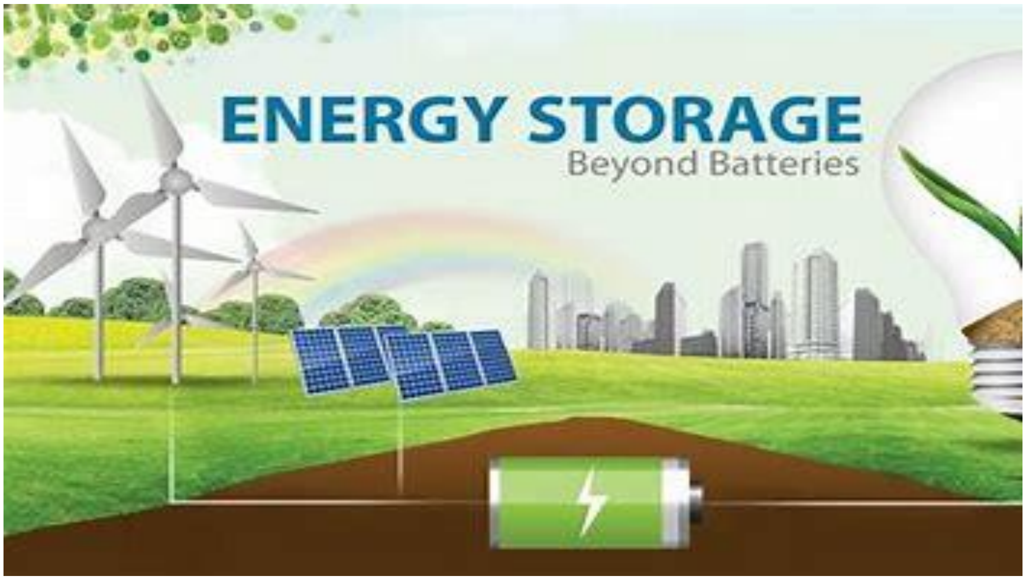
Module – II



1. **ENERGY STORAGE SYSTEMS**

Energy storage systems play a crucial role in modern energy infrastructure, providing a means to store and release energy as needed. These systems are integral for balancing the intermittent nature of renewable energy sources, enhancing grid stability, and ensuring a reliable power supply. Here's an overview of different types of energy storage systems:

1. Battery Energy Storage Systems (BESS):

Lithium-Ion Batteries:

Widely used for their high energy density, efficiency, and long cycle life.

Flow Batteries:

Utilize chemical compounds dissolved in liquid electrolytes, enabling scalability and longer durations.

Solid-State Batteries:

Emerging technology with potential for higher energy density and safety improvements.

2. Pumped Hydro Storage:

Mechanical Energy Storage:

Involves pumping water to an elevated reservoir during periods of excess energy and releasing it to generate electricity during high-demand periods.

3. Compressed Air Energy Storage (CAES):

Adiabatic CAES:

Compresses air, stores it in underground caverns, and then expands it through a turbine to generate electricity.

Diabatic CAES:

Uses natural gas to heat the compressed air before expansion, improving efficiency.

4. Flywheel Energy Storage:

Rotating Mass:

Converts electrical energy into kinetic energy by spinning a rotor and vice versa.

Rapid response for short-duration energy storage.

5. Thermal Energy Storage:

Sensible Heat Storage:

Stores and releases energy by changing the temperature of a material (e.g., water or molten salt).

Latent Heat Storage:

Involves phase change (solid to liquid or vice versa) to store and release energy.

6. Hydrogen Energy Storage:

Electrolysis:

Produces hydrogen by splitting water using electricity.

Fuel Cells:

Convert stored hydrogen back into electricity.

7. Superconducting Magnetic Energy Storage (SMES):

Magnetic Fields:

Stores energy in the form of a magnetic field in a superconducting coil.

Provides quick response times for grid stabilization.

8. **Ultracapacitors: Electrostatic Storage:**

Store energy electrostatically, offering high power density and rapid charge/discharge capabilities.

9. Advanced Rail Energy Storage (ARES):

Gravitational Potential Energy:

Uses the weight of heavy rail cars to store and release energy as they travel uphill and downhill on a track.

1.1 Energy Demand

Understanding energy demand is essential for developing sustainable and efficient energy systems. Energy demand refers to the total amount of energy needed for various purposes, including electricity generation, transportation, heating, and industrial processes. Here are key aspects and considerations related to energy demand:

1. **Types of Energy Demand:**

Primary Energy Demand:

The total energy demand before any conversion or transformation processes.

Final Energy Demand:

The energy demanded by end-users for specific purposes, such as lighting, heating, and transportation.

Useful Energy Demand:

The energy that performs useful work after conversion processes, considering efficiency losses.

2. **Factors Influencing Energy Demand:**

Population Growth:

Increasing population leads to higher energy demand for residential and commercial needs.

Economic Growth:

Strong correlation between economic development and energy demand.

Urbanization:

Urban areas tend to have higher energy demands due to concentrated populations and increased industrial activity.

Technological Advances:

Emerging technologies may increase or decrease energy demand depending on their efficiency and adoption.

3. **Sectoral Distribution of Energy Demand:**

Residential Sector:

Energy demand for heating, cooling, lighting, and appliances.

Commercial Sector:

Energy demand for businesses, offices, and public institutions.

Industrial Sector:

High energy demand for manufacturing processes.

Transportation Sector:

Energy demand for vehicles, including road, air, and maritime transport.

4. **Seasonal and Daily Variations:**

Energy demand often fluctuates based on daily and seasonal patterns.

For example, increased heating demand during winter and higher cooling demand during summer.

5. **Energy Demand Management:**

Strategies to balance and optimize energy demand to enhance system reliability and efficiency.

Includes demand response programs, time-of-use pricing, and smart grid technologies.

6. **Renewable Energy Integration:**

The transition to renewable energy sources impacts energy demand patterns due to their intermittent nature.

Storage solutions and demand-side management become crucial for grid stability.

7. **Energy Efficiency Measures:**

Promoting energy-efficient technologies and practices reduces overall energy demand.

Government policies and incentives play a role in driving energy efficiency improvements.

8. **Global and Regional Trends:**

Energy demand varies globally based on economic development, industrialization, and cultural factors.

Developing regions often experience rapid increases in energy demand.

9. **Environmental Considerations:**

Managing energy demand is critical for achieving environmental sustainability and mitigating climate change.

Encouraging the adoption of clean and renewable energy sources helps reduce environmental impact.

10. **Technological Advances:**

Advancements in technology, such as electric vehicles, energy-efficient appliances, and smart home systems, influence energy demand patterns.

Future Challenges and Considerations:

Addressing the energy demands of a growing global population.

Balancing energy demand with environmental sustainability goals.

Adapting energy systems to emerging technologies and changing consumer behaviors.

Understanding and managing energy demand is a complex task that requires a combination of technological innovation, policy measures, and behavioral changes. Sustainable energy practices and the adoption of efficient technologies are crucial for meeting the world's energy needs while minimizing environmental impact.

2. Energy storage Systems

2.1 Mechanical and hydraulic Energy storage systems usually store energy by converting electricity into energy of compression, elevation, or rotation. Pumped storage is proven, but quite limited in its applicability by site considerations. Compressed-air ES has been tried successfully in Europe, although limited applications appear in the United States. This concept can be applied on a large scale using depleted natural gas fields for the storage reservoir. Alternatively, energy can be stored chemically as hydrogen in exhausted gas fields. Energy of rotation can be stored in flywheels, but advanced designs with high tensile materials appear to be needed to reduce the price and volume of storage. A substantial energy penalty of up to 50% is generally incurred by mechanical and hydraulic systems in a complete storage cycle because of inefficiencies.

2.2 Reversible chemical reactions can also be used to store energy. There is a growing interest in storing low-temperature heat in chemical form, but practical systems have not yet emerged. Another idea in the same category is the storage of hydrogen in metal hydrides (lanthanum, for instance). Tests of this idea are ongoing.

2.3 Electrochemical ES systems have better turnaround efficiencies but very high prices. lntensive research is now directed toward improving batteries, particularly by lowering their weight-to storage capacity ratios, as needed in many vehicle applications. As a successor to the lead-acid battery, sodiumsulfur and lithium sulfide alternatives, among others, are being tested. A different type of electrochemical system is the redox flow cell, so named because charging and discharging is achieved through reduction and oxidation reactions occurring in fluids tored in two separate tanks. To make the leading candidate (an iron redox system) competitive with today’s batteries, its price would have to be at least halved.

2.4 Thermal energy storage (TES) systems are varied and include designed containers, underground aquifers and soils and Lakes, bricks and ingots. Some systems using bricks are operating Europe. ln these systems, energy is stored as sensible heat. Alternatively, thermal energy can be stored in the latent heat of melting in such materials as salts or paraffin. Latent storages can reduce the volume of the storage device by as much as 100 times, but after several

decades of research many of their practical problems have still not been solved. Finally, electric energy can be stored in superconducting magnetic systems although the costs of such systems are high.

