Mechanical Energy Storage

Flywheels, Pumped Hydro, Compressed Air Energy Storage

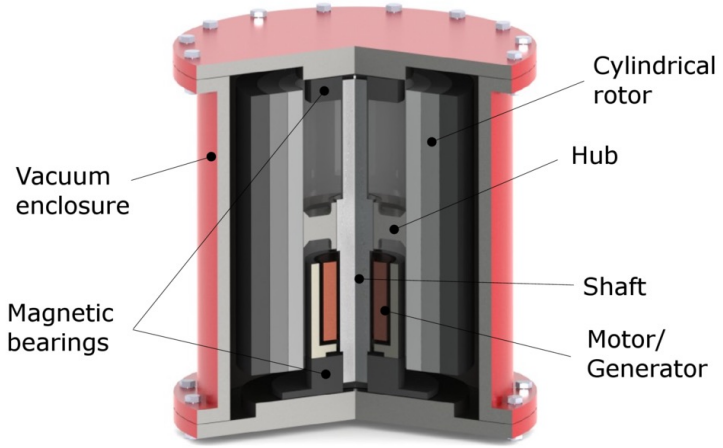
Recommended for grades 7 – 12

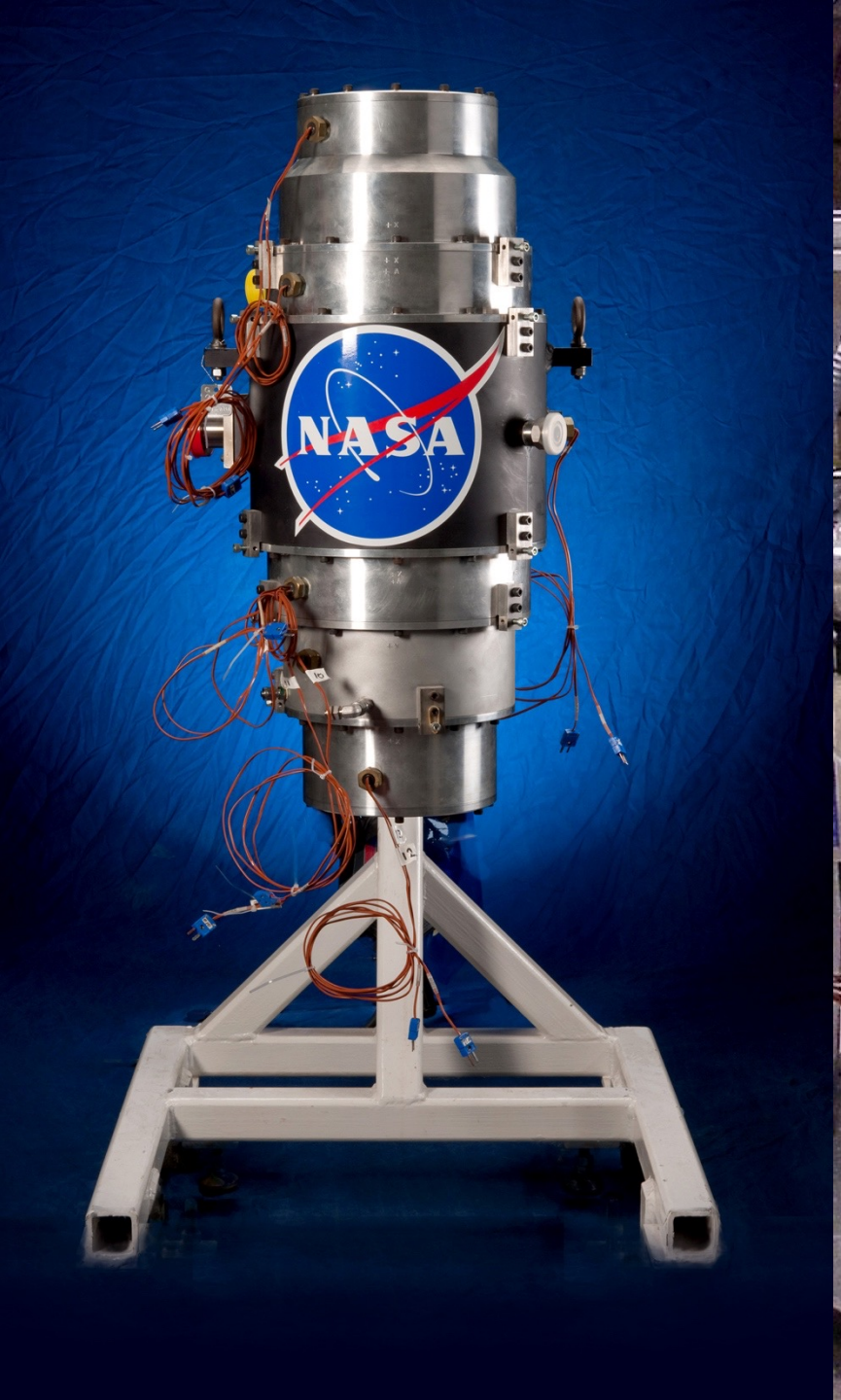
Mechanical Energy Storage

Chemical	Batteries, fuel cells, thermochemical energy storage
Electrical	Capacitors, supercapacitors, superconducting magnetic energy storage (SMES)
Mechanical	Flywheels, pumped hydro, compressed air energy storage (CAES)
Thermal	Low and high temperature storage

Flywheels

- Flywheels store rotational energy
- The energy is contained in the device when rotated at high speeds
- When energy is discharged, the rotational speed decreases
  - Principle of conservation of energy
- Alternatively, when energy is added, the speed increases
- Flywheels have a lifetime of decades with little maintenance
- Flywheels are 90-95% efficient and has an energy range of 25 kWh

