# Lecture 26: Energy Storage

**Course:** MECH-422 – Power Plants

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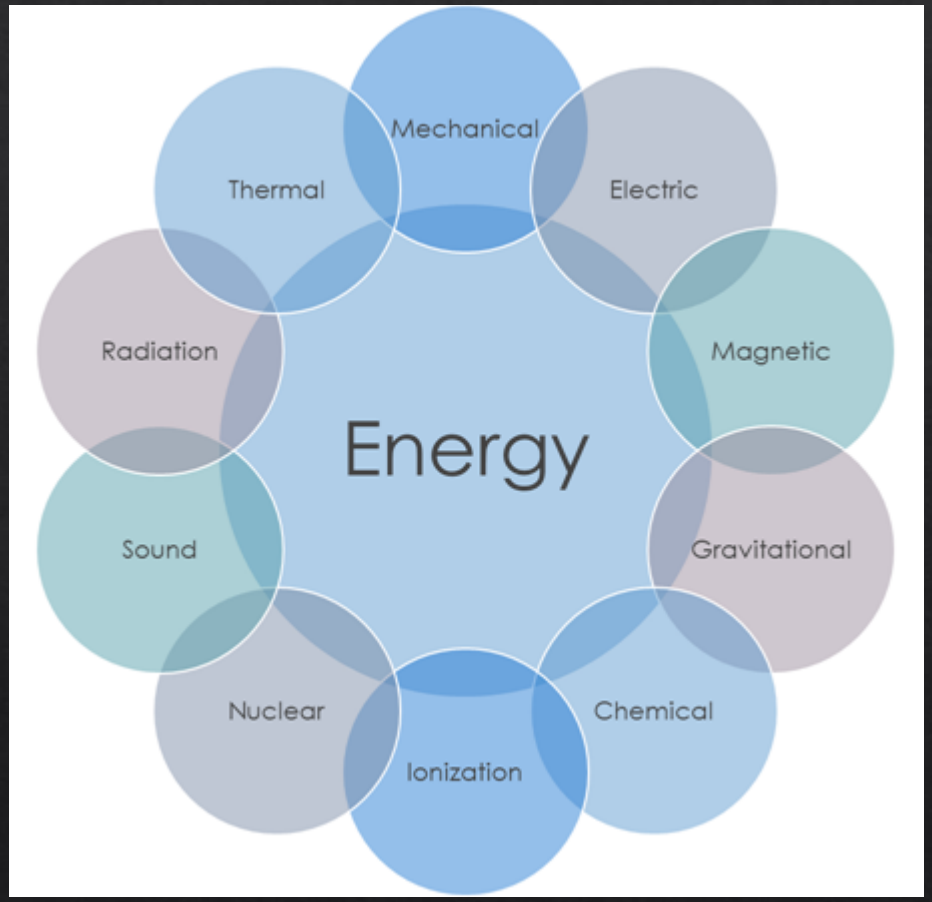
**Term:** Fall 2021

BUITEMS – DEPARTMENT OF MECHANICAL ENGINEERING

# Energy

Energy is defined as a quantitative property held by an object or a system that can be consumed to perform work or convert the form of energy.



# Energy Storage

- An Energy Storage System (ESS) is defined by the quantity of energy and power it is capable of storing (MWh and MW).

- Why?
  - Grid Flexibility – Handling Fluctuations
  - Resource uncertainty

# History

- The first electrical energy storage systems appeared in the second half of the 19th Century with the realization of the first pumped-storage hydroelectric plants in Europe and the United States.

- Storing water was the first way to store potential energy that can then be converted into electricity. Pumped-storage hydroelectric plants are very important for electrical systems, as they accumulate energy in periods where the demand is low and give back the energy stored once the demand increases.

# Types of Energy Storage Systems

# Energy Storage Technologies (EST)

## CLASSIFICATION OF TECHNOLOGIES

### MECHANICAL EST

- Pumped hydro EST (2)
- Compressed air EST (7)
- Liquid air EST (3)
- Flywheel EST (3)
- Gravity EST (2)

### CHEMICAL EST

- Conventional batteries (12)
- High-temperature batteries (3)
- Flow batteries (3)
- Metal-air batteries (3)
- Fuel cell batteries (5)
- Others (5)

### ELECTRO-CHEMICAL EST

- Superconducting magnetic EST (2)
- Supercapacitors (1)
- Other capacitors (1)