Some current research and development areas in the field of ES are follows: Advanced ES and conversion systems with phase transformation, chemical and electro chemical reactions.

- fundamental phenomena inside a single cell as well as engineering integration of whole battery packs into vehicles.
- high-dielectric-constant polymers.
- high K composites for capacitors.
- polymer electrode interfaces (low- and high-frequency effects):
- integrated Polymer capacitors.

3. Energy Storage Methods

For many energy technologies, storage is a crucial aspect. If we Consider the storage of fuels as the storage of the energy embedded in them, then oil is an excellent example. The massive amounts of petroleum stored worldwide are necessary for the reliable, economic availability of gasoline and petrochemicals.

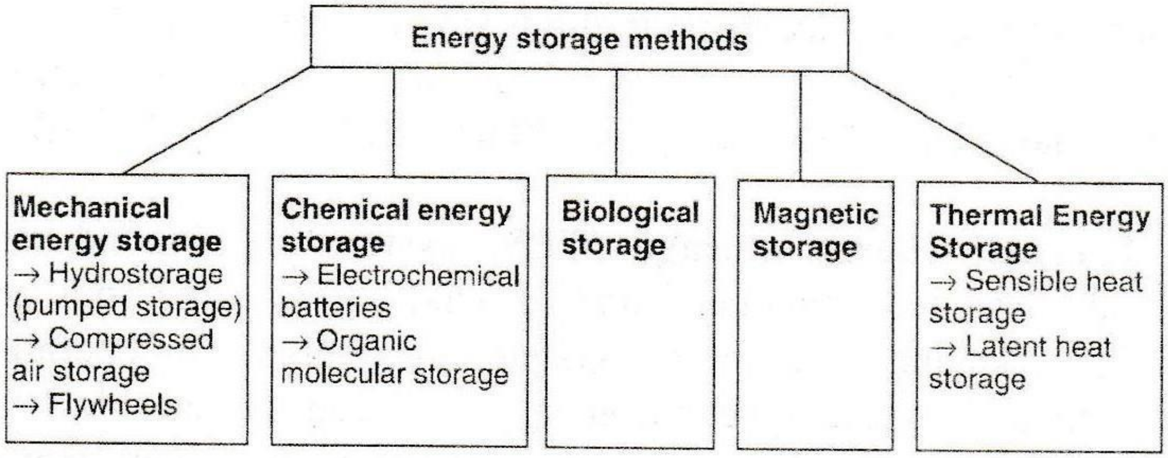


Fig: A classification of energy storage methods

3.1 MECHANICAL ENERGY STORAGE

Mechanical energy may be stored as the kinetic energy of linear or rotational motion as the potential energy in an eleted object, as the compression or strain energy of an elastic material, or as the compression energy in a gas. tt is difficult to store large quantities of energy in linear motion because one would have to chase after the storage medium continually. However, it is quite simple to store rotational kinetic energy. In fact, the potter's wheel, perhaps the first form of ES used by man, w as developed several thousand years ago and is still being used there are three main mechanical storage types that have discuss in this section: hydro storage. compressed-air storage and flywheels

3.1.1 HYDROSTORAGE (PUMPED STORAGE)

Hydrostorage, also known as pumped storage, is a type of energy storage system that involves using two water reservoirs at different elevations to store and generate electricity. It is a well-established and widely used method for grid energy storage. Here's an overview of how pumped storage works and its key features:

How Hydrostorage (Pumped Storage) Works:

Upper and Lower Reservoirs:

A pumped storage system consists of two water reservoirs positioned at different elevations.

Pumping Process (Charging):

During periods of low electricity demand or when there is excess electricity on the grid (e.g., from renewable sources like wind or solar), surplus electricity is used to pump water from the lower reservoir to the upper reservoir.

Potential Energy Storage:

The water lifted to the upper reservoir is now stored as potential energy. The system essentially acts as a large "water battery."

Generating Electricity (Discharging)

When there is high electricity demand, or additional power is needed on the grid, water from the upper reservoir is released back to the lower reservoir.

Hydroelectric Generation:

As the water flows downhill, it passes through turbines that generate electricity.

Efficiency and Grid Stabilization:

Pumped storage systems are known for their relatively high efficiency. They can respond quickly to changes in electricity demand, providing grid stabilization and balancing.

Key Features of Hydrostorage (Pumped Storage):

Scalability:

Pumped storage systems can be built on a large scale, making them suitable for grid-level energy storage.

High Efficiency:

Pumped storage systems are known for their relatively high round-trip efficiency, which is the ratio of the energy recovered to the energy input.

Grid Stabilization

Provides grid stability by balancing supply and demand in real-time.

Rapid Response:

Can respond quickly to fluctuations in electricity demand, making them valuable for supporting the integration of variable renewable energy sources.

Long Lifecycle:

Pumped storage systems typically have a long lifecycle with low maintenance requirements.

Storage Duration:

Can store energy for both short and long durations, depending on the design and capacity of the system.

Environmental Considerations:

While there are environmental considerations related to the construction and operation of reservoirs, pumped storage is often considered environmentally friendly compared to some other forms of energy storage.

Challenges and Considerations:

Geographical Constraints:

Pumped storage systems require specific geographical features, such as suitable elevation differences and available water sources.

Initial Capital Costs:

Building pumped storage facilities can involve significant upfront costs, although the operating costs are generally lower.

Permitting and Environmental Impact:

The construction of reservoirs can have environmental and permitting challenges.

Land Use:

Requires large land areas for the construction of reservoirs.

Applications:

Grid Balancing:

Responds to variations in electricity demand and supply to maintain grid stability.

Renewable Energy Integration:

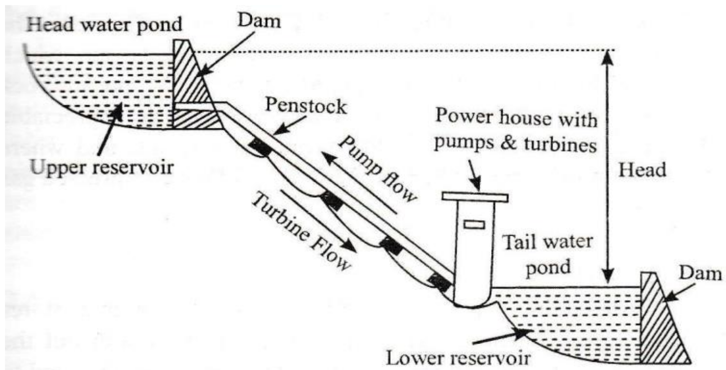
Complements variable renewable energy sources by storing excess energy during periods of high generation.

Peak Shaving:

Stores energy during low-demand periods and releases it during peak demand to reduce strain on the grid.

Emergency Backup:

Provides a reliable source of electricity during grid outages.



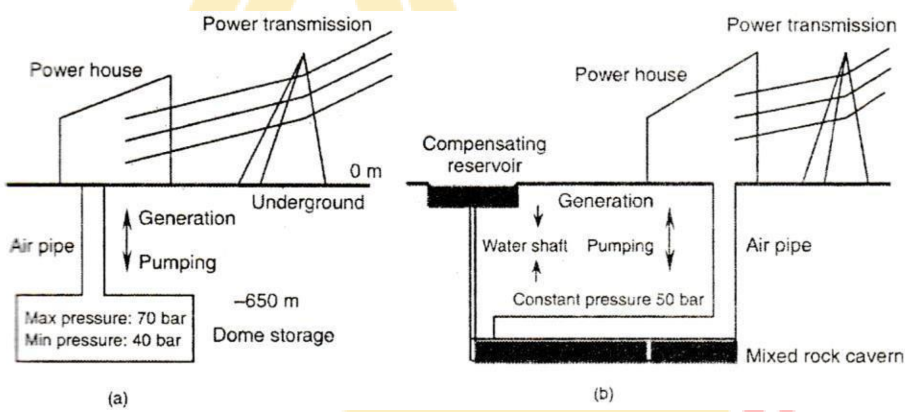
Pumped storage is a proven and effective technology for large-scale energy storage and grid stability. As the world transitions to a more renewable and sustainable energy future, pumped storage will likely continue to play a crucial role in supporting the integration of variable renewable energy sources.Fig: Compresses air ES systems (a) Sliding Pressure System (b) Compensated Pressure System

The technique used by such a system to compress air to store energy is relatively straightforward. ln a conventional gas turbine, high-pressure hot gas is supplied. and about two-thirds of the gross power output is used to drive the compressor. A compressed-air ES system decouples the compressor and the turbine

Fig: Pump Storage

3.1.2 COMPRESSED.AIR STORAGE

In a compressed -air ES system, air is compressed during off - peak hours and stored in large underground reservoirs, which may be naturally occurring caverns, salt domes. abandoned mine shafts, depleted gas and oil fields, or man -made caverns. During peak hours, the air is released to drive a gas turbine generator.



and operates the former during off-peak hours to produce compressed air, which is stored in natural cavefish. old oil or gas wells, or porous rock formations. Such ES storage is advantageous when an appreciable part of the power load is carried by nuclear stations. and where suitable spent salt caverns make it easy to build the compressed gas reservoirs.

