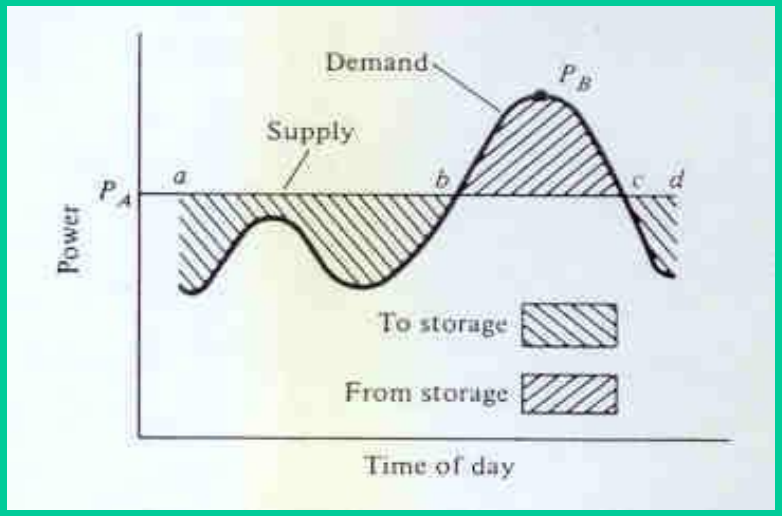
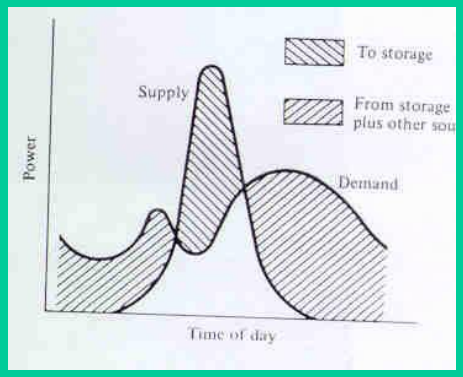
STORAGE TECHNOLOGIES





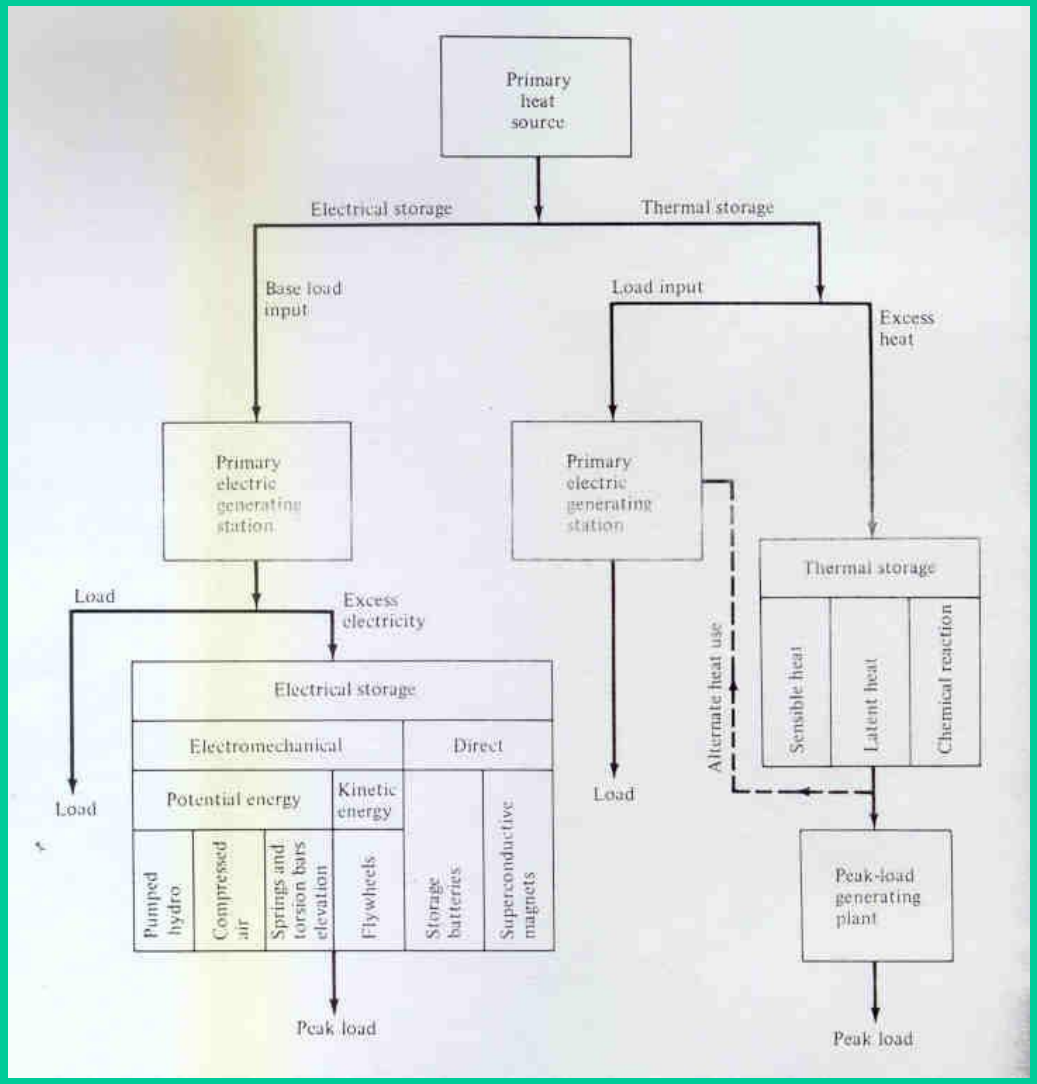
- **Energy Storage -** used to store and regenerate power for peak shaving and to even out generation fluctuations created by fluctuations in the resource being exploited

