Energy Storage Systems

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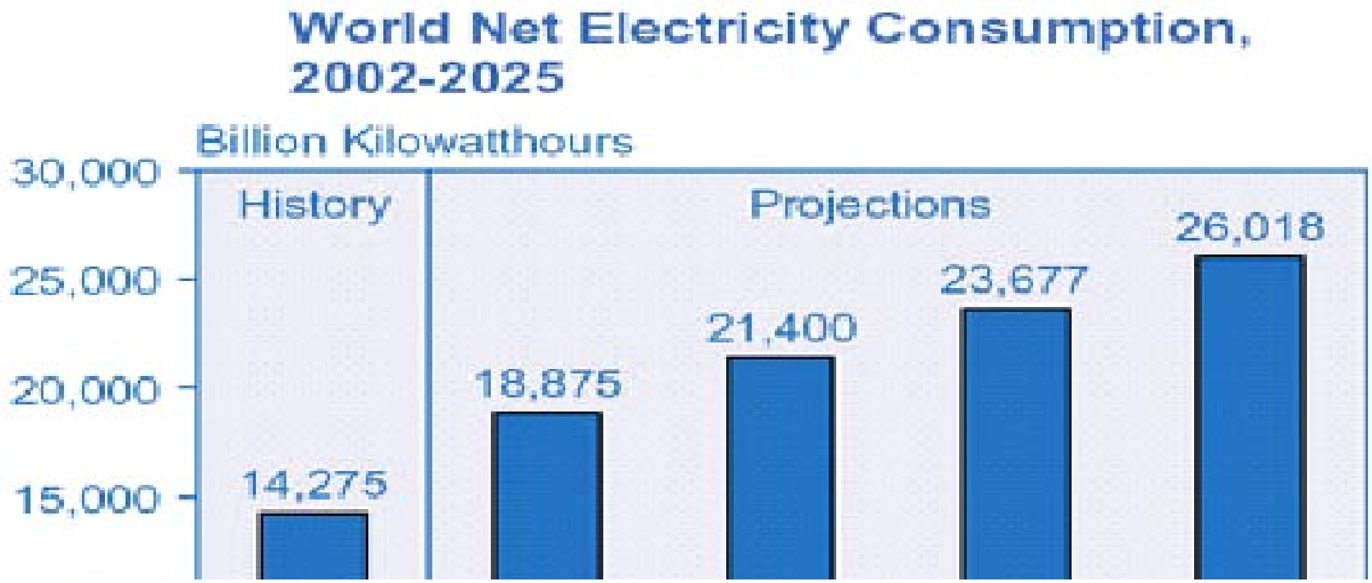
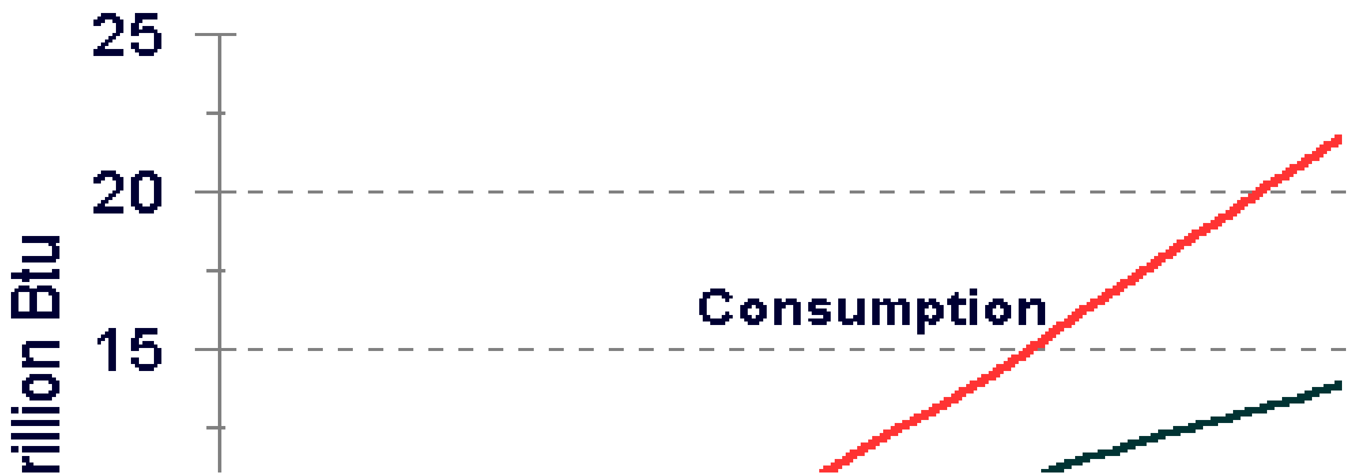