### THERMAL EST

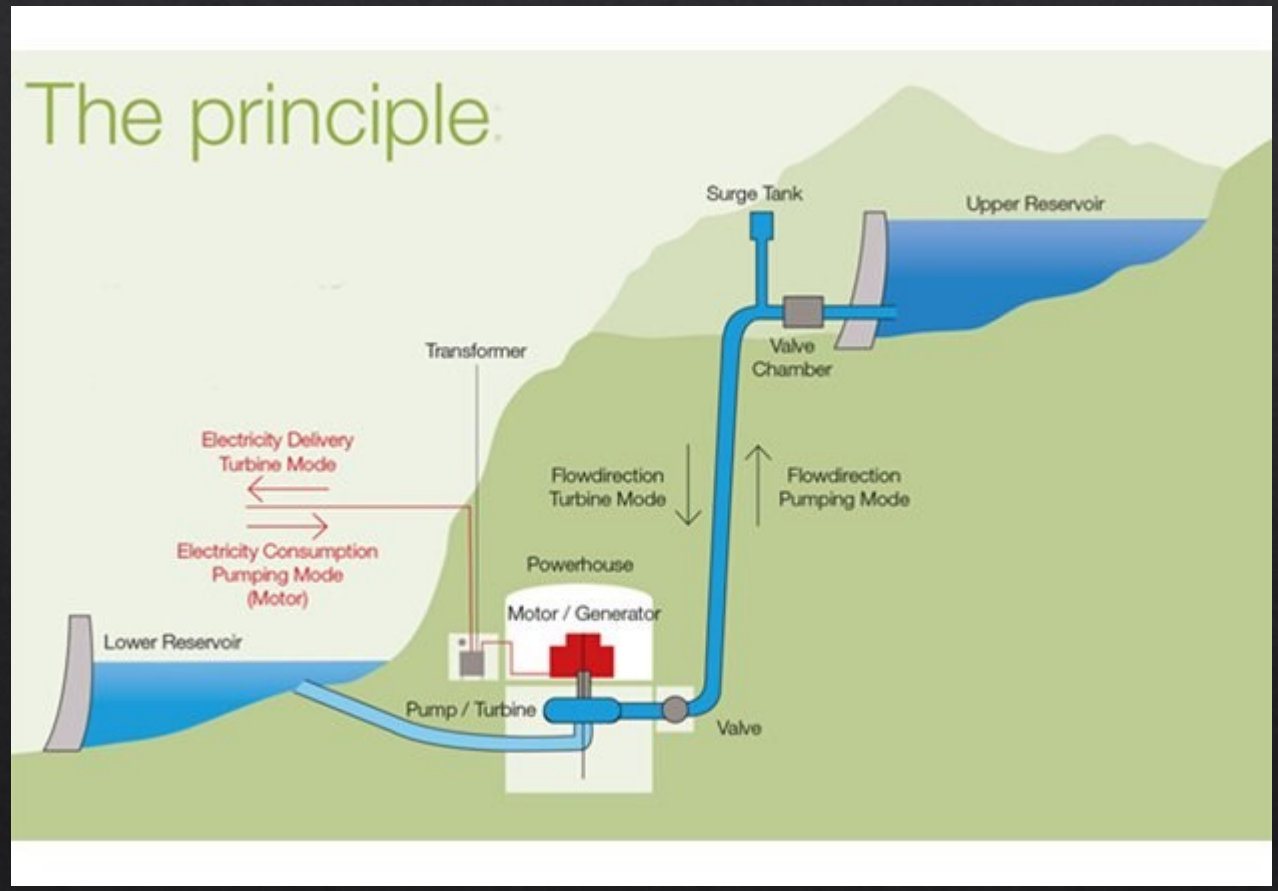
- Pumped thermal EST (1)
- Hot/cold thermal EST (2)
- Sensible/latent/reaction heat EST (3)
- Cryogenic EST (1)
- Molten salt EST(1)
- Underground(aquifer) EST (1)

# 1. Pumped Hydroelectric Energy Storage

Potential Energy Storage (Hydroelectric Pumping)

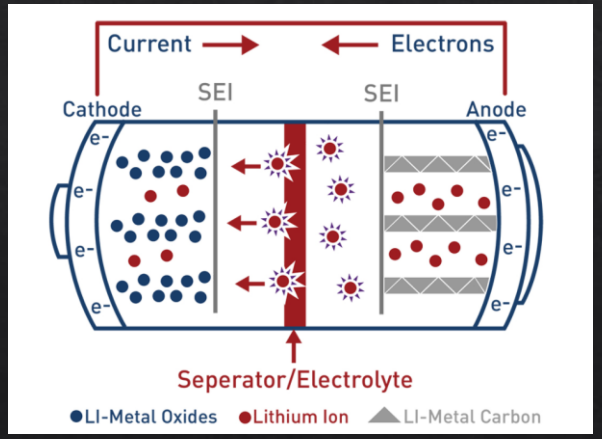
Operation:

- It consists of two large reservoirs located at different elevations.
- During peak demand, water is released from the upper reservoir.
- If Production exceeds Demand, water is pumped up and stored in the upper reservoir.