- **Allows greater use of intermittent renewable energy technologies** – off-peak wind, solar, ocean wave, tidal power are stored in batteries, pumped storage hydro or stored hydrogen from electrolysis of water.

Topics – Storage Technologies

- Energy Storage, Its Uses
- Energy Storage Systems and Types
- Hourly and Daily Power Consumption
- Principles of Energy Storage
- Cost of Energy Storage Technologies
- Benefits from Energy Storage
- Environmental Impact & Risks
- Distributed Generation

Energy Storage Systems



- When demand is lower than capacity, energy is stored.
- When demand is higher than capacity, stored energy is released or regenerated.
- End result – reliable, efficient and economic supply of electricity.
- Generic energy storage in utility systems:

  Electrical storage

  Thermal storage

Types of Energy Storage Technologies

- **ELECTRICAL-MECHANICAL ENERGY STORAGE:**

  POTENTIAL - Pumped Storage Hydropower

  POTENTIAL - Compressed Air Energy Storage (CAES):

  Reservoirs, Salt/Rock Caverns, Aquifers, Adiabatic, Hybrid

  POTENTIAL - Springs, Torsion Bars, Mass Elevation

  KINETIC - Flywheel storage

- **DIRECT ELECTRICAL ENERGY STORAGE:**

  Utility Battery Storage (UBS) – Lead acid, Sodium-sulfur, Lithium-chlorine, Lithium-telluride, Zinc-chlorine

  Super-conducting Magnetic Energy Storage (SMES)

  Hybrid SMES-UBS

  Super Capacitors

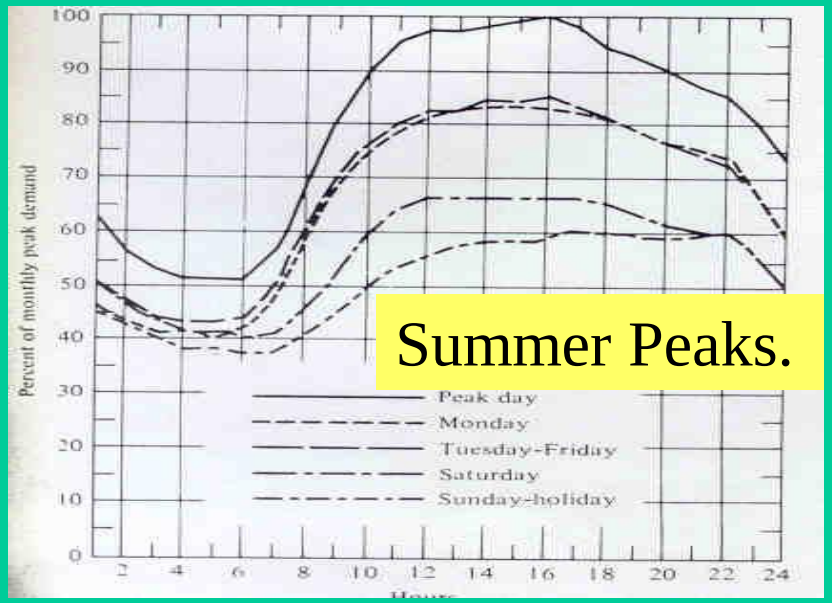
- ***THERMAL STORAGE:***

  Sensible Heat Energy Storage – Pressurized water, Organic liquid, Packed/Fluidized solid beds

