar fuels

- The principle of solar fuels is Using optical devices, scattered sunlight can be concentrated and the heat generated from concentrated solar power can be used to carry out endothermic chemical transformation to produce storable and transportable fuels.

- A few examples are solar hydrogen, solar metal and the solar chemical heat pipe. The engine which combust hydrogen to generate power is called the hydrogen engine.

- There are three different ways to generate hydrogen with solar power: electrochemical, photochemical and thermochemical.

- Electrical energy can be directly stored as solar fuel as well.

- It is not efficient to convert electricity into thermal energy and then produce hydrogen, therefore, this option is not considered.

- By using the thermochemical route, water and fossil fuel can be used as sources for hydrogen.