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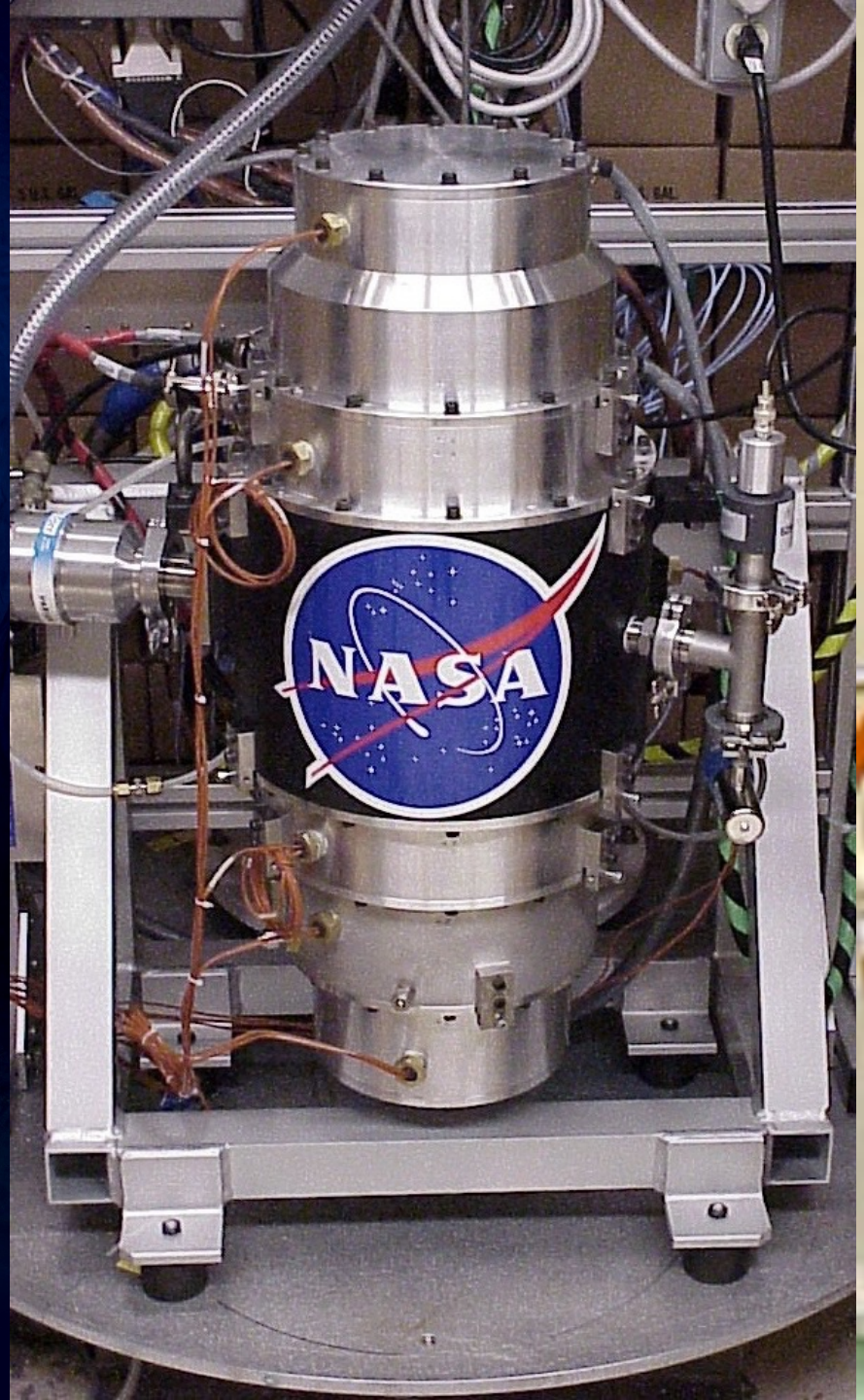