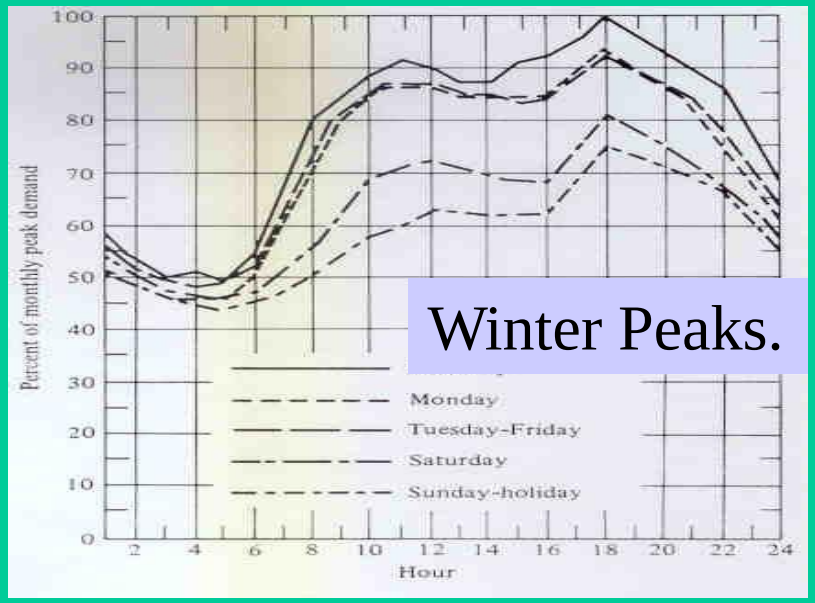
  Latent Heat Energy Storage – High temp. gas-cooled reactor (HTGR)

  Chemical Reaction Storage - Regenerative fuel cells (RFC)

Hourly and Daily Power Consumption



Summer Peaks.

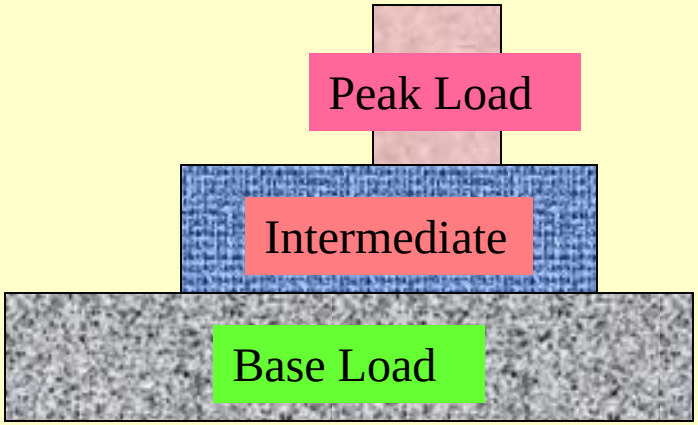


Winter Peaks.