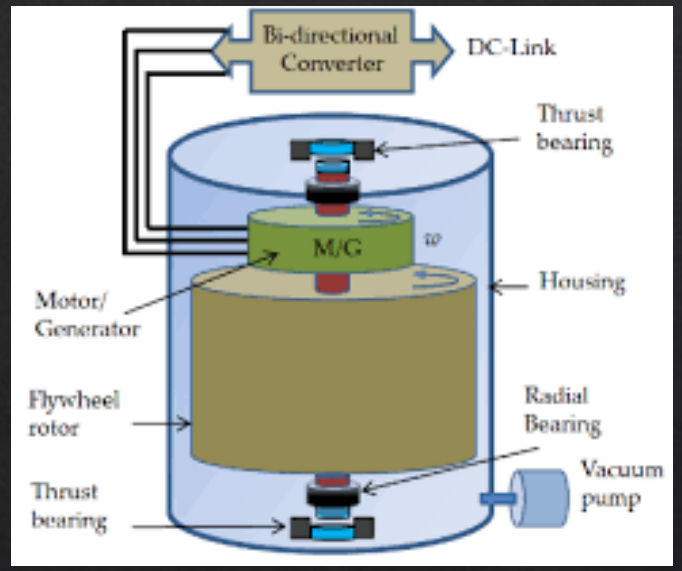
# 2. Electrochemical Energy Storage (Batteries)

- This kind of storage system is based on chemical reactions associated with the elements used to manufacture the battery.
- The common battery is composed of cells, with two electrodes (anode and cathode) and an electrolyte.
- Chemical reactions within the battery provide the electromotive force required for the flow of electric current.

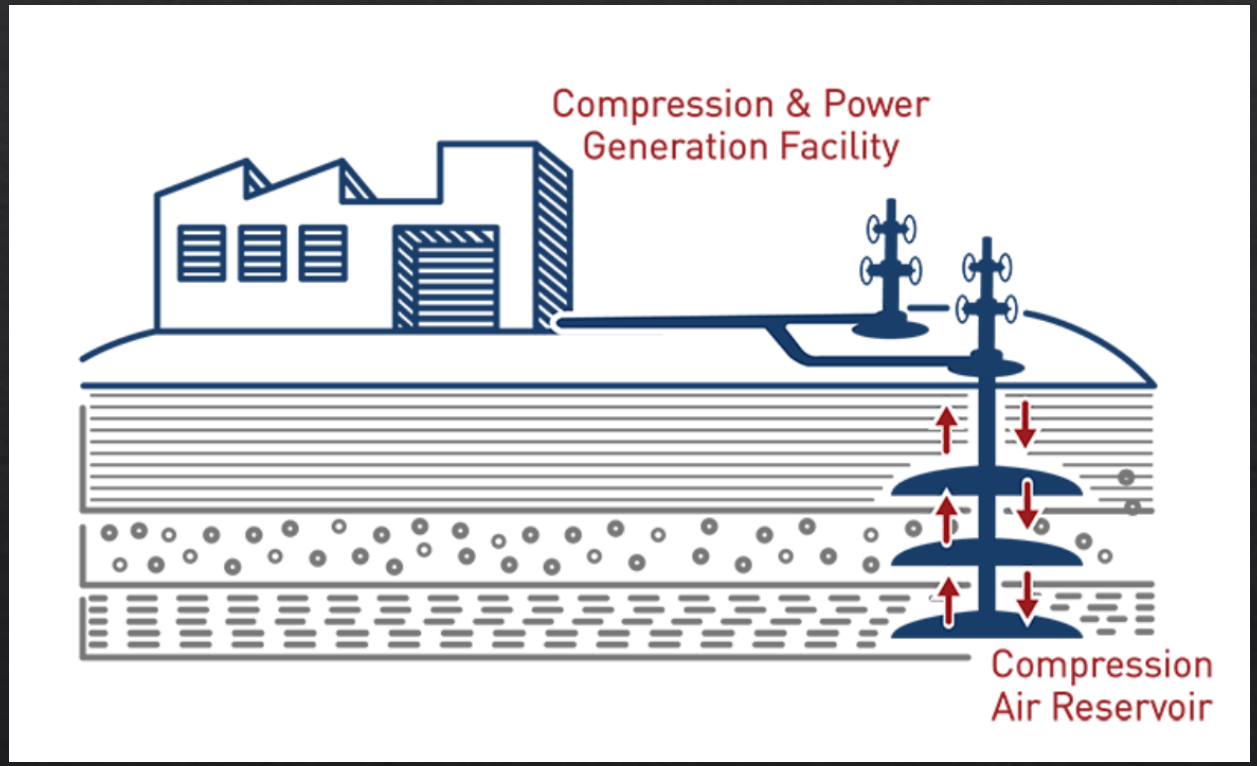
# 3. Mechanical Energy Storage (Flywheels, CAES)