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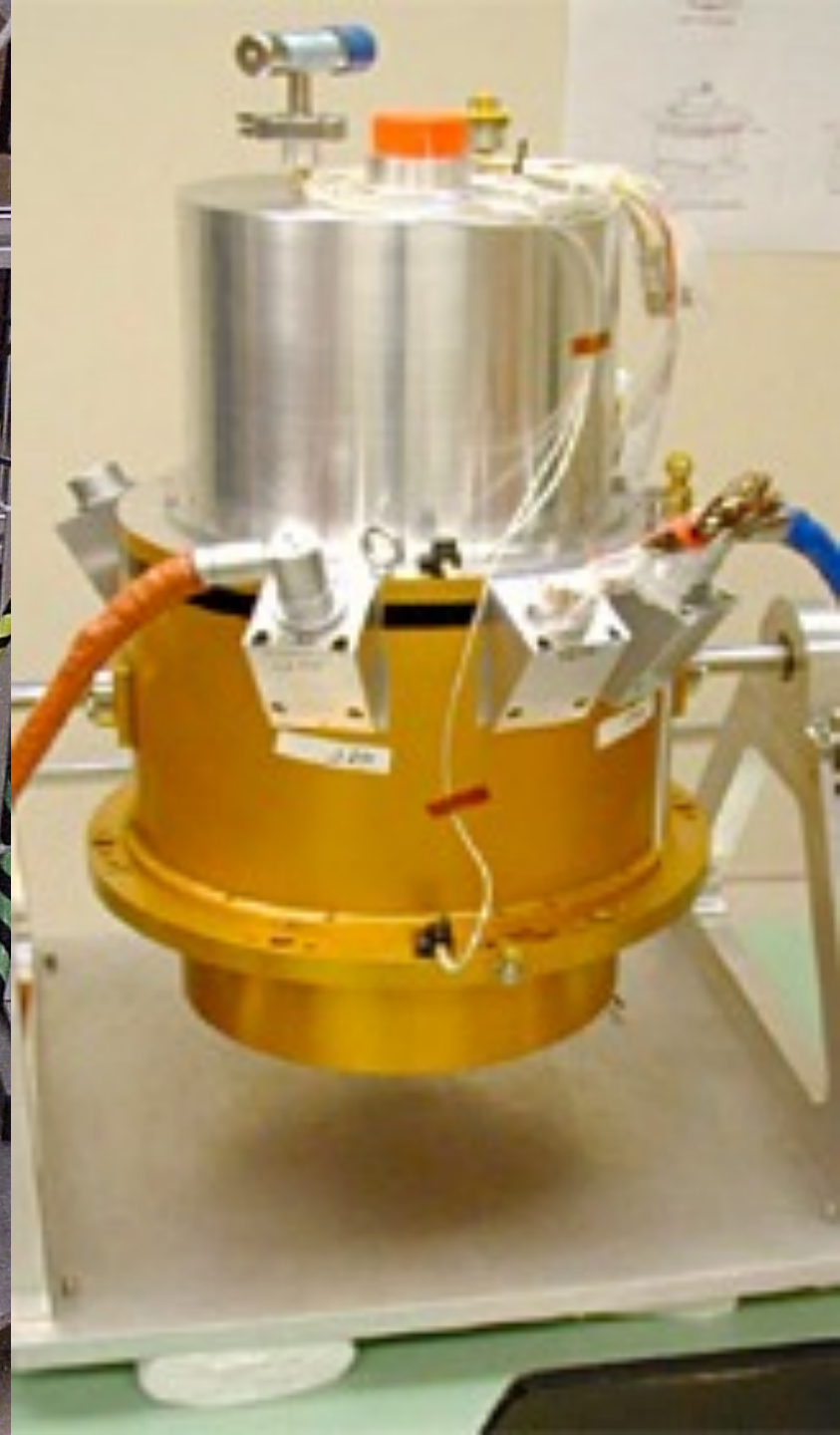