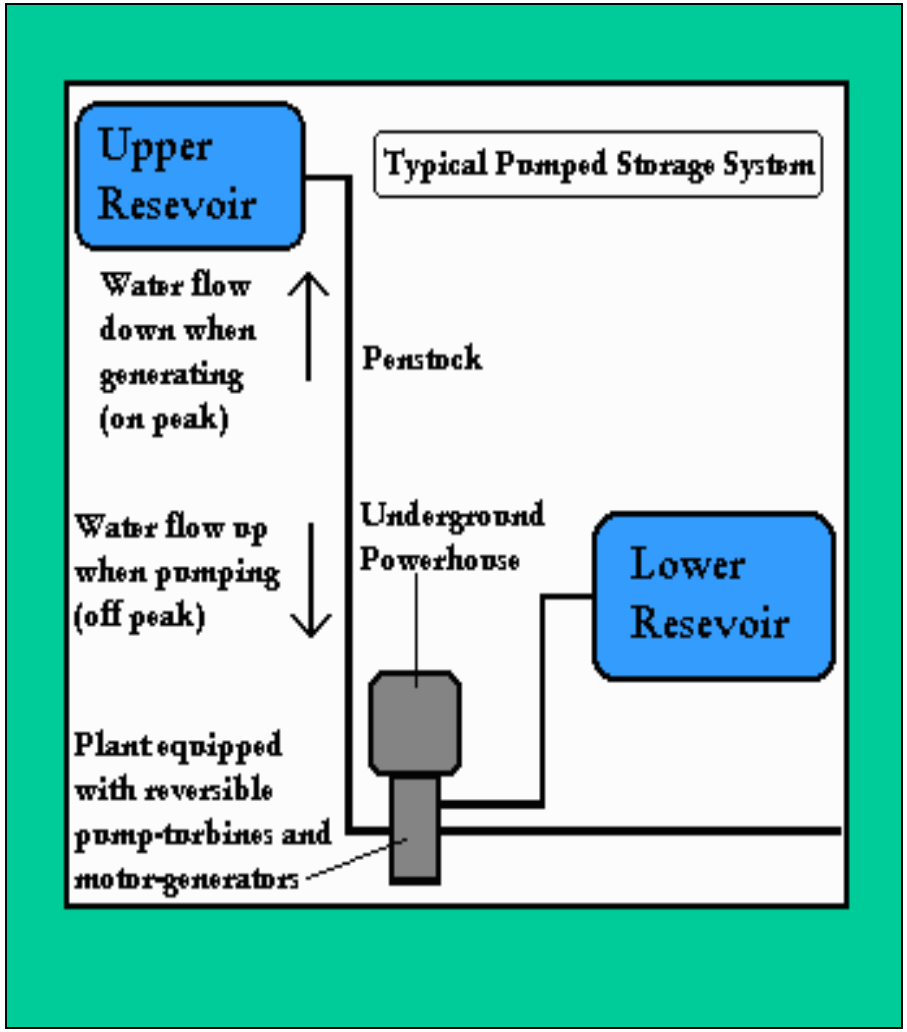
Base Load: 60% to 100%

Intermediate: 15% to 60%

Peaking Load: <= 15%

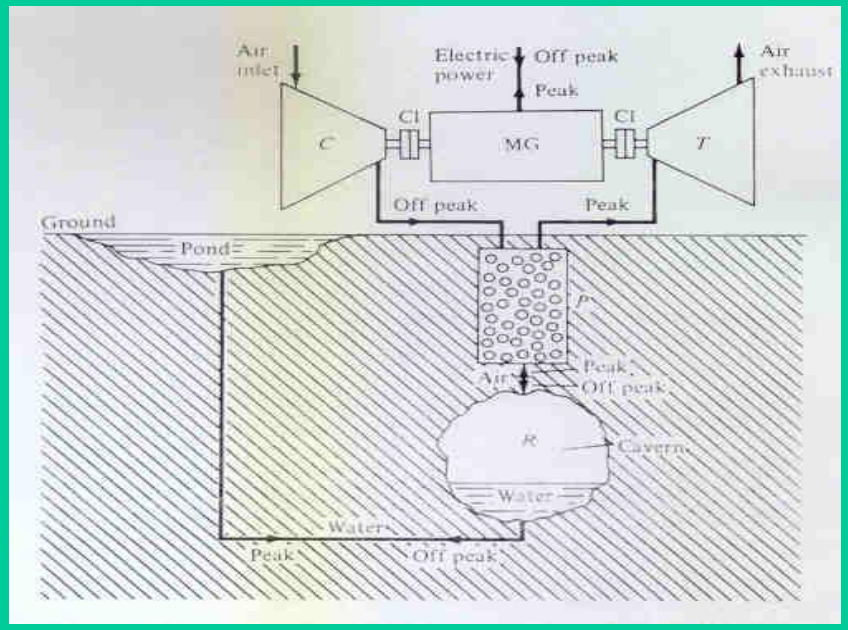


Pumped Storage Hydropower



- Most widely used; like conventional hydro but uses two reservoirs instead of one; cheap off-peak power is used to pump water to the higher reservoir; water is then released using pumped hydro in turbine mode.
- Most efficient and cheapest operation of storing energy. Off-peak power may come from cheaper nuclear or renewable energy.
- Water pumps and turbines are at best 90% and 95% efficient for a storage and regeneration cycle efficiency of 86%.
- A 1800 MW pumped storage can ramp up quickly in 10 sec.

Compressed Air Energy Storage (CAES)



Single-stage adiabatic compressed-air with pressure-compensation pond. **C**ompressor, **T**urbine, **M**otor-**G**enerator, **P**acked-bed thermal energy storage, air-storage **R**eservoir

- Air is compressed using cheap off-peak power and stored under pressure; release of pressurized air is then exploited to regenerate electricity using a gas turbine with separate compressor and turbine, each linked to motor generator using a system of clutches.
- Man-made or salt caverns is used to store compressed air.
- Aquifers can store compressed air with the displaced water setting-up a constant pressure storage system.

Utility Battery Storage (UBS)

- Large scale batteries - oldest and best established way of storing electricity in the form of chemical energy, e.g. lead acid batteries, reduction oxidation (RedOx) batteries, NaS batteries, and lithium ion batteries (under development)
- Instantaneous storage and delivery at 70-90% efficiency.