- Flywheel energy storage systems (FESS) use electric energy input which is stored in the form of kinetic energy. Kinetic energy can be described as "energy of motion," in this case the motion of a spinning mass, called a rotor. The rotor spins in a nearly frictionless enclosure. When short-term backup power is required because utility power fluctuates or is lost, the inertia allows the rotor to continue spinning and the resulting kinetic energy is converted to electricity.



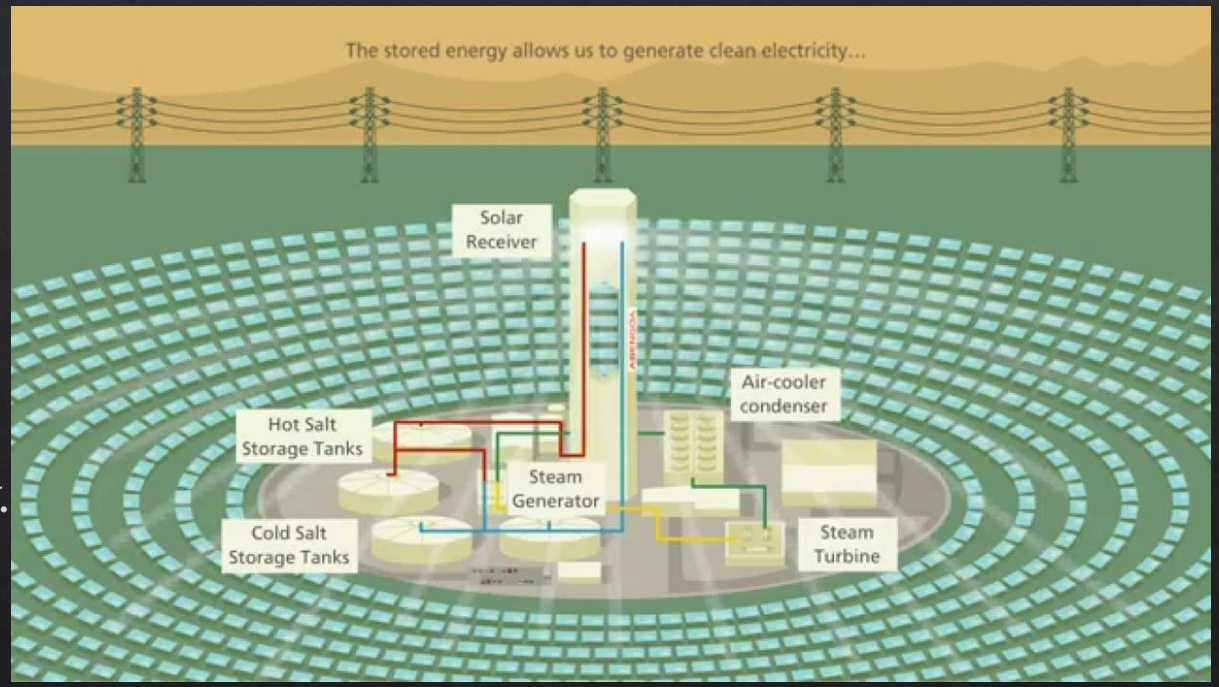
# Compressed Air Energy Storage

- Compressed Air Energy Storage or CAES stores energy in the form of compressed air in an underground reservoir for use at a later time.
- CAES is very similar to pumped hydro power in storage concepts, however, usage of the stored air is different than simply releasing water through a turbine.
- CAES systems release the pressurized air by heating it in order to expand it, which then turns a turbine, generating electricity.