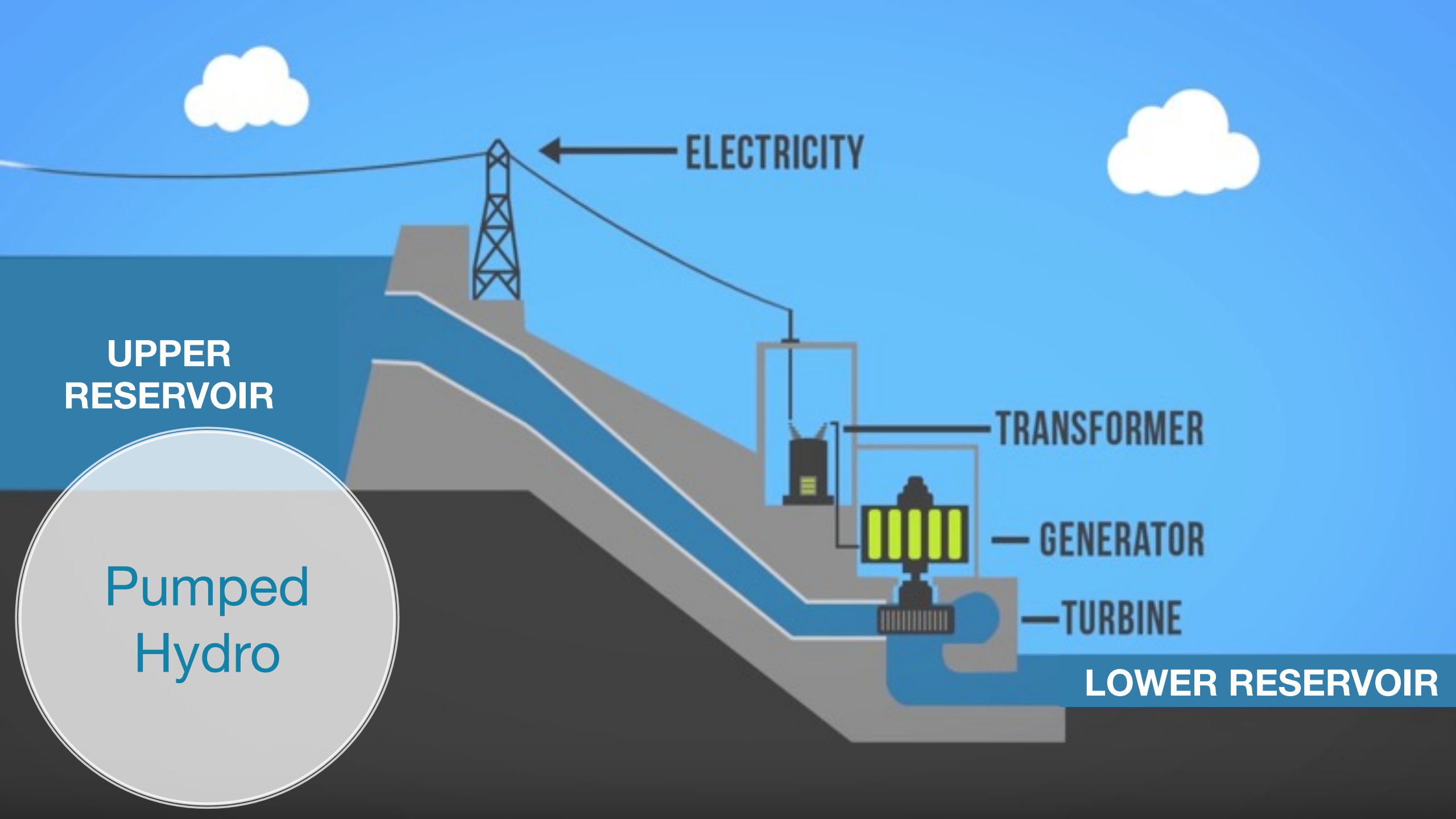
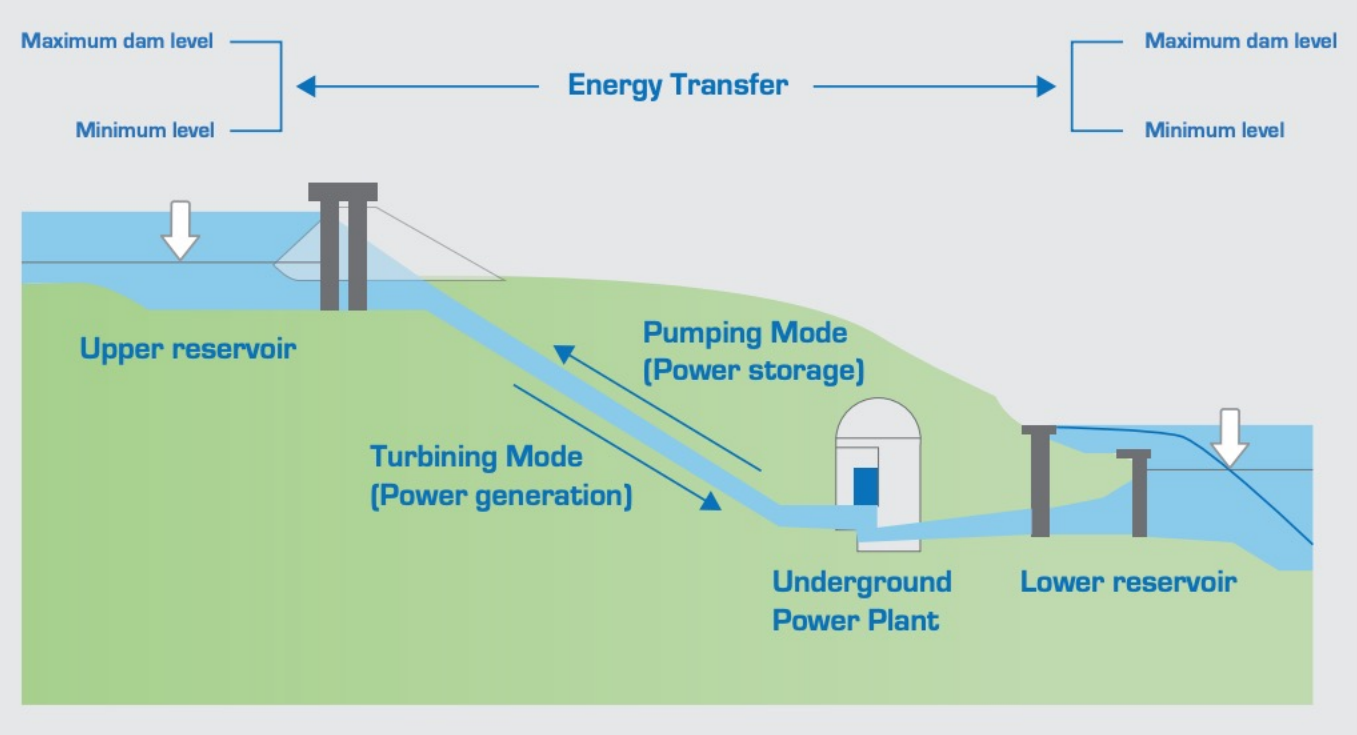