World Net Electricity Consumption, 2002-2025
Billion Kilowatthours
30,000
25,000
20,000
15,000
History
Projections
14,275
18,875
21,400
23,677
26,018

India's Energy Balance



Importance of ESS…

- Thrust for Renewable Energy sources
- Variable outputs
- Energy Buffering
- Importance in the present context
- Why new technologies and devices?

Different Types of ESS…

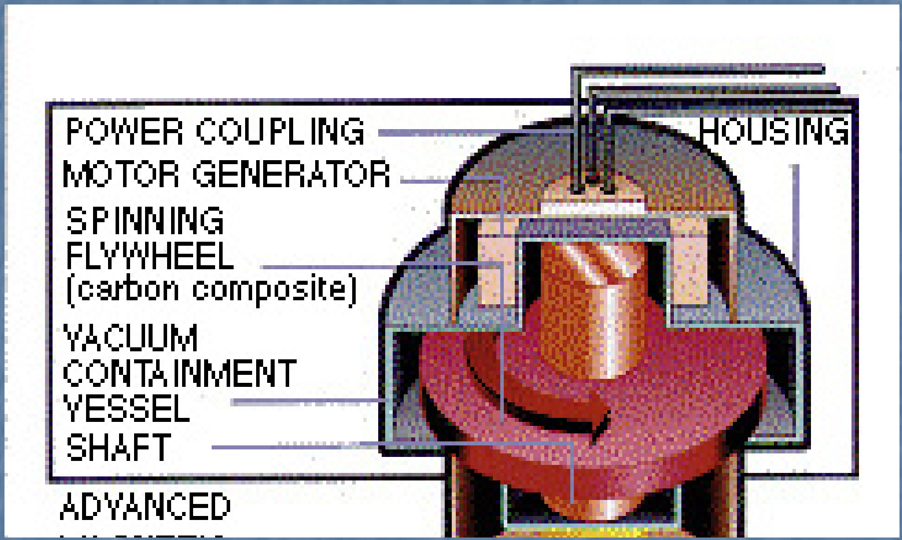
ESS can be classified as

- Mechanical Energy Storage.
- Magnetic Energy Storage.
- Thermal Energy Storage.
- Chemical Energy Storage.

Mechanical Energy Storage

Fly Wheels

- Principle: Energy is stored in the form of Mechanical Energy.
- Light weight fiber composite materials are used to increase efficiency.
- Energy density =0.05MJ/Kg, η=0.8



- The Energy Density is defined as the Energy per unit mass:

$$\frac{E}{m} = \frac{1}{2}V^2 = \frac{\sigma}{\rho}$$

- Where,

  V is the circular velocity of the flywheel
  σ is the specific strength of a material
  ρ is the density of the material

