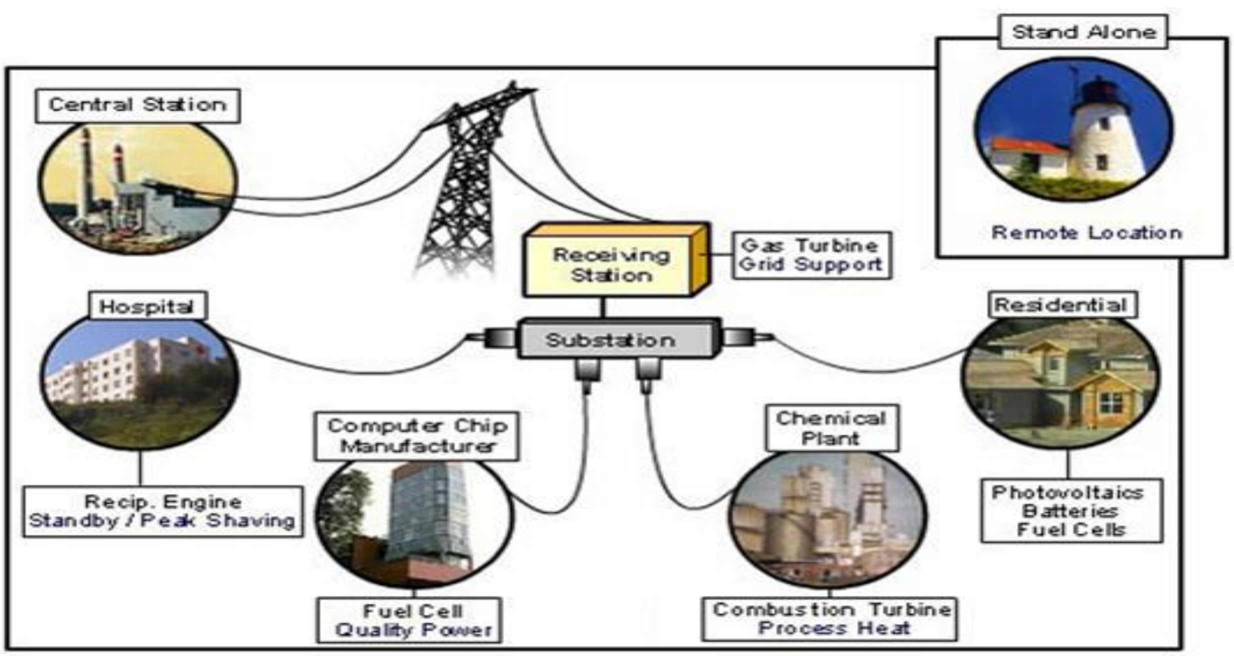
DISTRIBUTED ENERGY RESOURCES

- Distributed energy resources are small, modular, energy generation and storage technologies that provide electric capacity or energy where needed. Typically producing less than 10 megawatts (MW) of power, DER systems can be sized to meet your particular needs and installed on site. DER systems may be either connected to the local electric power grid or isolated from the grid in stand-alone applications. DER technologies include wind turbines, photovoltaic (PV), fuel cells, micro turbines, reciprocating engines, combustion turbines, cogeneration, and energy storage systems.
- DER systems can be used in several ways. They can help you manage energy bills and ensure reliable power by augmenting your current energy services. DER systems also enable a facility to operate independently of the electric power grid, whether by choice or out of necessity. Certain DER systems can even lower emissions and improve fuel utilization on-site. Utilities can use DER technologies to delay, reduce, or even eliminate the need to obtain additional power generation, transmission, and distribution equipment and infrastructure. At the same time, DER systems can provide voltage support and enhance local reliability.



Benefits of distributed energy resources

- Distributed energy resources have the potential to provide consumers with a range of benefits:
- Consumers who install DER units may be able to reduce the price they pay for electricity or may obtain improved reliability outcomes.
- DER may also help reduce the cost of power system augmentation, helping to reduce the overall cost of supply faced by consumers.
- Increased penetration of DER may also help reduce the overall emissions intensity of the NEM, by displacing other more emissions-intensive generation.
- While DER provides a range of benefits, it also includes a range of relatively new and developing technologies. Power systems and networks need to adjust to the effects of these new technologies. It is important that these initial issues are recognized and addressed in order to ensure that the benefits of DER can be fully realized.