3.1.3 FLYWHEELS

Flywheel energy storage is a technology that stores energy in the form of kinetic energy by spinning a rotor (flywheel) at high speeds. When electricity is needed, the spinning rotor's kinetic energy is converted back into electrical energy. Here are the key aspects of flywheel energy storage systems:

How Flywheel Energy Storage Works:

Charging (Energy Input):

When excess electricity is available, it is used to accelerate the flywheel's rotor, increasing its rotational speed.

Kinetic Energy Storage:

The kinetic energy generated during the acceleration of the flywheel is stored in the spinning rotor.

Discharging (Energy Output):

When electricity is required, the kinetic energy stored in the spinning flywheel is converted back into electrical energy.

Generator Operation:

The rotational energy is transferred to a generator, producing electrical power.

Control Systems:

Sophisticated control systems manage the charging and discharging processes, ensuring stability and efficiency.

Key Features of Flywheel Energy Storage:

High Power Density:

Flywheels can store and release energy at a high power density, allowing for rapid response times.

Quick Response:

Flywheels can respond to changes in energy demand within milliseconds, making them suitable for grid stabilization.

Long Cycle Life:

Flywheels typically have a long cycle life with minimal degradation over time.

Efficiency:

The efficiency of flywheel energy storage systems is relatively high, with round-trip efficiencies typically exceeding 90%.

Modularity:

Flywheel systems are modular and can be easily scaled by adding more flywheels to increase storage capacity.

No Chemicals or Hazardous Materials:

Flywheel systems do not involve hazardous materials or chemicals, contributing to their safety and environmental friendliness.

Applications of Flywheel Energy Storage:

Grid Stabilization:

Rapid response and short-duration energy storage make flywheels suitable for grid stabilization, frequency regulation, and balancing.

Renewable Energy Integration:

Complements intermittent renewable energy sources by providing short-term energy storage to manage fluctuations.

Uninterruptible Power Supply (UPS):

Used for providing backup power in critical facilities such as data centers, hospitals, and industrial processes.

Ride-Through Capability:

Offers ride-through capability to mitigate brief power interruptions and fluctuations in industrial processes.

Microgrid Support:

Supports microgrid applications by providing fast response and stability.

Regenerative Braking in Transportation:

In transportation, flywheels can be used for regenerative braking in vehicles to recover and store kinetic energy during braking.

Challenges and Considerations:

Energy Storage Duration:

Flywheels are typically used for short-duration energy storage, and their application may be limited for longer storage needs.

Heat Dissipation

Managing heat generated during charging and discharging processes is crucial to maintaining system efficiency.

Cost: While costs have been decreasing, flywheel energy storage systems may still face competition from other energy storage technologies.

Future Developments: Advances in materials, especially composite materials, are improving the energy storage capacity and efficiency of flywheels.

Integration with smart grid technologies for improved efficiency and grid management.

Flywheel energy storage continues to evolve, and ongoing research and development aim to address its limitations and enhance its performance for a variety of applications in the evolving energy landscape.

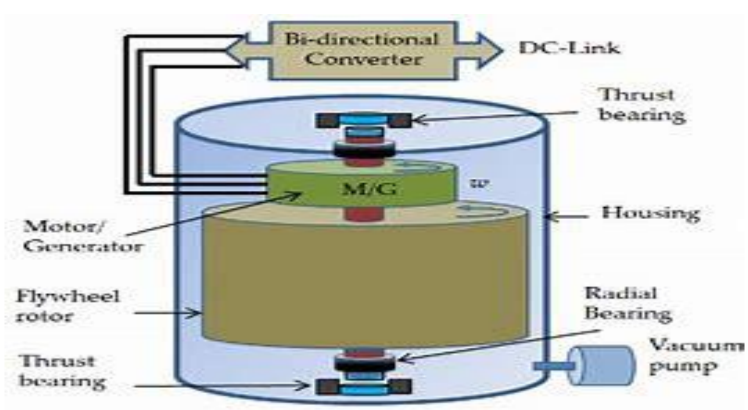


Fig: Flywheel Storage Energy

3.2 Chemical Energy Storage

Chemical energy storage involves converting electrical energy into chemical energy and storing it in the form of chemical compounds. This stored energy can then be released later by converting the chemical energy back into electricity. Here are some common types of chemical energy storage systems:

1. Battery Energy Storage Systems (BESS):
Lithium-Ion Batteries:
Most commonly used for their high energy density, lightweight design, and efficiency.
Applications include electric vehicles, portable electronics, and grid storage.
Lead-Acid Batteries:
Traditional and cost-effective batteries used for applications like uninterruptible power supplies (UPS) and automotive starter batteries.
Flow Batteries:
Use liquid electrolytes stored in external tanks, enabling scalability and flexibility.
Common types include vanadium flow batteries and zinc-bromine flow batteries.
2. Hydrogen Energy Storage:
Electrolysis:
Electrical energy is used to split water into hydrogen and oxygen.
Hydrogen is then stored and can be used in fuel cells to generate electricity when needed.
Fuel Cells:
Hydrogen reacts with oxygen in a fuel cell, producing electricity and water as byproducts.
Applications include stationary power generation, vehicles, and backup power.
3. Solid-State Batteries:
Emerging technology that replaces the liquid or gel electrolyte found in traditional batteries with a solid electrolyte.
Potential advantages include higher energy density, safety improvements, and longer cycle life.
4. Thermal Energy Storage:
Sensible Heat Storage:
Involves storing and releasing energy by changing the temperature of a material.
Common materials include water, molten salts, and phase-change materials.
Latent Heat Storage:
Utilizes phase changes (e.g., solid to liquid or vice versa) for energy storage.
Materials like paraffin wax or hydrated salts are used.
5. Redox Flow Batteries:
Utilize reversible reduction-oxidation reactions to store and release energy.
The electrolyte is stored in external tanks, allowing for flexibility in capacity.
Vanadium redox flow batteries are a well-known example.
6. Organic Batteries:
Use organic materials as electrodes or electrolytes in battery systems.
Organic flow batteries, for example, aim to provide sustainable and cost-effective energy storage solutions.
7. Metal-Air Batteries:

Use metals like zinc or aluminum reacting with oxygen to generate electricity.
Have the potential for high energy density, making them suitable for electric vehicles and other applications.
8. Electrochemical Capacitors (Supercapacitors):
Store energy through the electrostatic separation of charges.
Provide rapid charge and discharge capabilities but generally have lower energy density compared to batteries.
Used in applications requiring quick bursts of power, such as regenerative braking in vehicles.
9. Advanced Lithium-Based Batteries:
Beyond traditional lithium-ion batteries, ongoing research includes lithium-sulfur batteries, lithium-air batteries, and other advanced chemistries with the aim of improving energy density and performance.
Applications of Chemical Energy Storage:
Grid Energy Storage:

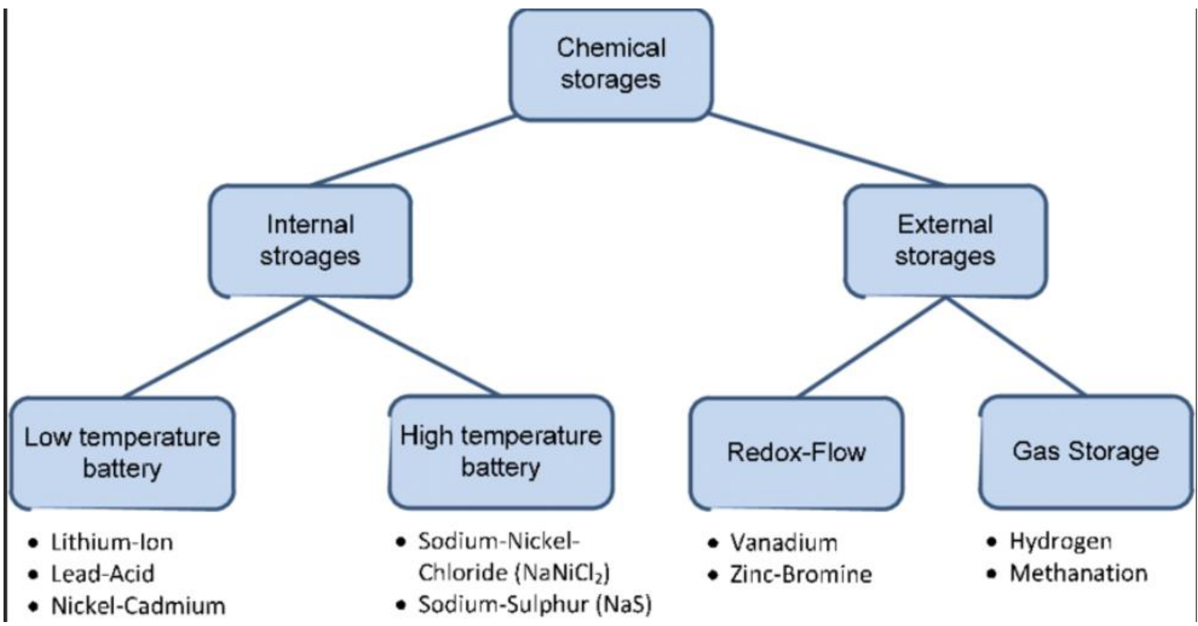


Fig: Chemical Energy Storage

Ongoing research and development to improve energy density, safety, and cost-effectiveness.
Chemical energy storage technologies are continuously evolving, driven by the need for more efficient and sustainable solutions. Advances in materials science, manufacturing processes, and system integration are contributing to the development of more reliable and environmentally friendly energy storage systems.