Pumped Hydro

Pumped Storage

Pumped storage hydro is like a battery



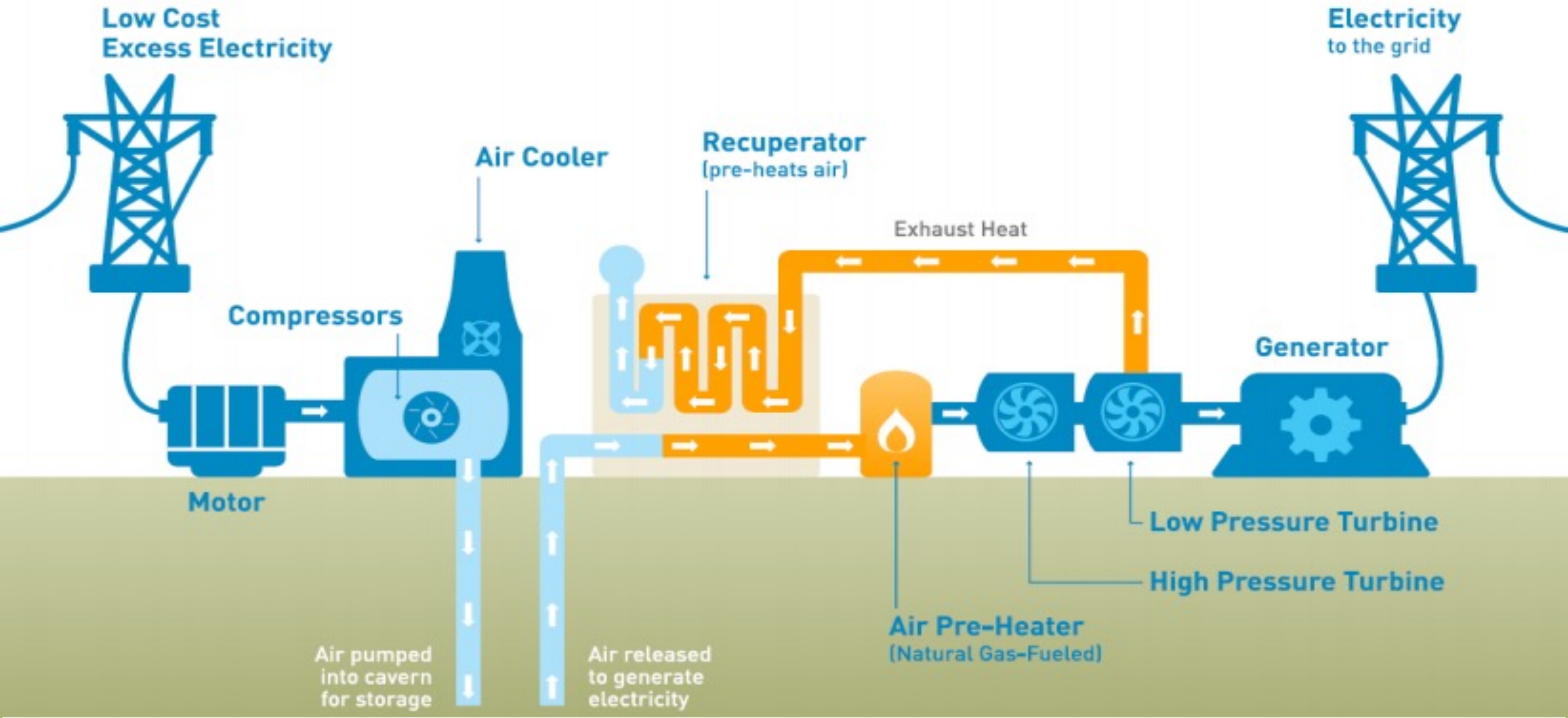
Pumped Hydro Storage Video

- Pumped-storage hydropower – Statkraft
  - 2 minutes, 30 seconds
  - https://www.youtube.com/watch?v=IsSUPpwtqhQ

Pumped Hydro Energy Storage