# 4. Thermal Energy Storage (TES)

- Thermal energy storage takes excess energy and stores it in various materials, including rocks, cement, storage tanks, hydrogen, and in liquid air.
- This is really a transfer of energy into a material that is capable of storing the energy for a longer time frame instead of wasting the excess or less expensive energy.
- A great example of this is solar thermal water heating.



# Types of Thermal Energy Storage

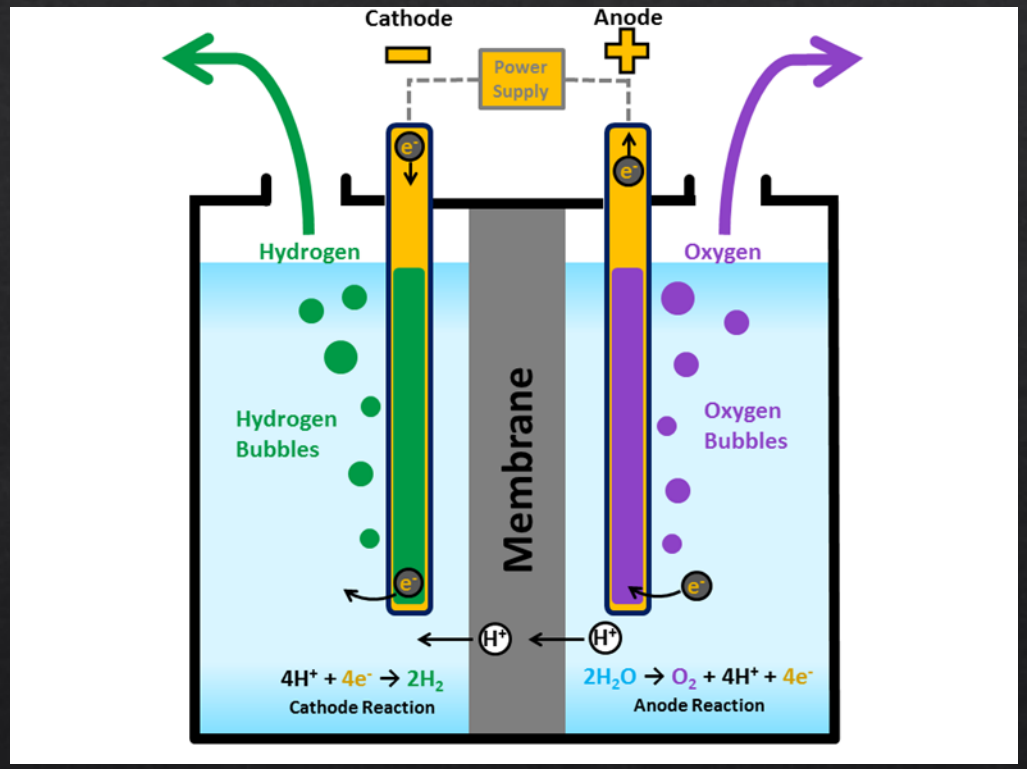
**Sensible Heat**
- Energy stored in vibrational modes of molecules (sand, concrete, molten salts, etc.)