Types of DER technologies

- **Microturbines**
- Microturbines are small combustion turbines that produce between 25 kW and 500 kW of power. Microturbines were derived from turbocharger technologies found in large trucks or the turbines in aircraft auxiliary power units.

- **Combustion Turbines**
- Conventional combustion turbine (CT) generators typically range in size from about 500 kW up to 25 MW for DER, and up to approximately 250 MW for central power generation. They are fueled by natural gas, oil, or a combination of fuels ("dual fuel"). Modern single-cycle combustion turbine units typically have efficiencies in the range of 20 to 45% at full load. Efficiency is somewhat lower at less than full load.

- **Internal Combustion Engines**
- A reciprocating, or internal combustion (IC), engine converts the energy contained in a fuel into mechanical power. This mechanical power is used to turn a shaft in the engine. A generator is attached to the IC engine to convert the rotational motion into power. They are available from small sizes (e.g., 5 kW for residential back-up generation) to large generators (e.g., 7 MW). Reciprocating engines use commonly available fuels such as gasoline, natural gas, and diesel fuel.

- **Stirling Engines**
- Stirling engines are classed as external combustion engines. They are sealed systems with an inert working fluid, usually either helium or hydrogen. They are generally found in small sizes (1–25 kW) and are currently being produced in small quantities for specialized applications in the space and marine industries.

- **Energy Storage/UPS Systems**
- Energy storage technologies produce no net energy but can provide electric power over short periods. They are used to correct voltage sags, flicker, and surges that occur when utilities or customers switch suppliers or loads. They may also be used as an uninterruptible power supply (UPS). As such, energy storage technologies are considered to be a distributed energy resource

- **Photovoltaic System**
- Photovoltaic (PV) cells, or solar cells, convert sunlight directly into electricity. PV cells are assembled into flat plate systems that can be mounted on rooftops or other sunny areas. They generate electricity with no moving parts, operate quietly with no emissions, and require little maintenance.

- **Wind Systems**
- Wind turbines use the wind to produce electrical power. A turbine with fan blades is placed at the top of a tall tower. The tower is tall to harness the wind at a greater velocity, free of turbulence caused by interference from

obstacles such as trees, hills, and buildings. As the turbine rotates in the wind, a generator produces electrical power. A single wind turbine can range in size from a few kW for residential applications to more than 5 MW.

- **Hybrid Systems**
- Developers and manufacturers of DER are looking for ways to combine technologies to improve the performance and efficiency of distributed generation equipment. Several examples of hybrid systems include:
- Solid oxide fuel cell combined with a gas turbine or microturbine.
- Stirling engine combined with a solar dish.
- Wind turbines with battery storage and diesel backup generators.
- Engines (and other prime movers) combined with energy storage devices such as flywheels.

QUESTION BANK

1. What are Distributed Energy Resources (DER)?
2. What are the benefits of distributed energy resources?
3. How does distributed energy work?
4. What are the types of distributed energy resources?
5. Explain all types of distributed energy resources.
6. What is the characteristic of distributed energy resources? Explain.

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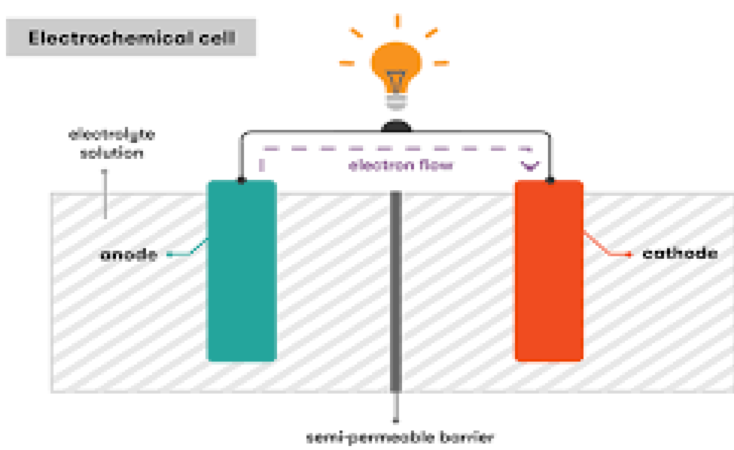
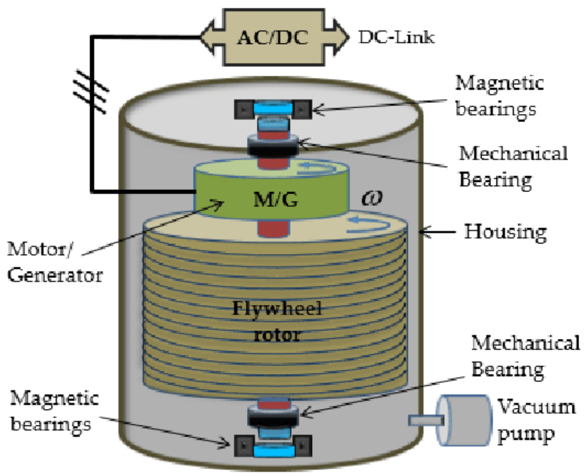
ENERGY STORAGE