3.2.1 Electrochemical batteries

Batteries chemically store energy and release it as electric energy on demand. Batteries are a stable form of storage and can provide high energy, such as those needed for transportation. The lead-sulfuric acid battery has long been considered to be advantageous and has been widely applied. Recently. fuel cells have demonstrated the ability to act as large-scale chemical storages like batteries.

3.2.2 Organic molecular storage

The intermittent availability of solar radiation, its seasonal and geographical variations, and its relatively-low intensity. will limit the exploitation of that resource until it can be converted to forms of energy that can be efficiently stored and transported. However, most technologies that are presently available for the utilization of solar energy depend on the direct conversion of solar radiation to lowgrade heat or electricity, both of which are difficult to store.

3.3 BIOLOGICAL STORAGE

Biological storage is the storage of energy in chemical form by means of biological processes and is considered an important method of storage for long periods of time.

3.4 MAGNETIC STORAGE

Magnetic storage refers to the storage of information in magnetic form. This technology has been widely used for decades and is commonly found in various data storage devices. Here are some key aspects of magnetic storage:

1. **Hard Disk Drives (HDDs):**

Structure:Consists of one or more rigid disks coated with a magnetic material.

Data is written and read using a magnetic head that hovers just above the disk surface.

Applications:

Primary storage in computers and servers.

External hard drives for backup and additional storage.

2. Magnetic Tape Storage:

Structure:A long strip of plastic film coated with a magnetic layer.

Data is stored as magnetic patterns along the tape.

Applications:

Historically used for data backup and archival storage.

Still used in some industries for long-term data storage.

3. Magnetic Stripe Cards:

Structure:

A thin strip of magnetic material on the back of a plastic card.

Data is encoded as magnetic patterns on the stripe.
Applications:
Credit and debit cards for financial transactions.
Access cards for security systems.

4. Floppy Disks:

Structure:
A flexible disk coated with a magnetic material.Data is written and read using a magnetic head.
Historical Significance:
Once a common storage medium for personal computers.
Now largely obsolete due to the limited storage capacity.

5. Magneto resistive Random Access Memory (MRAM): Structure: Utilizes magnetic elements to store data.Non-volatile memory with fast read and write speeds.
Applications:
Emerging as a potential alternative to traditional RAM and flash memory.

6. Magnetic Bubble Memory:

Structure:
Utilizes magnetic domains (bubbles) to store data.
Non-volatile memory used in the past but largely replaced by other technologies.

7. Magnetooptic Storage:

Structure:
Combines magnetic and optical technologies.Uses a laser to heat a magnetic medium, altering its magnetic properties for data storage.
Applications:
Used in some optical data storage systems.
Key Advantages:
Non-Volatile:
Magnetic storage retains data even when power is turned off.
High Density:
Enables high storage capacities due to the tiny magnetic domains used to represent bits.
Challenges and Considerations:
Integration with Other Technologies:
Magnetic storage may be combined with other technologies for enhanced performance and reliability.
Magnetic storage remains a crucial part of the data storage landscape, especially in large-scale applications where cost-effective and high-capacity solutions are essential. While other technologies like solid-state drives are gaining popularity, magnetic storage continues to evolve and adapt to meet the demands of various industries.

3.5 THERMAL ENERGY STORAGE (TES) WHY THERMAL STORAGE

Thermal Energy Storage (TES) is a technology that allows for the capture and retention of thermal energy for later use. This type of storage is crucial for enhancing energy efficiency, optimizing energy use in various applications, and addressing the intermittency and variability of renewable energy sources. Here are several reasons why thermal energy storage is important:

1. Integration with Renewable Energy:
Intermittency Management:
Renewable energy sources like solar and wind are intermittent, meaning they don't produce a constant supply of energy. TES helps store excess energy when it's available for use during periods of low renewable energy generation.
2. Grid Stabilization and Load Management:
Peak Shaving:
TES systems can store excess energy during periods of low demand and release it during peak demand, helping to balance the load on the grid.
Load Leveling:
Balancing the electrical load over time to avoid sudden spikes or drops in demand.
3. Industrial Processes:
Process Heat:
TES can store heat generated during industrial processes, allowing for more efficient operation and reduced energy consumption.
CSP (Concentrated Solar Power) Plants:
TES is widely used in CSP plants, where heat from the sun is stored for later use in electricity generation.
4. Buildings and HVAC Systems:
Space Heating and Cooling:
TES systems in buildings store excess thermal energy during off-peak hours, reducing the need for conventional heating and cooling during peak demand periods.
District Heating and Cooling:
Centralized TES systems can provide heating or cooling to multiple buildings in a district.
5. Electric Vehicles and Transportation:
Battery Thermal Management:
TES is used for managing the thermal conditions of batteries in electric vehicles, ensuring optimal performance and extending battery life.
6. Reducing Energy Costs:
Time-of-Use Energy Pricing:
TES allows users to store energy during off-peak hours when electricity rates are lower and use it during peak hours when rates are higher, resulting in cost savings.
7. Waste Heat Recovery:
Industrial Applications:

TES systems can store waste heat generated by industrial processes for later use, contributing to overall energy efficiency.

8. Environmental Impact:

Reducing Greenhouse Gas Emissions:

By optimizing the use of energy and integrating with renewables, TES contributes to reducing greenhouse gas emissions and mitigating climate change.

9. Efficiency and Energy Conservation:

Reducing Energy Waste:

TES helps avoid the waste of excess energy by storing it for use when needed.

Improves overall energy system efficiency.

10. Resilience and Reliability:

Emergency Backup:

TES can provide a source of stored energy for critical applications during power outages or emergencies.

Challenges and Considerations:

Material Selection:

Choosing suitable materials for storing and releasing thermal energy efficiently.

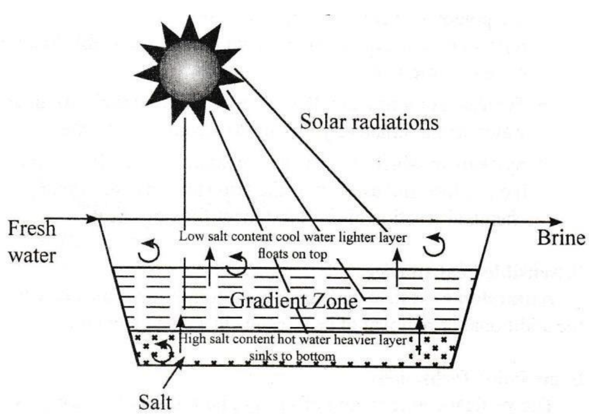
Thermal Storage Medium:

Selecting the appropriate medium (e.g., water, molten salts, phase-change materials) based on the specific application requirements.

System Design and Integration:

Designing and integrating TES systems into existing infrastructure require careful consideration of various factors.

In summary, thermal energy storage is a versatile and essential technology that plays a significant role in enhancing the efficiency, reliability, and sustainability of energy systems across various sectors. Its ability to store and release thermal energy provides valuable flexibility in managing energy resources and addressing the challenges associated with renewable energy integration.