**Latent Heat**
- Energy stored in media as it changes phase (ice/water, etc.)

**Thermochemical Energy**
- Energy stored in chemical bonds of molecules (metal oxides, reversible oxidation, etc.)

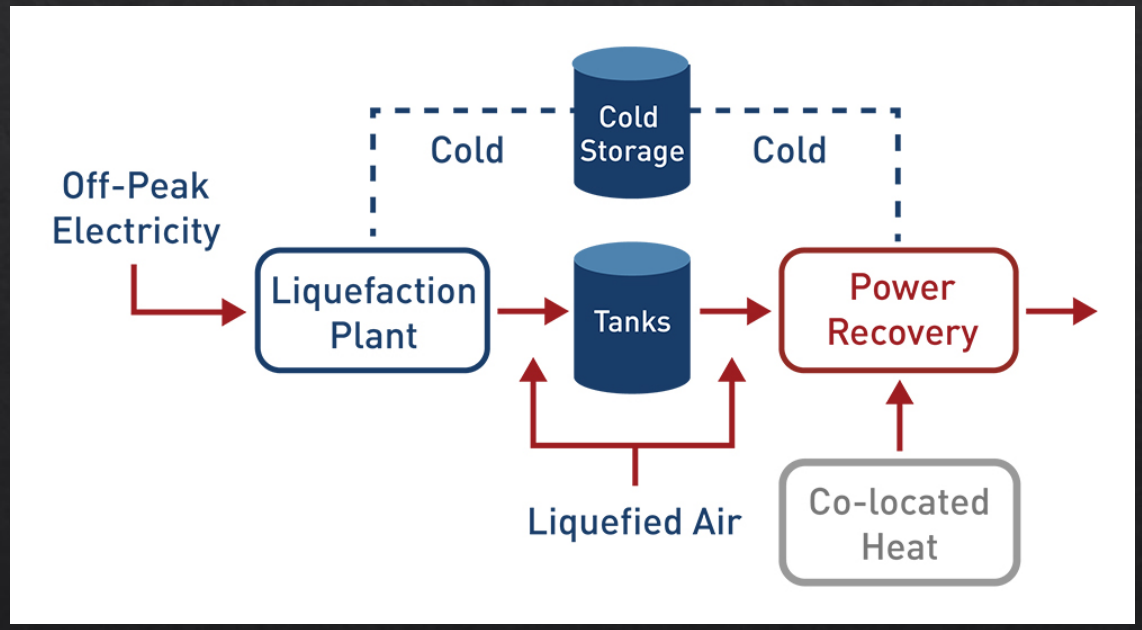
# Hydrogen Energy Storage

- Hydrogen Energy Storage stores electrical energy in hydrogen through electrolysis. This means electricity is used for hydrogen production through a process called electrolysis where water molecules are split into oxygen and hydrogen ions. The oxygen is released, and the hydrogen is stored in pressurized containers and can be used as a fuel to be burned in combined cycle gas fired power plants or re-electrified later through fuel cells.