- Electricity is more versatile in use than other types of power, because it is a highly ordered form of energy that can be converted efficiently into other forms. For example, it can be converted into mechanical form with efficiency near 100% or into heat with 100% efficiency. Heat energy, on the other hand, cannot be converted into electricity with such high efficiency, because it is a disordered form of energy in atoms. For this reason, the overall thermal-to-electrical conversion efficiency of a typical fossil thermal power plant is less than 50%.
- A disadvantage of electricity is that it cannot be easily stored on a large scale. Almost all electric energy used today is consumed as it is generated. This poses no hardship in conventional power plants, in which fuel consumption is continuously varied with the load requirement. Wind and photovoltaic (PV), both being intermittent sources of power, cannot meet the load demand at all times, 24 h a day, 365 d a year. Energy storage, therefore, is a desired feature to incorporate with such power systems, particularly in stand-alone plants. It can significantly improve the load availability, a key requirement for any power system.
- The present and future energy storage technologies that may be considered for stand-alone wind or PV power systems fall into the following broad categories:

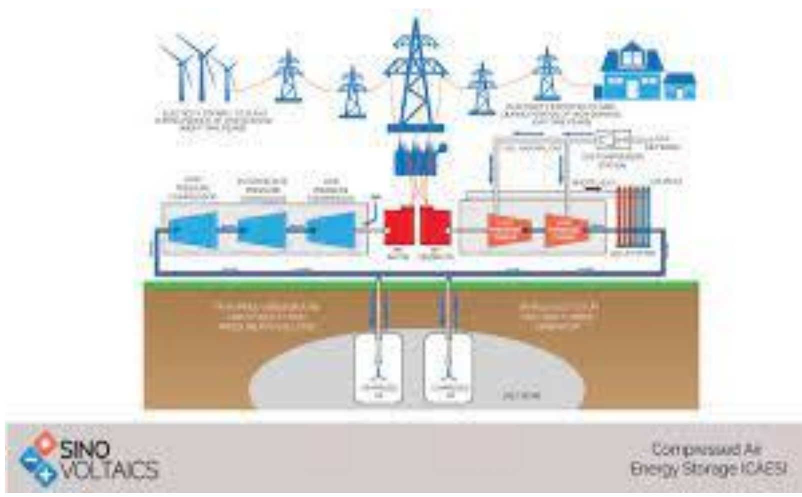
- **Electrochemical battery**



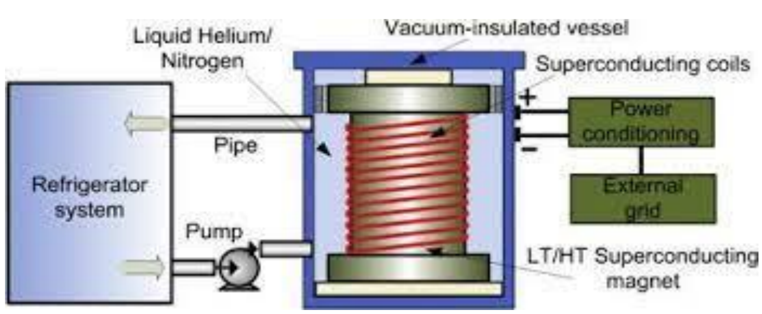
- **Flywheel**



- **Compressed air**



- **Superconducting coil**

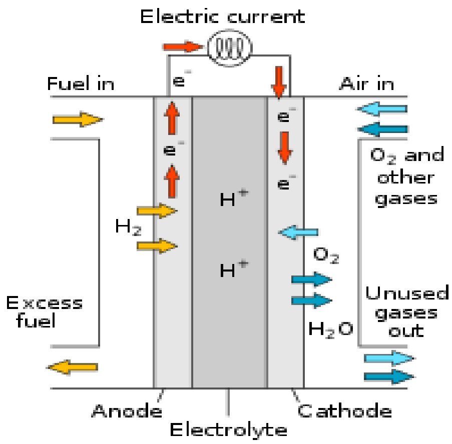


- There are a lot of problems in storing electricity in large quantities. Energy that can be converted into electricity can be stored in several ways. Storage of any nature is, however, very costly, and its economics must be worked out properly. Various options available are: pumped storage, compressed air, heat, hydrogen gas, secondary batteries, flywheels, and superconducting coils.