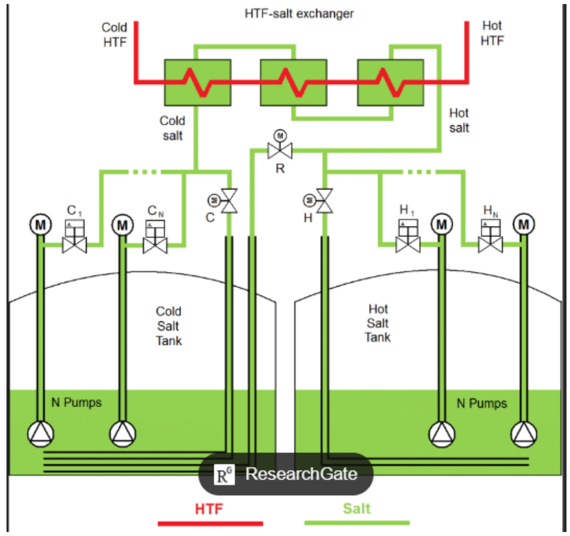


Fig: THERMAL ENERGY STORAGE (TES)

Other early applications of PCMs included "eutectic plates" used for cold storage in trucking and railroad transportation applications. another important application of PCMs is association with space technology, with NASA sponsoring a project on PCM applications for thermal control of electronic packages.

Advantages of latent heat storage systems

1) More compact storage systems as compared to sensible heat storage systems.
2) Energy stored per unit volume is high. 3) Variety of materials are available to suit the applications.

SITUATIONS FAVOR THE USE OF THERMAL STORAGE SYSTEMS

The storage systems are most likely to be cost-effective in situations when :- • A facility's maximum cooling load is much greater than the average load.

- Limited electric power is available at the site;
- Backup cooling capacity is desirable;
- Loads are of short duration, infrequently, cyclical in nature
- Loads are not well matched to the availability of the energy source

5.1 WHAT IS ENERGY MANAGEMENT

Energy management refers to the strategic and systematic process of planning, controlling, and optimizing the use of energy in a system, organization, or facility. The goal of energy management is to achieve energy efficiency, reduce energy costs, and minimize environmental impact while ensuring that energy needs are met effectively. It involves a combination of technical, economic, and organizational measures to improve energy performance. Here are key components and aspects of energy management:

Key Components of Energy Management:

Energy Audits and Assessments:

Conducting detailed assessments of energy usage, systems, and processes to identify opportunities for improvement.

Analyzing energy consumption patterns and identifying areas of inefficiency.

Energy Planning and Policy Development:

Establishing energy goals, targets, and policies to guide energy management initiatives.

Developing a comprehensive energy management plan aligned with organizational objectives.

Energy Monitoring and Measurement:

Installing energy monitoring systems to track real-time energy consumption.

Analyzing energy data to identify trends, anomalies, and areas for improvement.

Energy Efficiency Measures:

Implementing technologies and practices to reduce energy consumption without compromising performance.

Upgrading equipment, improving insulation, optimizing processes, and adopting energy-efficient technologies.

Renewable Energy Integration:

Exploring and integrating renewable energy sources to diversify the energy mix and reduce dependence on conventional sources.

Implementing solar, wind, or other renewable energy systems.

Energy Procurement and Cost Management:

Strategically managing energy procurement to optimize costs.

Negotiating favorable contracts with energy suppliers.

Behavioral Changes and Training:

Educating and engaging employees to promote energy-conscious behaviors.

Conducting training programs to raise awareness about energy efficiency.

Energy Storage and Demand Response:

Implementing energy storage solutions to store excess energy for later use.

Participating in demand response programs to adjust energy consumption based on grid conditions.

Regulatory Compliance:

Staying informed about and complying with energy-related regulations and standards.
Implementing measures to meet energy efficiency and environmental targets.
Continuous Improvement:

Establishing a culture of continuous improvement in energy management.
Regularly reviewing and updating energy management plans based on evolving technology and organizational needs.
Benefits of Energy Management:
Cost Savings:

Reduced energy consumption leads to lower energy bills and operational costs.
Environmental Sustainability:

Minimizing the environmental impact by reducing carbon emissions and resource use.
Increased Resilience:

Improving the resilience of operations by optimizing energy use and incorporating renewable sources.
Compliance and Reputation:

Meeting regulatory requirements and enhancing the organization's reputation as a socially responsible entity.
Risk Mitigation:

Reducing vulnerability to energy price volatility and supply disruptions.
Competitive Advantage:

Gaining a competitive edge through improved efficiency and sustainability.
Employee Engagement:

Fostering a culture of environmental responsibility and engaging employees in energy-saving initiatives.
Challenges in Energy Management:
Initial Investment:

Upgrading equipment and implementing energy-efficient technologies may require upfront investment.
Behavioral Change:

Overcoming resistance to change and ensuring that employees adopt energy-efficient practices.

Data Accuracy and Availability:

Ensuring accurate and reliable energy data for informed decision-making.

Technological Complexity:

Navigating the complexity of integrating new technologies and systems.

Changing Regulatory Landscape:

Adapting to evolving energy regulations and standards.

Effective energy management involves a holistic approach, considering both technical and behavioral aspects. It requires ongoing commitment, monitoring, and adaptation to ensure sustained benefits over the long term. Organizations that prioritize energy management contribute not only to their bottom line but also to broader environmental and societal goals

5.2 PRINCIPLES OF ENERGY MANAGEMENT

Effective energy management involves the application of principles and strategies to optimize energy use, enhance efficiency, and achieve sustainable outcomes. Here are key principles of energy management:

1. Commitment and Leadership:

Principle: Commitment starts at the top.

Explanation: Leadership commitment is essential for establishing a culture of energy efficiency within an organization. Top-level executives should champion energy management initiatives and allocate resources to support energy-saving projects.

2. Continuous Improvement:

Principle: Embrace a culture of continuous improvement.

Explanation: Regularly assess and reassess energy performance, identify areas for improvement, and implement changes. Continuous improvement ensures that energy management remains an ongoing process rather than a one-time effort.

3. Energy Policy and Planning:

Principle: Develop and implement a comprehensive energy policy.

Explanation: Establish clear goals, targets, and guidelines for energy management. Develop a robust energy management plan that aligns with organizational objectives, regulatory requirements, and sustainability goals.

4. Energy Audits and Assessments:

Principle: Conduct regular energy audits and assessments.

Explanation: Regularly analyze energy consumption patterns, identify inefficiencies, and assess the performance of energy systems. Energy audits provide valuable insights into areas where improvements can be made.

5. Employee Engagement and Training:

Principle: Engage employees and provide training.

Explanation: Educate and involve employees at all levels to create awareness about energy efficiency. Training programs can empower employees to adopt energy-saving practices and contribute to the organization's energy goals.

6. Data Monitoring and Analysis:

Principle: Implement effective data monitoring and analysis.

Explanation: Use advanced monitoring systems to collect and analyze real-time energy data. Accurate data helps in making informed decisions, identifying trends, and evaluating the effectiveness of energy-saving measures.

7. Investment in Energy Efficiency Technologies:

Principle: Invest in energy-efficient technologies.

Explanation: Adopt technologies that enhance energy efficiency, reduce waste, and optimize energy use. This may include upgrading equipment, incorporating smart systems, and investing in renewable energy sources.

8. Renewable Energy Integration:

Principle: Integrate renewable energy sources.

Explanation: Explore and integrate renewable energy technologies like solar, wind, or geothermal to diversify the energy mix, reduce dependence on conventional sources, and contribute to sustainability goals.

9. Lifecycle Management and Maintenance:

Principle: Implement effective lifecycle management and maintenance.

Explanation: Regular maintenance and lifecycle management of equipment are crucial for ensuring optimal performance. Well-maintained systems operate more efficiently, reducing energy consumption.

10. Benchmarking and Performance Measurement:

Principle: Benchmark against industry standards.

Explanation: Compare energy performance against industry benchmarks and standards. This helps in setting realistic targets, identifying outliers, and understanding where the organization stands relative to peers.

11. Policy Compliance:

Principle: Comply with energy-related regulations and policies.

Explanation: Stay informed about and adhere to energy-related regulations and standards. Compliance ensures that the organization operates within legal frameworks and avoids potential penalties.

12. Risk Management:

Principle: Integrate energy risk management.

Explanation: Identify and assess risks related to energy supply, pricing, and potential disruptions. Develop strategies to mitigate risks and enhance the resilience of energy-related operations.

13. Communication and Reporting:

Principle: Maintain transparent communication and reporting.

Explanation: Regularly communicate energy performance and achievements to stakeholders. Transparency builds trust and fosters a sense of responsibility among employees, customers, and the wider community.

14. Strategic Planning and Goal Setting:

Principle: Align energy management with strategic planning.

Explanation: Integrate energy management goals into broader organizational strategies. Aligning energy management with overall business objectives ensures that it becomes an integral part of the organization's success.

15. Cost-Benefit Analysis:

Principle: Conduct thorough cost-benefit analyses.

Explanation: Evaluate the economic viability of energy projects by considering both the costs and benefits. This analysis helps prioritize investments and ensures that the organization gets the maximum return on investment.

Conclusion:

By adhering to these principles, organizations can establish and maintain effective energy management practices that contribute to cost savings, environmental sustainability, and long-term success. Energy management is a dynamic process that evolves with changes in technology, regulations, and organizational priorities.