Key Performance Data – European Association for Storage of Energy

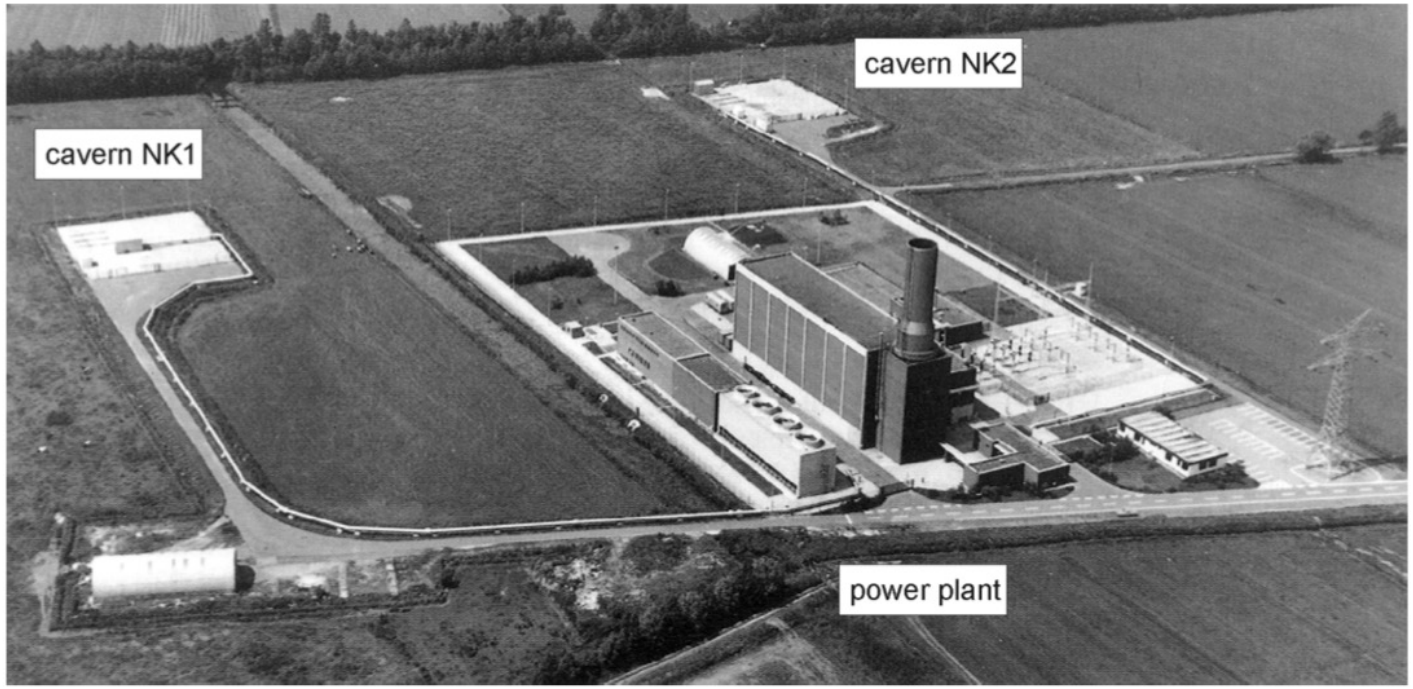
Power Range	10 MW – 3 GW
Energy Range	100's GWh
Discharge Time	Minutes – 10 hours
Life Duration	> 80 years
Reaction Time	Seconds - minutes
Efficiency	70-85%