- As already mentioned, gas turbines are normally used for meeting peak loads but are very expensive. A significant amount of storage capable of instantaneous use would be a better way of meeting such peak loads, and so far, the most important way is to have a pumped storage plant, as discussed earlier. Energy storage can play an important role where there is a time or rate mismatch between the supply and demand of energy. Other methods are discussed below very briefly.

- **Secondary Batteries**

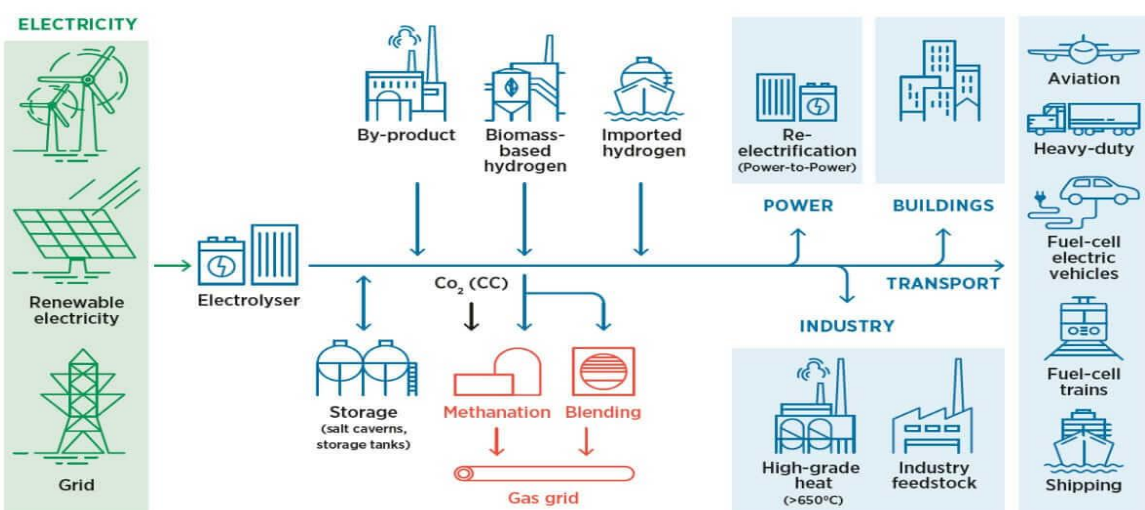
- Large-scale battery use is almost ruled out, and they will be used for battery-powered vehicles and local fluctuating energy sources such as wind mills or solar. The most widely used storage battery is the lead acid battery, invented by Plante in 1860. Sodium-sulfur battery (200 Wh/kg) and other combinations of materials are also being developed to get more output and storage per unit weight

- **Fuel Cells**
- A fuel cell converts the chemical energy of a fuel into electricity directly, with no intermediate combustion cycle. In the fuel cell, hydrogen is supplied to the negative electrode and oxygen (or air) to the positive. Hydrogen and oxygen are combined to give water and electricity. The porous electrodes allow hydrogen ions to pass.



- The main reason why fuel cells are not in wide use is their cost (> $ 2000/kW). Global electricity generating capacity from full cells will grow from just 75 MW in 2001 to 15000 MW by 2010. US. Germany and Japan may take the lead for this.

- **Hydrogen Energy Systems**



- Hydrogen can be used as a medium for energy transmission and storage. Electrolysis is a well-established commercial process yielding pure hydrogen. H2 can be converted very efficiently back to electricity employing fuel cells.
- Also, the use of hydrogen as fuel for aircraft and automobiles could encourage its large-scale production, storage, and distribution.