6 ENERGY PRICING

Energy pricing refers to the cost associated with the consumption of energy, typically measured in monetary terms per unit of energy (e.g., kilowatt-hour for electricity, therms or British thermal units for natural gas). Energy pricing is a critical aspect of the energy industry, influencing consumer behavior, investment decisions, and overall economic activity. Here are key aspects of energy pricing:

1. Factors Influencing Energy Pricing:

Supply and Demand:

The fundamental economic principle of supply and demand plays a significant role in determining energy prices. Scarcity of energy resources or high demand can drive prices up.

Fuel Costs:

For energy sources like natural gas and coal, the cost of fuel extraction and processing directly influences pricing.

Infrastructure and Transportation:

Costs associated with the infrastructure required to generate, transmit, and distribute energy can impact pricing. Transportation costs for fuels also contribute to the overall price.

Market Competition:

The level of competition in energy markets can influence pricing. Competitive markets often lead to lower prices.

Government Policies and Taxes:

Government regulations, taxes, and subsidies can significantly impact energy prices. For example, carbon taxes or renewable energy incentives can influence the cost of energy.

Global Events

Events such as geopolitical tensions, natural disasters, or disruptions in energy-producing regions can cause fluctuations in energy prices.

Technological Advances:

Advances in technology, especially in renewable energy, can contribute to changes in the cost structure of energy production and influence pricing.

2. Types of Energy Pricing:

Fixed Pricing:

Consumers pay a set rate for energy consumption regardless of fluctuations in market prices. Common in regulated markets.

Variable or Time-of-Use Pricing:

Prices vary based on the time of day or demand. Consumers pay more during peak hours and less during off-peak periods.

Spot Pricing:

Prices are determined in real-time based on market conditions. Common in wholesale electricity markets.

Indexed Pricing:

Prices are tied to a specific index or benchmark, such as the cost of natural gas or oil.

Tiered Pricing:

Consumers pay different rates based on the volume of energy consumed. Higher consumption levels may result in higher per-unit prices.

3. Electricity Pricing:

Wholesale Electricity Markets:

Electricity generators and suppliers participate in wholesale markets where prices are determined by supply and demand.

Retail Electricity Markets:

Consumers purchase electricity at retail prices, which may be fixed, variable, or follow a time-of-use structure.

Capacity Payments:

Payments made to generators to ensure the availability of sufficient capacity to meet peak demand.

4. Natural Gas Pricing:

Spot Market: Prices determined by supply and demand conditions in the spot market.

Contracts:Long-term contracts may involve fixed prices, indexed prices, or a combination.

Liquified Natural Gas (LNG) Pricing:Influenced by global LNG markets and transportation costs.

5. Factors Affecting Energy Prices for Consumers:
Location: Prices can vary based on geographic location and proximity to energy sources.
Seasonal Variation: Demand for heating or cooling can lead to seasonal variations in energy prices.
Consumer Behavior:

Consumer choices, such as energy conservation or the adoption of energy-efficient technologies, can influence overall demand and pricing.
Regulatory Environment:

Regulations affecting energy markets can impact pricing structures.
6. Energy Price Volatility:
Market Dynamics:

Energy markets can be subject to significant price volatility due to various factors, including geopolitical events, natural disasters, or sudden changes in supply and demand.
Renewable Energy Integration:

The integration of variable renewable energy sources (such as solar and wind) can contribute to price volatility, as these sources depend on weather conditions.
Conclusion:
Understanding energy pricing is crucial for consumers, businesses, and policymakers as it directly impacts costs, investment decisions, and the overall economic landscape. It involves a complex interplay of market dynamics, geopolitical factors, and regulatory frameworks, and it is subject to continuous change and adaptation as the energy landscape evolves.

6.1 POWER COSTS

Power costs, often referred to as the cost of electricity or electric power costs, represent the expenses associated with generating, transmitting, and distributing electrical energy. These costs can vary based on a range of factors, including the energy source, geographic location, market dynamics, and regulatory environment. Here are key elements that contribute to power costs:

1. Generation Costs:
Fuel Costs:

For power plants that rely on fossil fuels (coal, natural gas, oil), the cost of fuel extraction, processing, and transportation significantly influences the overall generation cost.
For renewable energy sources (solar, wind, hydro), generation costs are associated with the initial capital investment, operation, and maintenance, with little to no fuel costs.
Capital Expenditures (CapEx):

The initial cost of building power plants, including the construction of facilities, purchase of equipment, and installation of generation units.
Operating and Maintenance (O&M) Costs:

Ongoing costs for maintaining and operating power plants, including labor, materials, and routine maintenance.
2. Transmission and Distribution Costs:
Infrastructure Costs:

The expenses associated with building and maintaining the infrastructure for transmitting and distributing electricity, including power lines, substations, and transformers.
Grid Operation and Management:

Costs related to the operation and management of the electrical grid, including monitoring, control systems, and grid maintenance.
3. Regulatory and Compliance Costs:
Environmental Compliance:

Costs associated with complying with environmental regulations, such as emissions control measures and environmental impact assessments.
Grid Access Fees:

Charges imposed by regulatory bodies for access to the electrical grid.
4. Market Dynamics:
Market Prices:

In deregulated markets, power costs can be influenced by supply and demand dynamics, and prices may fluctuate based on market conditions.
Capacity Payments:

Payments made to power plants to ensure the availability of sufficient capacity to meet peak demand.
5. Renewable Energy Costs:
Solar and Wind Costs:

The declining costs of solar panels and wind turbines have contributed to making renewable energy more competitive.
Storage Costs:

Costs associated with energy storage technologies, such as batteries, for managing the intermittent nature of renewable energy sources.
6. Technology and Innovation:
Advancements in Technology:

Technological innovations can lead to improvements in efficiency and cost reductions in power generation, transmission, and distribution.
Smart Grid Technologies:

Investments in smart grid technologies that enhance grid efficiency, reliability, and resilience.
7. Geographic Variation:
Resource Availability:

The availability of local energy resources (e.g., sunlight for solar, wind patterns for wind power) can impact power costs.
Transmission Distance:

The distance between power generation sources and consumption centers affects transmission losses and costs.
8. Consumer Behavior and Efficiency:
Energy Efficiency Programs:

Initiatives aimed at promoting energy efficiency can influence overall power costs by reducing demand.
Consumer Adoption of Technology:

Consumer adoption of energy-efficient technologies, such as LED lighting and energy-efficient appliances, can impact power consumption and costs.
9. Global Events and Market Dynamics:
Geopolitical Factors:

Political events, international relations, and geopolitical tensions can affect the prices of fossil fuels and impact power costs.
Market Dynamics:

Global economic conditions and market dynamics influence commodity prices, which, in turn, affect fuel costs and power prices.
Conclusion:
Power costs are multifaceted and influenced by a combination of factors spanning from the cost of generating electricity to the infrastructure needed for its transmission and distribution. The transition to renewable energy sources, advancements in technology, and changes in regulatory environments contribute to the evolving landscape of power costs. Understanding these factors is crucial for policymakers, businesses, and consumers as they navigate the complex energy market.

7 Energy audit

An energy audit is a systematic assessment of the energy use and efficiency of a building, facility, or industrial process. The primary goal of an energy audit is to identify opportunities for energy savings, improve energy efficiency, and reduce overall energy consumption. Energy audits are conducted by professionals with expertise in energy management and engineering. The process typically involves the following key steps:

1. Preliminary Analysis and Planning:

Review of Utility Bills:

Analyzing historical energy bills to understand patterns of energy consumption and costs.

Site Visit and Data Collection:

Conducting an initial site visit to gather information about the building or facility, including its size, layout, equipment, and operational schedules.

2. Energy Use Profiling:

Energy Use Inventory:

Compiling a detailed inventory of energy-consuming systems and equipment, including lighting, HVAC (heating, ventilation, and air conditioning), appliances, and industrial machinery.

Data Logging and Monitoring:

Using data loggers and monitoring devices to collect real-time data on energy use, temperature, and other relevant parameters.

3. Building Envelope Assessment:

Thermal Imaging:

Using thermal imaging technology to identify areas of heat loss or gain in the building envelope.

Insulation and Window Assessment:

Evaluating the effectiveness of insulation and the condition of windows and doors.

4. HVAC Systems Evaluation:

System Performance Assessment:

Assessing the efficiency of heating, ventilation, and air conditioning (HVAC) systems.

Airflow and Ductwork Inspection:

Checking for leaks, blockages, or inefficiencies in ductwork and airflow systems.

5. Lighting Systems Analysis:

Lighting Efficiency Evaluation:

Assessing the efficiency of lighting systems, including the types of bulbs and fixtures used.