Compressed Air Energy Storage (CAES)

The First Utility-Scale CAES – Huntorf, Germany

- Built in the 1978 in Germany
- Still in operation
- Nameplate capacity over 290 MW
- It uses two salt domes as the storage caverns, and it runs on a daily cycle with 8 hours of compressed air charging and 2 hours of operation at a rated power of 290 MW.



CAES Types

Diabatic Storage

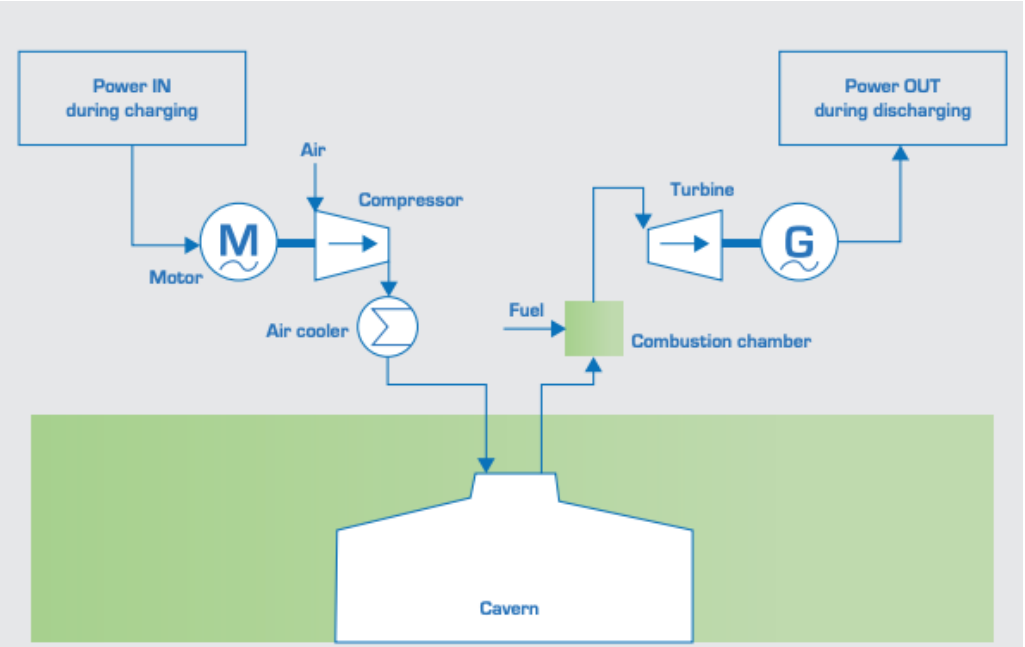
- Compresses air and stores underground. **Air is reheated with natural gas/fuel.**

Adiabatic Storage

- Compresses air for storage and retains the produced heat. **Recovered heat is used to generate electricity.**

Diabatic Compressed Air Energy Storage (D-CAES)

- The compression of air in underground caverns (typically salt caverns)
- Electricity being stored is used to compress air into the salt cavern between 500-800 metres deep and at a pressure of ~100 bar
- When energy is needed, the air is released and heated by natural gas/fuel combustion
  - This process expands the air, which drives a turbine and regenerates electricity.
- The use of natural gas in D-CAES is not completely emission free and is therefore considered a hybrid energy storage option.