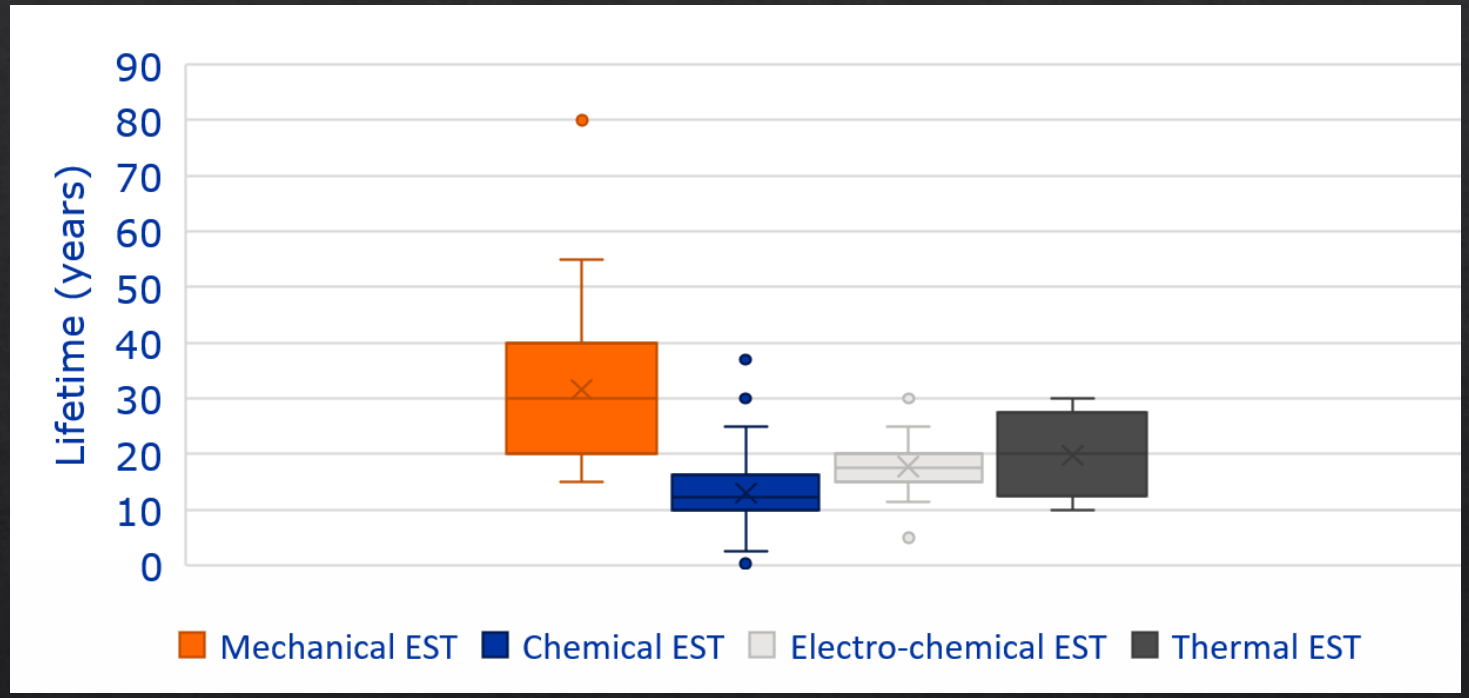
# Liquid Air Energy Storage

- Charging occurs when electrical energy pulls air from the environment, cooling the air until it liquefies and is then stored in an insulated tank at low pressure until it is needed later.
- When the energy is needed, the liquid air is pulled from the tank and pumped to a higher pressure, where it evaporates and is heated, producing a high-pressured gas that is used to turn a turbine.