Daylighting Opportunities:

Identifying opportunities for utilizing natural daylight to reduce the need for artificial lighting.

6. Appliance and Equipment Efficiency:

Equipment Inspection:

Evaluating the efficiency of appliances, machinery, and other equipment.

Load Profiles:

Analyzing load profiles to understand energy use patterns and identify opportunities for load management.

7. Energy Management Systems (EMS) and Controls:

EMS Assessment:

Evaluating the effectiveness of energy management systems and controls in place.

Opportunities for Automation:

Identifying areas where automation can optimize energy use.

8. Renewable Energy Potential:

Assessment of Renewable Resources:

Evaluating the potential for integrating renewable energy sources such as solar panels or wind turbines.

9. Occupant Behavior and Awareness:

Behavioral Analysis:

Examining occupant behavior and practices that may impact energy use.

Identifying opportunities for energy awareness campaigns.

10. Benchmarking and Comparison:

Comparison with Standards:

Benchmarking energy use against industry standards or similar buildings to identify areas for improvement.

Comparing the energy performance of the facility to historical data.

11. Energy Audit Report:

Findings and Recommendations:

Summarizing the findings of the energy audit, including areas of inefficiency and opportunities for improvement.

Prioritized Recommendations:

Providing a list of prioritized recommendations with estimated costs and potential savings.

12. Implementation Plan:

Actionable Steps:

Outlining a clear plan for implementing recommended energy-saving measures.

Identifying potential incentives, rebates, or financing options.

13. Monitoring and Verification:

Post-Implementation Monitoring:

Continuously monitoring energy use after implementing measures to verify actual savings.

Adjusting and optimizing systems based on real-time data.

Benefits of an Energy Audit:

Cost Savings:

Identify opportunities to reduce energy costs and improve operational efficiency.

Environmental Impact:

Contribute to sustainability goals by reducing the environmental impact of energy use.
Operational Efficiency:

Optimize the performance of systems and equipment for better overall efficiency.
Compliance:

Ensure compliance with energy efficiency regulations and standards.
Improved Comfort and Productivity:

Enhance the indoor environment for occupants, leading to increased comfort and productivity.

An energy audit serves as a valuable tool for organizations seeking to improve their energy performance, reduce operational costs, and contribute to environmental sustainability. The findings and recommendations from an energy audit provide a roadmap for implementing cost-effective energy-saving measures. The detailed energy auditing is carried out in three phases:

- Phase I – Pre-Audit Phase
- Phase II - Audit Phase
- Phase III - Post Audit Phase

Phase I -Pre Audit Phase Activities

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial Site Visit and Preparation Required for Detailed Auditing

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit. During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyze the major energy consumption data with the relevant personnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering/production

The main aims of this visit are: -

- To finalize Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
    - To decide whether any meters will have to be installed prior to the audit eg. kWh, steam, oil or gas meters.

- To identify the instrumentation required for carrying out the audit.
- To plan with time frame
- To collect macro data on plant energy resources, major energy consuming centers
- To create awareness through meetings/programme

Phase II- Detailed Energy Audit Activities

- Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out.
- Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.
- The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process.
- Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed.
- The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

Phase –III- Post Audit Phase

On completion of energy audit, energy action plan should be prepared. The energy action plan list the ENCONs which should be implemented first, and suggest an overall implementation schedule. Energy audit is incomplete without monitoring and its associated feedback. Monitoring consists of collecting and interpreting data. The data to be collected depends upon goals chosen in the energy action plan. Electrical power consumption and fuel consumption must be evaluated and monitored.

The monitoring data should provide direct feedback to those most able to implement the changes. often additional instruments should be installed in various department in addition to main metering.

7.2 Energy Audit Reporting Format

After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation in a typical energy audit report format. This format may vary with the type of the company also format can be suitably modified for specific requirement applicable for a particular type of industry.

7.3 Organizing Energy management in Industries

Following are the guidelines for carrying out energy management in industries

- Developing ideas and plans for enlisting employee support and participation
- Planning and participation in energy audits
- Surveying and literature on the ways to conserve energy and communicating these ideas and suggestions.

- Establishing realistic and achievable energy conservation goals.
- Developing uniform record keeping, reporting and energy auditing.
- Planning and conducting continuing program of activities to stimulate interest in energy conservation efforts.

7.4 Duties and responsibilities of energy manager

- Creation of a data base related to inputs and outputs of the manufacturing process. For this purpose, extensive metering instrumentation at various points of energy and material flows through the plant might be required.
- To carry out energy audits from the data base on a regular basis and to reconcile energy audits with financial audits.
- To analyze energy consumption centers such as boilers, furnaces, electric motor driven instruments like compressors, pumps etc and to identify the energy conservation opportunities.
- To report plant's energy conservation progress to the top management.
- To advise the top-level management as the ways of long-term energy conservation opportunities.
- To coordinate energy consumption between energy consuming centers.
- To build thorough inventory of all machines, equipment and facilities which consume energy – their capacity, time worked since installation, parts and components repaired or replaced and other working specifications.
- To survey and review the literature on energy development and to properly disseminate this information.
- To develop and communicate energy saving technique and ideas to divisional heads.

8. Economic Analysis

Among the most important indicators of the success of an engineering enterprise are the profit achieved and the return on investment. Therefore, economic considerations play a very important role in the decision-making processes that govern the design of a system. It is generally not enough to make a system technically feasible and to obtain the desired quality of the product. The costs incurred must be taken into account to make the effort economically viable. It is necessary to find a balance between the product quality and the cost.

Because of the crucial importance of economic considerations in most engineering decisions, it is necessary to understand the basic principles of economics and to apply these to the evaluation of investments, in terms of costs, returns, and profits.

- **Simple interest**

If the interest is calculated only on the principal over a given duration, without considering the change in investment due to accumulation of interest with time and without including the interest with the principal for subsequent calculations, the resulting interest is known as *simple interest*. Then, the simple interest on the principal sum P invested over n years is simply Pni, and the final amount F consisting of the principal and interest after n years is given by $F = P(1 + ni)$.

- **Compound interest**

The interest may be calculated several times a year and then added to the amount on which interest is computed in order to determine the interest over the next time period. This procedure is known as compounding and interest is called as compound interest.

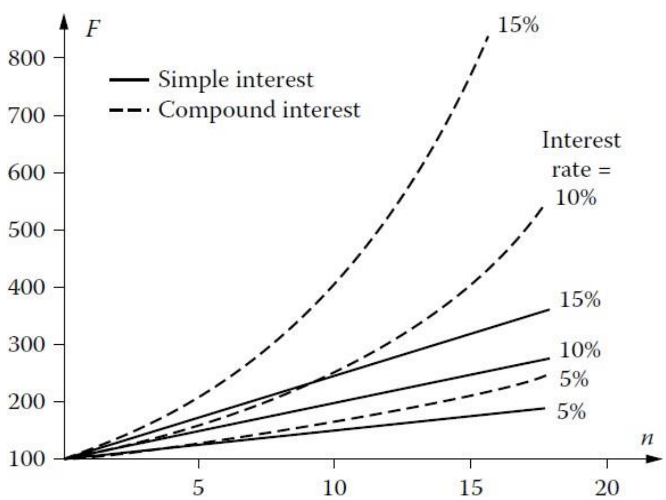
If the interest is compounded *m* times a year, the interest on a unit amount in the time between two compounding is *i*/*m*. Then the final sum *F*, which includes the principal and interest, is obtained after *n* years as

m

$$F = P\left(\frac{1}{m} + i\right)$$

For monthly compounding m =12, daily compounding m =365 etc.

Variation of sum F consisting of the principal, and accumulated interest as a function of number of years for simple and compounding at different rates of interests are shown in the graph.



Two approaches that are commonly used for bringing all financial transactions to a common time frame are the present and future worth of an investment, expenditure, or payment.

- **Present worth**

Present worth (PW) of a lumped amount given at a particular time in the future is its value today. Thus, it is the amount that, if invested at the prevailing interest rate, would yield the given sum at the future date. If we consider the resulting sum *F* after *n* years at a nominal interest rate *i*, Then *P* is the present worth of sum *F* for the given duration and interest rate. Therefore, the present worth of a given sum *F* may be written, for yearly compounding,

$$\mathbf{PW = P = F(1+i)^{-n} = (F)\ (P/F,\ i,\ n)}$$

Where P/F is known as present worth factor and is given by

$$\boldsymbol{P/F = (1+i)^{-n}}$$

The **future worth** of a lumped amount *P*, given at the present time, may similarly be determined after a specified period of time. Therefore, the future worth (FW) of *P* after *n* years with an interest rate of *i*, compounded yearly or *m* times yearly, are given, respectively, by the following equations: **FW= F= P(1+i)^n = (P) (F/P, I, n)**

$$\mathbf{FW = F = P\left(1+\frac{i}{m}\right)^{mn} = (P)\left(F/P, \frac{i}{m}, mn\right)}$$

Where *F/P* is known as the *future factor worth* or *compound amount factor*

- **SERIES OF PAYMENTS**

A common circumstance encountered in engineering enterprises is that of a series of payments. Frequently, a loan is taken out to acquire a given facility and then this loan is paid off in fixed payments over the duration of the loan. Recurring expenses for maintenance and labor may be treated similarly as a series of payments over the life of the project. Both fixed and varying amounts of payments are important, the latter frequently being the result of inflation, which gives rise to increasing costs. The series of payments is also brought to a given point in time for consideration with other financial aspects. As before, the time chosen may be the present or a time in the future.