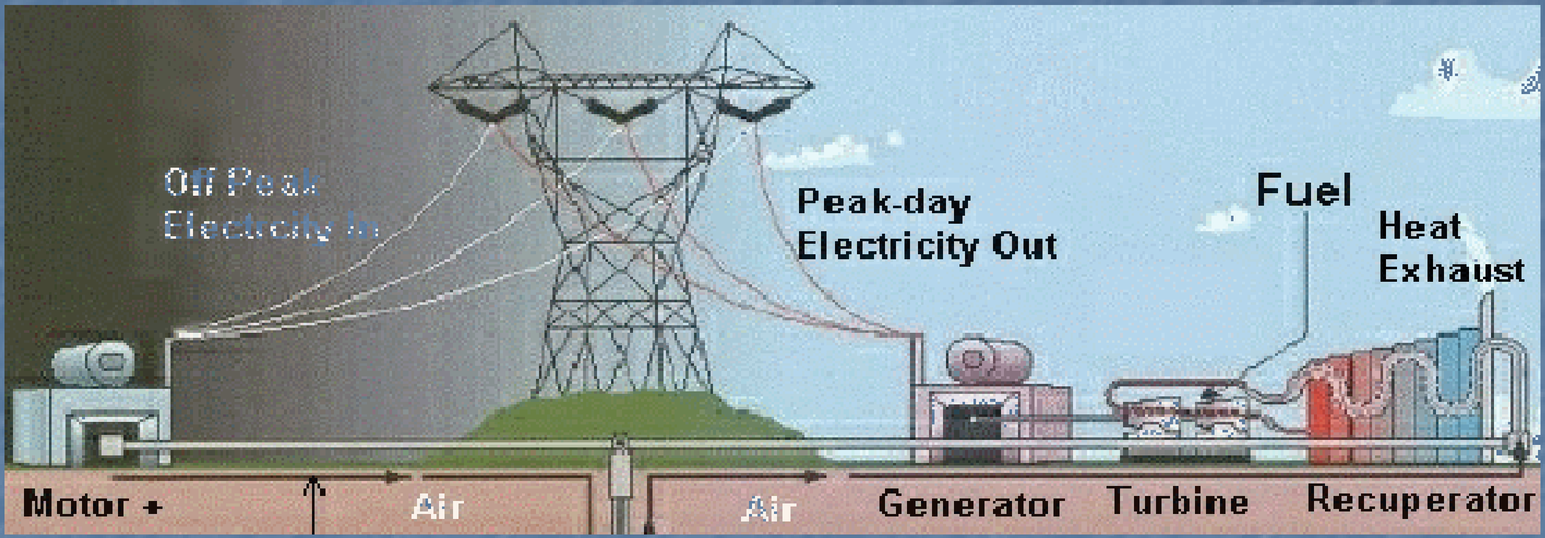
Properties of some materials used for building flywheels.

Materials	Density, ρ(Kg/m3)	Specific strength, σ(MNm/Kg)
Steel	7800	0.22
Aluminium alloy	2700	0.22
Titanium	4500	0.27
Glass fibre reinforced	2000	0.80

Advantages and disadvantages:

- Very compact when compared to other energy storage systems.
- Flywheels are used for starting and braking locomotives.
- A flywheel is preferred due to light weight and high energy capacity.
- It is not economical as it had a limited amount of charge/discharge cycle.

Compressed Air Energy Storage



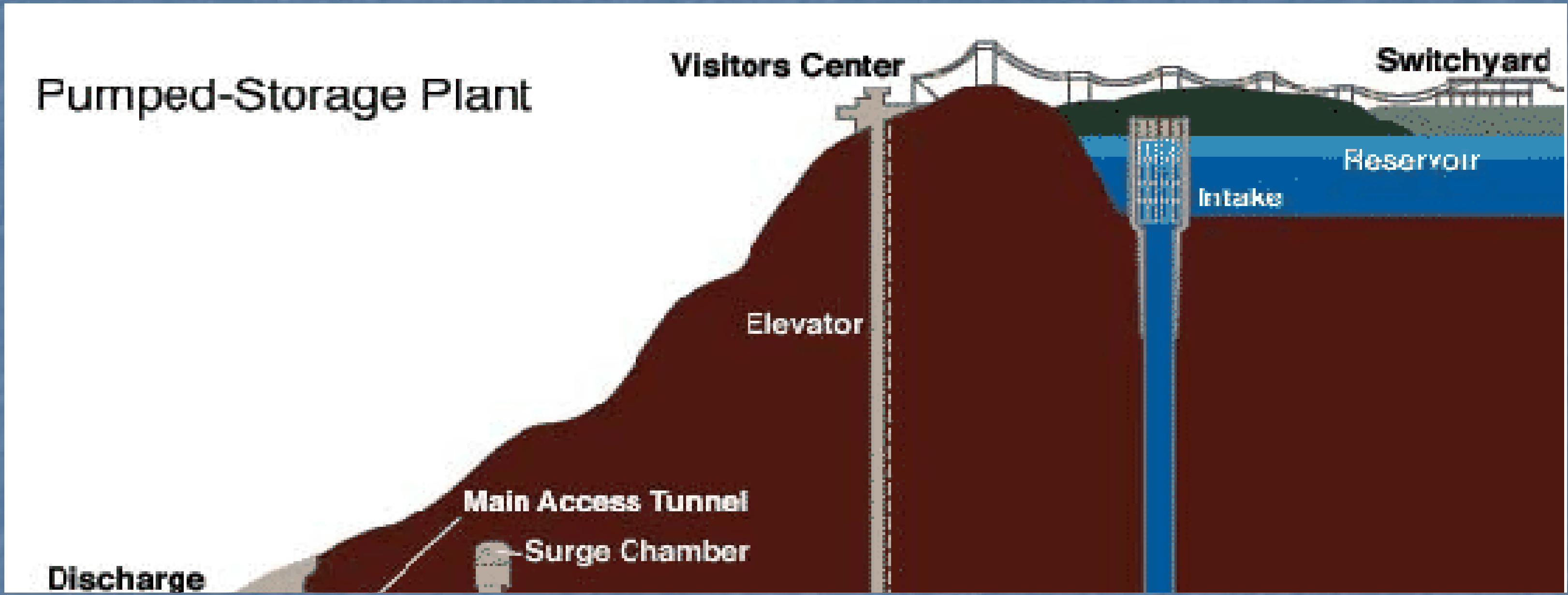
Operation:

- Uses off-peak electricity to compress air and store it in airtight underground caverns.
- When the air is released from storage, it expands through a combustion turbine to create electricity.
- Energy density = 0.2~2 MJ/Kg, η=0.5

Advantages and disadvantages:

- Fast start-up.
- Draw back - Geological structure reliance

Pumped Hydroelectric Energy Storage



Operation:

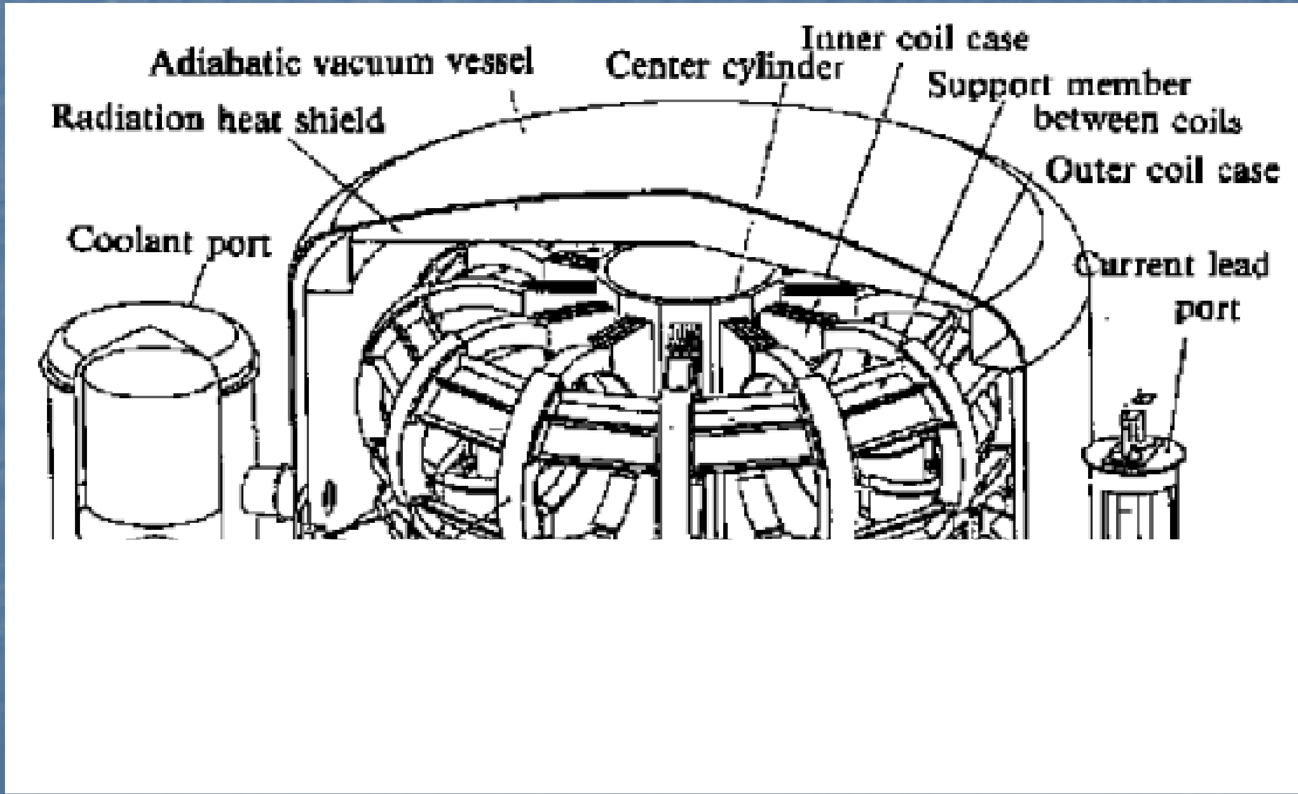
- It consists of two large reservoirs located at different elevations.
- During peak demand, water is released from the upper reservoir.
- If Production exceeds Demand, water is pumped up and stored in the upper reservoir.
- Pump used is a Combined Motor and Dynamo.