European Association for Storage of Energy – D-CAES

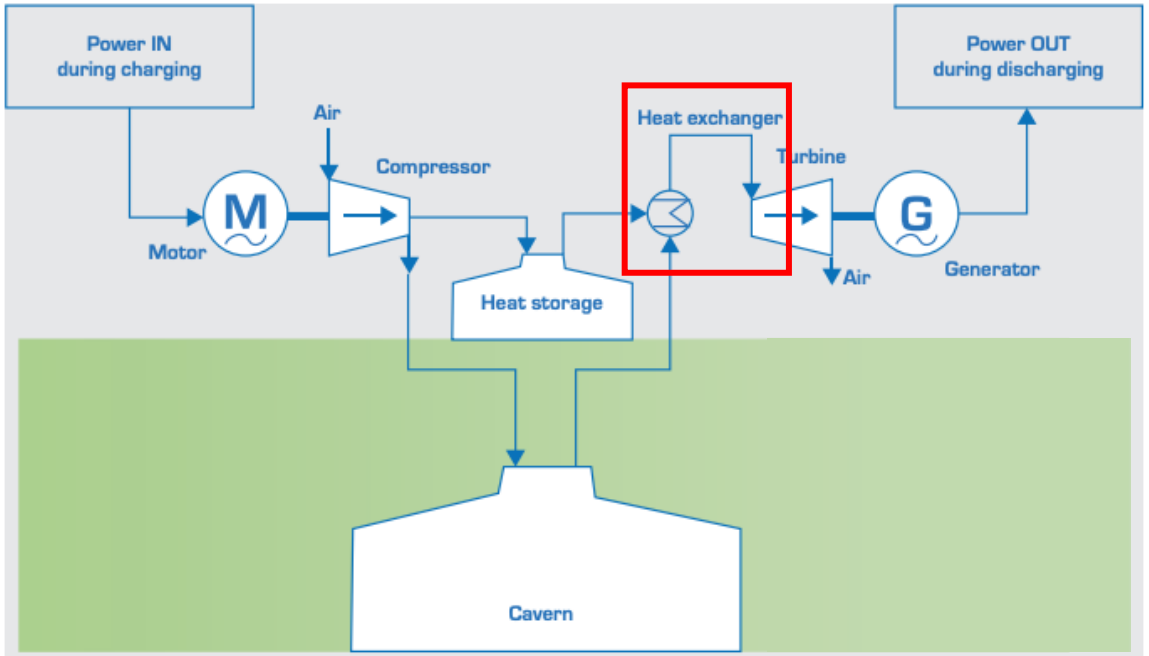
Diabatic Compressed Air Energy Storage (D-CAES)

Key Performance Data – European Association for Storage of Energy

Power Range	100's MW
Energy Range	100 MWh – 10 GWh
Discharge Time	1 – 10 hours
Life Duration	> 30 years
Reaction Time	Minutes
Efficiency	~55%
Applications	Load balancing, arbitrage, reserve, ancillary services

Adiabatic Storage (A-CAES)

- A-CEAS uses electricity to compress air and store in an underground cavern 100's of metres below ground and a pressure of ~100 bar
- The heat produced due to compression is stored with Thermal Energy Storage
- When energy is needed, the compressed air is released and drives a turbine to produce electricity
- At the same time, heat is recovered
- Adiabatic differs from diabatic in the sense that is **preserves** the heat
  - Diabatic releases the heat and reheats the air with fuel/gas
- A-CAES is an emerging technology and is currently not used at large scale



European Association for Storage of Energy – A-CAES

Adiabatic Compressed Air Energy Storage (A-CAES)

Key Performance Data – European Association for Storage of Energy

Power Range	100's MW
Energy Range	100 MWh – 10 GWh
Discharge Time	1 – 10 hours
Life Duration	> 30 years
Reaction Time	Minutes
Efficiency	~70%
Applications	Load balancing, reserve, ancillary services

Advantages and Disadvantages of Mechanical Energy Storage

ADVANTAGES	DISADVANTAGES

• Environmentally friendly
• Does not require hazardous chemical or harmful materials
• CAES can store large amounts of energy
• CAES has a fast response time
• CAES is a low-cost way to store energy
• High energy efficiency:
  • Flywheels – 80-90%,
  • Pumped Hydro – 75-80%,
  • CAES – 73-80%
	• Safety risk in the rare occasion more energy is loaded than the system can handle
	• Energy loss due to friction
	• CAES and pumped hydro have geography requirements

Mechanical Energy Storage Project in Canada

- Project: Goderich Adiabatic Compressed Air Energy Storage (A-CAES) Facility
- Developer: Hydrostor
- Location: Goderich, Ontario
- Description: 1.75 MW (discharge), 2.20 MW (charge) was commissioned in 2019. The project is the world's first commercial A-CAES facility. The facility is intended for peaking capacity, ancillary services, and market participation to support grid reliability. The facility produces zero greenhouse gas emissions!

*The charge and discharge capacities differ due to losses

https://www.hydrostor.ca/goderich-a-caes-facility/

Thank you!

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