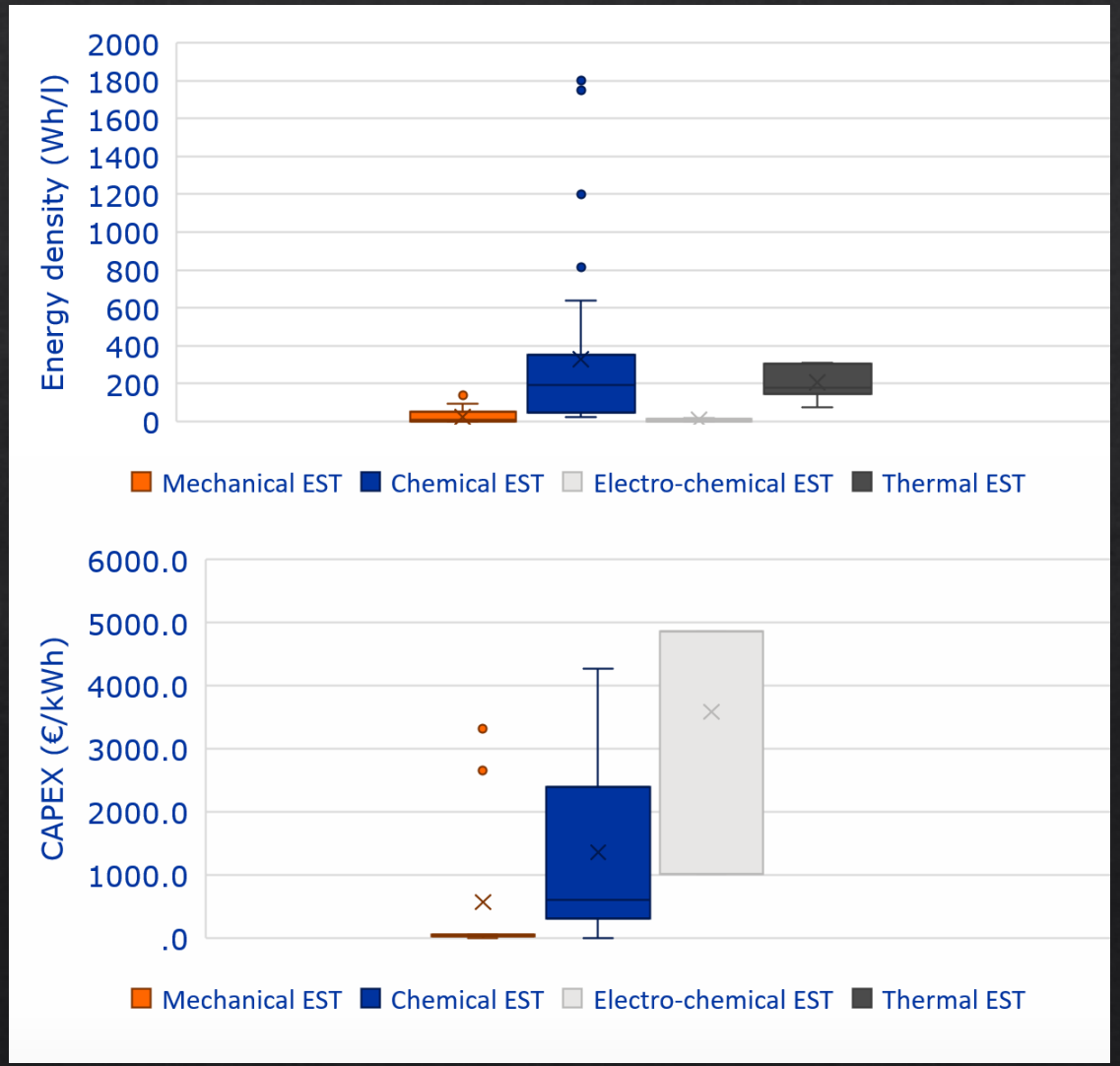


## AVERAGE LIFETIME

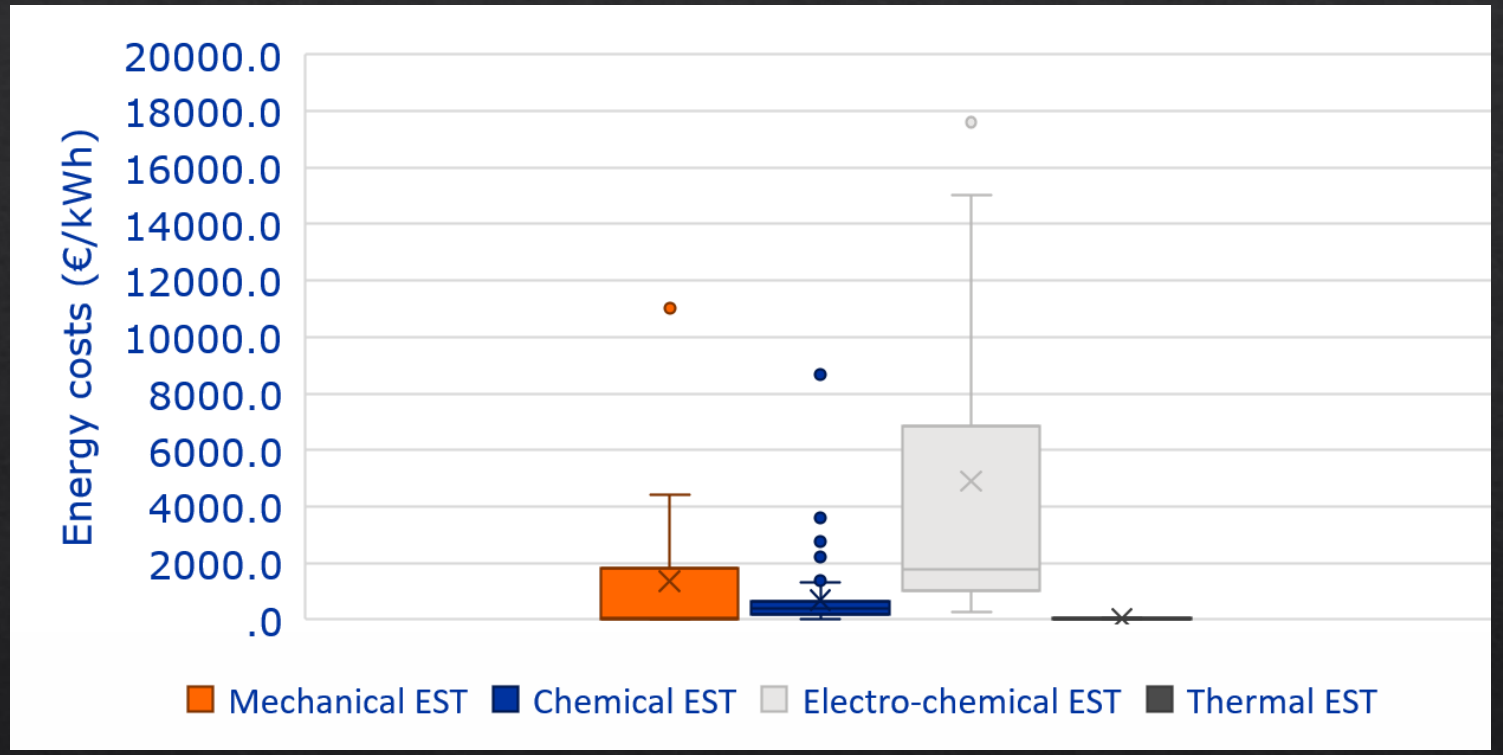
- Most frequently reported parameter
- Longest lifetime (years): mechanical EST with lifetime between 15 and 80 years



# Average energy density and capex



# Energy costs



# End of Lecture!