Advantages and disadvantages:

- Most effective with largest capacity of electricity (over 2000 MW).
- Energy density = 0.001MJ/Kg, η=0.8
- Geographical dependence.
- The capital cost is massive.
- Soil erosion, land inundation, Silting of dams.

Magnetic Energy Storage

Super Conductors



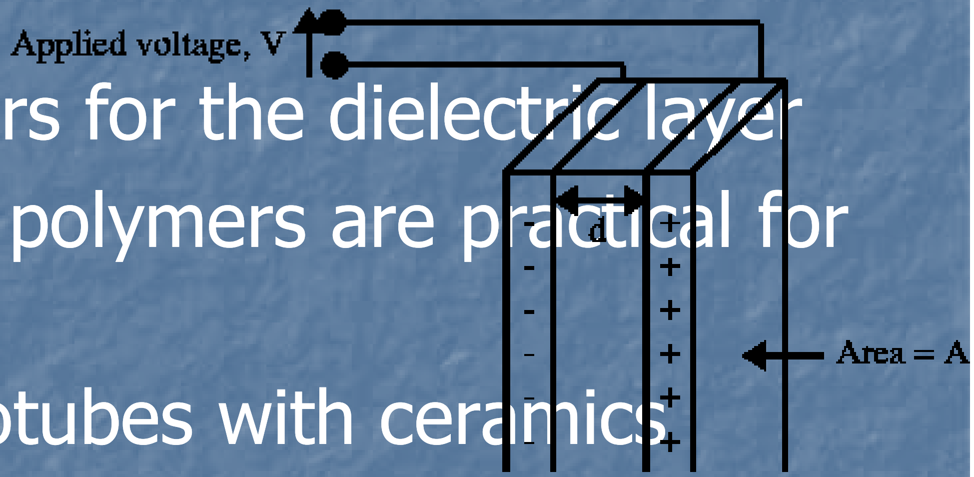
- SMES systems store energy in a magnetic field created by the flow of direct current in a coil of superconducting material that has been cryogenically cooled.
- Principle: At low-temperatures, electric currents encounter almost no resistance.
- Stores energy in the magnetic field.
- Environmental friendly and Highly efficient.

Specifications of the SMES system.

SMES current	1000 A
Stored energy	2.1 MJ
Average power	200 kW
Maximum power	800 kW
Carryover time	> 8 s
DC link voltage	Up to 800 V
Magnetic field	4.5 T
Inductivity	4.1 H

Depending on the peak field and ratio of the coil's height and diameter capacity of storage varies.

Super Capacitors



- Use of thin film polymers for the dielectric layer
- Carbon nanotubes and polymers are practical for super capacitors
- In future - carbon nanotubes with ceramics
- Reduce the effect of fluctuations
- Longer life time which reduces maintenance costs.

Electrochemical Storage

Types of Batteries:

- Small Capacities
- Lead-Acid Batteries
  - They use a chemical reaction to do work on charge and produce a voltage between their output terminals.
  - Energy density is 0.6 MJ/Kg.
  - Efficiency of the cell is only 15%
- Large Scale