- **FUTURE WORTH OF UNIFORM SERIES OF AMOUNTS**

Let us consider a series of payments, each of amount *S*, paid at the end of each year starting with the end of the first year. The future worth of this series at the end of *n* years is to be determined. This can be done easily by summing up the future worths of all these individual payments. The first payment accumulates interest for *n* – 1 years, the second for *n* – 2 years, and so on, with the second-to-last payment accumulating interest for 1 year and the last payment accumulating no interest. Therefore, if *i* is the nominal interest rate and yearly compounding is used, the future worth *F* of the series of payments is given by the expression

$$F = S\left(\frac{(1+i)^{n}-1}{(1+i)-1}\right) = S\left(\frac{(1+i)^{n}-1}{i}\right) = S\left(\frac{F}{S}, i, n\right)$$

Where F/S is often known as the series future worth factor or the series compound amount factor. It yields the future worth of a series of payments of equal amount *S* when *S* is multiplied by this factor. The amount *S* of a series of payments to pay off an amount *F.*

- **Taxes**

  Government depends heavily on taxes to finance its operations and to provide services. It is necessary to include taxes in the evaluation of the overall return on the investment in an engineering enterprise and also for comparing different financial alternatives for a venture. There are two main forms of taxation that are of concern to an engineering company: income tax and real estate, or property, tax.

  The overall profit made by a given company is the income that is taxed by the federal, state, and local governments. Though the federal taxation rate remains unchanged with location, the state and local taxes are strongly dependent on the location, varying from close to zero to as high as 20% across the country. However, the federal tax may vary with the size of the company and the nature of the industry. Since the amount paid in taxes is lost by the company, diligent efforts are made to reduce this payment by employing different legal means. Certainly, locating and registering the company at a place where the local taxes are low is a common approach. Similarly, providing bonuses and additional benefits to the employees, expanding and upgrading facilities, and acquisition of new facilities or enterprises increase the expenses incurred and reduce the taxes owed by the company.

- **Real estate and local taxes**

  Taxes are also levied on the property owned by the company. These may simply be real estate taxes on the value of the buildings and land occupied by the company or may include charges by the local authorities to provide services, such as access roads, security, and solid waste removal. All these are generally included as expenses in the operation of the company. Different alternatives involve different types of expenses and, therefore, the design of the system may be affected by these taxes. For instance, a system that involves a smaller floor area and, therefore, a smaller building and lower real estate taxes is more desirable than one that requires a large floor area. Similarly, the raw materials needed and the resulting waste are important in determining expenses for transportation and disposal, possibly making one system more cost effective than another.

- **Depreciation**

  The decrease in the value of the power plant equipment and building due to constant use is known as depreciation. An important concept with respect to the calculation of taxes is that of depreciation. Since a given facility has a finite useful life, after which it must be replaced, it is assumed to depreciate in value as time elapses until it is sold or discarded at its salvage value. In essence, an amount is allowed to be put aside each year for its replacement at the end of its useful life. This amount is the depreciation and is taken as an expense each year, thus reducing the taxes to be paid by the company. There are several approaches to calculating depreciation, as allowed by the federal government.

  The book value of the item is the initial cost minus the total depreciation charged up to a given point in time. Therefore, the book value B at the end of the j th year is given by

$$B = P - \frac{J}{n}(P - Q)$$

In actual practice, most facilities depreciate faster in the initial years than in later years, as anyone who has ever bought a new car knows very well. This is largely because of the lower desirability and unknown maintenance of the used item. As time elapses and the wear and tear are well established, the depreciation usually becomes quite small. Different distributions are used to represent this trend of greater depreciation rate in the early years. These include sum of-years digits (SYD), the declining balance, Modified accelerated cost recovery methods.

- **SYD method (Sum of the Years digits) D=** $\left[\frac{n-n1+1}{n(n+1)/2}\right]$ **(P-Q)**

Where the denominator is the sum n(n+1)/2 of the digits representing the years, 1,2,3….n. the numerator is the digit corresponding to the given year when the digits are arranged in reverse order, as n,n-1,n-2. And so on. By using this calculation procedure, the depreciation is larger than that obtained by the linear method in the early years and smaller in the later years.

GENERAL CHARACTERISTICS OF CAPITAL INVESTMENTS

When companies spend money, the outlay of cash can be broadly categorized into one of two classifications; expenses or capital investments. Expenses are generally those cash expenditures those are routine, on-going, and necessary for the ordinary operation of the business.

Capital investments, on the other hand, are generally more strategic and have long term effects. Decisions made regarding capital investments are usually made at higher levels within the organizational hierarchy and carry with them additional tax consequences as compared to expenses. Three characteristics of capital investments are of concern when performing life cycle cost analysis. First, capital investments usually require a relatively large initial cost. "Relatively large" may mean several hundred dollars to a small company or many millions of dollars to a large company. The initial cost may occur as a single expenditure such as purchasing a new heating system or occur over a period of several years such as designing and constructing a new building. It is not uncommon that the funds available for capital investments projects are limited. In other words, the sum of the initial costs of all the viable and attractive projects exceeds the total available funds. This creates a situation known as capital rationing which imposes special requirements on the investment analysis.

The second important characteristic of a capital investment is that the benefits (revenues or savings) resulting from the initial cost occur in the future, normally over a period of years. The period between the initial cost and the last future cash flow is the life cycle or life of the investment. It is the facts that cash flows occur over the investment's life that requires the introduction of time value of money concepts to properly evaluate investments. If multiple investments are being evaluated and if the lives of the investments are not equal, special consideration must be given to the issue of selecting an appropriate planning horizon for the analysis.

The last important characteristic of capital investments is that they are relatively irreversible. Frequently, after the initial investment has been made, terminating or significantly altering the nature of a capital investment has substantial (usually negative) cost consequences.

This is one of the reasons that capital investment decisions are usually evaluated at higher levels of the organizational hierarchy than operating expense decisions.

Capital Investment Cost Categories

In almost every case, the costs which occur over the life of a capital investment can be classified into one of the following categories:

- Initial Cost,
- Annual Expenses and Revenues,
- Periodic Replacement and Maintenance, or
- Salvage Value.

As a simplifying assumption, the cash flows which occur during a year are generally summed and regarded as a single end-of-year cash flow. While this approach does introduce some inaccuracy in the evaluation, it is generally not regarded as significant relative to the level of estimation associated with projecting future cash flows. Initial costs include all costs associated with preparing the investment for service. This includes purchase cost as well as installation and preparation costs. Initial costs are usually nonrecurring during the life of an investment. Annual expenses and revenues are the recurring costs and benefits generated throughout the life of the investment. Periodic replacement and maintenance costs are similar to annual expenses and revenues except that they do not (or are not expected to) occur annually. The salvage (or residual) value of an investment is the revenue (or expense) attributed to disposing of the investment at the end of its useful life.

Cash Flow Diagrams

A convenient way to display the revenues (savings) and costs associated with an investment is a cashflow diagram. By using a cash flow diagram, the timing of the cash flows are more apparent and the chances of properly applying time value of money concepts are increased. With practice, different cash flow patterns can be recognized and they, in turn, may suggest the most direct approach for analysis. It is usually advantageous to determine the time frame over which the cash flows occur first. This establishes the horizontal scale of the cash flow diagram. This scale is divided into time periods which are frequently, but not always, years. Receipts and disbursements are then located on the time scale in accordance with the problem specifications. Individual outlays or receipts are indicated by drawing vertical lines appropriately placed along the time scale. The relative magnitudes can be suggested by the heights, but exact scaling generally does not enhance the meaningfulness of the diagram. Upward directed lines indicate cash inflow (revenues or savings) while downward directed lines indicate cash outflow (costs).

Theory questions:

1. List the difference types of thermal energy storage systems. Explain any two of them. **2.** Elaborate the different phases involved in detailed energy audit methodology

3. What are the general characteristics of capital investment?

4. Explain in detail various phases of energy audit methodology

5. List the various thermal energy storage methods. Explain sensible heat and latent heat storage methods.

6. Define energy audit. Explain the need for energy audit.

7. Write a short note on energy demand estimation

8. Elaborate the benefits of thermal energy storage.