ENERGY STORAGE-RELATED EXAMPLES

1) A car of mass 1500 kg brakes from 50 km/h in 3.5 seconds when meeting a red light. Based on the intermediate values in Table 1.2, determine

a) The mass needed for a super capacitor and a Li-ion battery.

b) The distance the technology can take you at 50 km/h (requires 10 kW).

Solution: -

a) First, we must determine the kinetic energy. At 50 km/h, this is

$$E_{kin} = \frac{1}{2}mv^2 = 0.5 \cdot 1500\ [\mathrm{kg}] \left(\frac{50\ [\mathrm{km/h}]}{3.6\ [\mathrm{ks/h}]}\right)^2 = 145\ [\mathrm{kJ}] = 0.040\ [\mathrm{kWh}].$$

The power thus becomes

$$P = \frac{\Delta E}{\Delta t} = \frac{145\ [\mathrm{kWs}]}{3.5\ [\mathrm{s}]} = 41\ [\mathrm{kW}].$$

The mass needed from an energy perspective is given as the energy divided by the specific energy:

$$m_i = \frac{E_i}{e_i}.$$

Concerning the power, the mass is given by the power needed divided by the power density:

$$m_i = \frac{P_i}{p_i}.$$

Intermediate values and corresponding weight needs are:

Technology	Specific energy /[kWh/kg]	Mass need /[kg]	Specific power /[kW/kg]	Mass need /[kg]
Supercapacitor	0.0035	11	3	14
Li-ion battery	0.35	0.11	0.2	205

To take up the energy from braking, the super capacitor and Li-ion battery must have masses of 11 and 0.1 kg, respectively. To take up the power, they must have masses of 14 and 205 kg, accordingly. Therefore, this braking requires 14 kg of a super capacitor or 205 kg of a battery. The super capacitor is the lighter choice.

b) When the car travels 50 km/h, a power need of 10 kW is suggested. We need to relate the energy in the storage device to the energy and the driving distance:

Energy need = Energy on board,

$$P_{need}\Delta t = e_i m_i,$$

$$P_{need}\frac{l}{v} = e_i m_i \Leftrightarrow l = \frac{v}{P_{need}} e_i m_i.$$

Thus, we can calculate the driving distance for the given technologies.

$$l_{supercap.} = \frac{50\ [\mathrm{km/h}]}{10\ [\mathrm{kW}]} 0.0035\ [\mathrm{kWh/kg}] 14\ [\mathrm{kg}] = 245\ [\mathrm{m}],$$

$$l_{sLi-ion\ B} = \frac{50\ [\mathrm{km/h}]}{10\ [\mathrm{kW}]} 0.35\ [\mathrm{kWh/kg}] 205\ [\mathrm{kg}] = 359\ [\mathrm{km}].$$

Thus, we see that a battery package has the capacity to brake a car from 50 km/h to still stand in 3.5 second and, at the same time, travel of 360 km in an urban area, which explains why Li-ion batteries are such a success in small short-range (200 km) vehicles.

2. A common figure used for energy loss in the electric grid is 8%. Suppose that water is pumped up at night time with an efficiency of 95% at night time and released at an efficiency of 85% in the morning.

a) What is the energy efficiency of sending the electric power to the energy storage facility at night and to have it returned in the morning?

b) What is the largest loss in energy and what is its relative contribution in the cycle?

Solution: -

a) We must first make an overview of the energy efficiency of each step in the series:

	Grid night	Pumping	Discharge	Grid morning
ε	0.92	0.95	0.85	0.92

The overall energy efficiency is given by Eq. (1.3) as

E=0.92*0.95*0.85*0.92=68%

b) The largest contribution to the loss in energy efficiency is the discharge. Comparing all the relative losses (not efficiencies), we get their relative contribution from the discharge 15/8+5+15+8 =22%

QUESTION BANK

1. What is energy storage?
2. Why is energy storage important?
3. Can energy storage technology work with all fuel sources?
4. Why do we need energy storage?
5. Explain energy storage methods.
6. How will energy storage cut power costs?
7. When we talk about storage, we talk a lot about batteries. How do energy storage batteries compare to the AA batteries in a flashlight?
8. What is the difference between residential and commercial energy storage?

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