Working of a Lead acid Battery

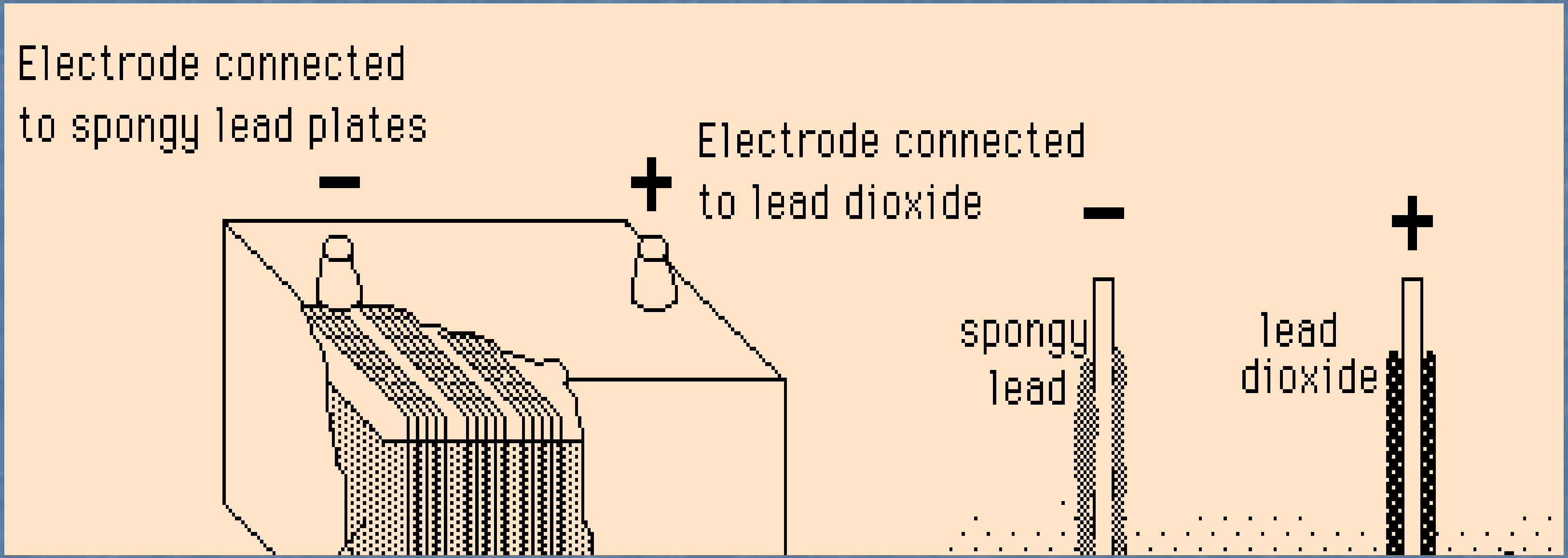


Table 3.1 Comparison of Different Battery Energy Storage Systems

	Lead acid	Nickel cadmium	Sodium sulphur	Lithium ion	Sodium nickel chloride
Achieved/demonstrated upper limit power	Multiple tens of MW	Tens of MW	MW scale	Tens of kW	Tens/low hundreds of kW
Specific energy (Wh/kg)	35 to 50	75	150 to 240	150 to 200	125

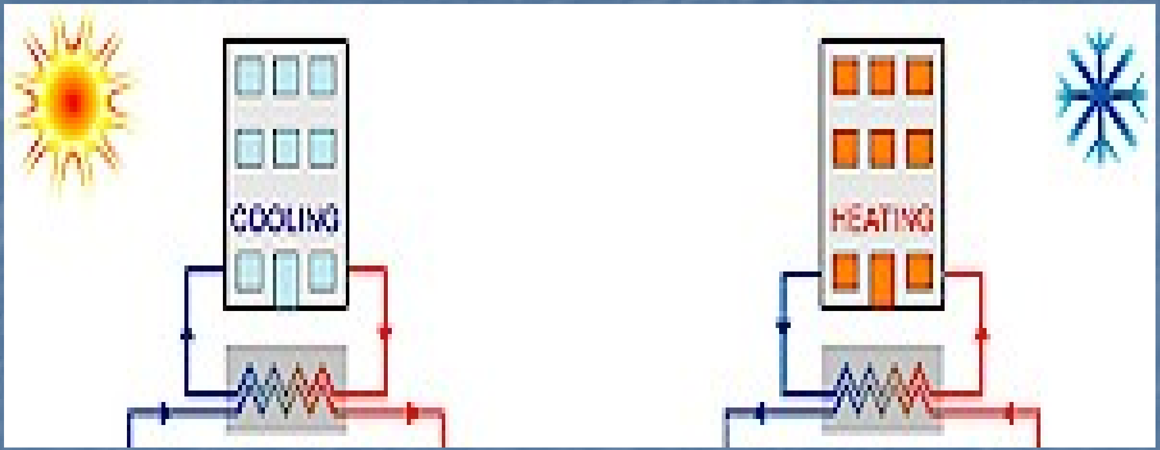
Table 3.2 Selected Lead Acid Battery Energy Storage Installations[7]

Plant name and location	Year of installation	Rated energy (MWh)	Rated power (MW)	Application
BEWAG, Berlin	1986	8.5	8.5	Spinning reserve Frequency control
Crescent, North Carolina	1987	0.5	0.5	Peak demand reduction
Chino, California	1988	40	10	Spinning reserve Load levelling
Herne-Sodingen, Germany	Late 1990s	1.2	1.2	Peak shaving Power quality

Under-Ground Thermal Energy Storage

- Using methods of heat exchange
  1. Aquifer thermal storage
     - Usage of underground water
  2. Duct thermal storage
     - Usage of Plastic Tubes
- Environmental impact

  Eg: De-ice frozen roads


COOLING
HEATING

Application of Thermal Energy Storage

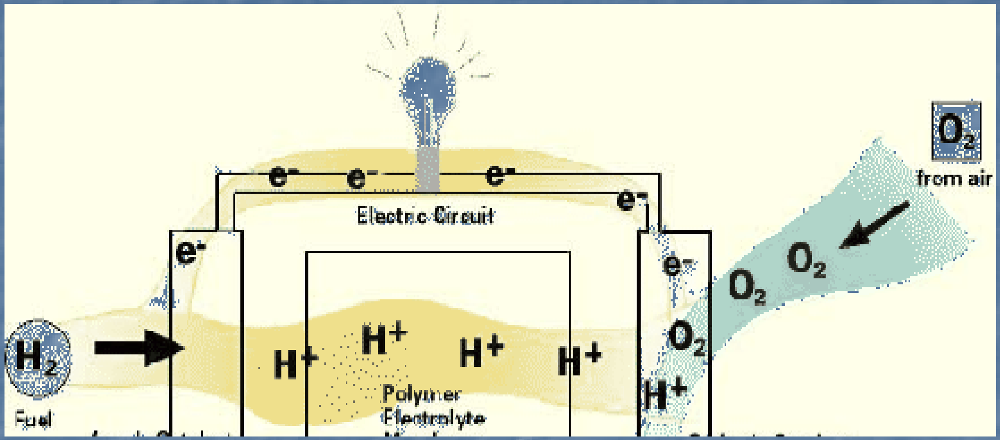
Air Conditioning:

- A salt hydrate acts as a cool heat sink for the air conditioner working fluid.
- The stored heat is rejected from the salt hydrate during night to heat the surrounding air.
- Energy density = 0.25MJ/Kg, η=0.8
- E.g.: Sodium Sulfate Decahydrate.

Fuel Cells

- Direct conversion
  Energy→Electricity
- Burning Fuel?
- High Efficiency
- Applications:

E.g.: NASA, Viable alternative to petrol engines.



$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$
$$(EP = +1.229\ V)$$

Types of fuel cells:

Classified on the basis of operating conditions and various electrolytes used.

- Alkaline fuel cells (AFC)
- Polymer electrolyte membrane (PEM)
- Phosphoric acid fuel cells (PAFC)
- Molten carbonate fuel cells (MCFC)
- Solid oxide fuel cells (SOFC)
- Regenerative fuel cells

Energy densities of some energy storage methods.

Storage method	Energy density (kWh/kg)
Hydrogen	38
Gasoline	14
Lead-acid batteries	0.04
Hydrostorage (per m^3)	0.3
[illegible]	[illegible]

Advantages:

- No green house gases
- Not much political dependence
- More operating time.

Disadvantages:

- Storage of Hydrogen due to highly inflammable nature of H_2. Though metal hydrides($FeTiH_{1.7}$) and NH_3 can be alternative.
- High capital cost due to Platinum catalyst used in the process.

Which is better ???

- Comparing one method of energy storage with another is pointless.
- The reason - None of them are optimal for all purposes.
- Different storage methods differ in capacity and maximum usable storage time.

- For large scale storage *Underground thermal, pumped hydro and compressed air energy storage* systems are preferable.

- Superconductors can store energy with negligible losses.

- Fuel cells are a viable alternative to petrol engines due to their high efficiency.

- Flywheels have a narrow range and are not an answer for large scale operations.

Conclusion:

- Reliable and affordable energy storage is a prerequisite for using renewable energy.
- Energy storage therefore has a pivotal role in the future.
- Energy storage is the most promising technology currently available to meet the ever increasing demand for energy.

Thank you

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