

Introduction to Energy Resources: Energy resources are vital for powering human activities and sustaining modern life. They can be categorized into two main types: renewable and non-renewable.

Renewable Energy Resources

These resources are naturally replenished on a human timescale and have a lower environmental impact compared to non-renewable sources.

1. **Solar Energy:** Harnessed from the sun using solar panels or solar thermal systems. It's abundant and can be used for electricity, heating, and more.
2. **Wind Energy:** Captured using wind turbines that convert wind into electricity. It's one of the fastest-growing energy sources.
3. **Hydropower Energy:** Generated from the movement of water, typically through dams or river flows. It's a well-established source of renewable energy.
4. **Geothermal Energy:** Derived from the heat stored beneath the Earth's surface. It's used for electricity generation and direct heating applications.
5. **Biomass Energy:** Produced from organic materials such as plant and animal waste. It can be converted into biofuels or used directly for heating.

Non-Renewable Energy Resources

These resources are finite and deplete over time, and their use often results in environmental challenges.

1. **Fossil Fuels:** Includes coal, oil, and natural gas. They are burned for electricity, heating, and transportation, but their use contributes to greenhouse gas emissions and climate change.
2. **Nuclear Energy:** Generated from nuclear reactions, typically involving uranium. It produces a large amount of energy but raises concern about radioactive waste and nuclear accidents.

Green Energy: The concept of green energy refers to the generation and use of energy from environmentally friendly sources that have minimal negative impact on the environment. These sources are renewable, meaning they are naturally replenished and do not run out over time, unlike fossil fuels. Green energy contributes to reducing greenhouse gas emissions, air pollution, and reliance on non-renewable resources, making it a crucial element in combating climate change and promoting sustainable development.

Green energy is a critical element of the global shift toward a sustainable and low-carbon future, as governments, businesses, and individuals continue to explore ways to transition from fossil fuels to renewable alternatives.

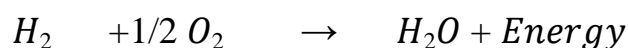
Benefits of Green Energy:

- **Reduces Carbon Footprint:** Since green energy sources emit little to no greenhouse gases during operation, they help mitigate climate change.
- **Sustainability:** Unlike fossil fuels, renewable energy sources are inexhaustible, making them more sustainable over the long term.
- **Energy Independence:** Countries relying on green energy reduce their dependence on imported fossil fuels, increasing energy security.
- **Job Creation:** The green energy sector creates jobs in manufacturing, installation, maintenance, and research.

Introduction to Hydrogen energy

Hydrogen as an energy can play important role as an alternative to conventional fuels. Hydrogen as highest energy content per unit mass compare to any chemical fuel, often it increases combustion efficiency.

The combination of Hydrogen with oxygen results in the liberation of energy with water as the only product



Burning process is non-polluting hence it can be utilizing to produce both electricity and useful heat.

Hydrogen production by electrolysis process

Process of splitting water into hydrogen and oxygen by means of direct current is known as electrolysis.

Construction

Electrolysis cell consist of two electrode commonly flat metals or Carbon plates. Electrodes immersed in aqueous conducting solution called electrolyte (e.g. KOH solution). Source of direct current voltage is connected to electrode so that current can flow through electrolyte from anode (-ve charge) to cathode (+ve charge).

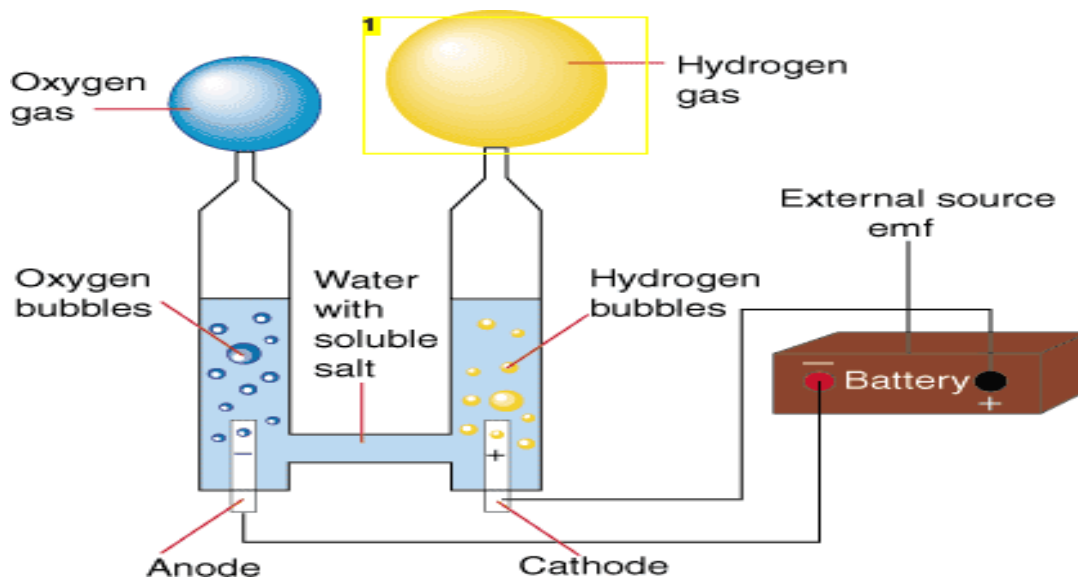
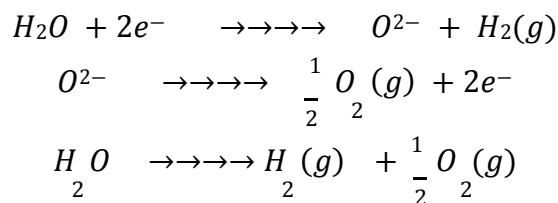


Figure 1. Electrolysis Process

Working Principle:

As direct current passes through electrolyte, the water in electrolyte solution decomposes into Hydrogen gas (H_2) which is released at cathode (+ve). Oxygen Gas (O_2) released at anode. Here electrolyte required KOH solution bcz water poor conductor of electricity.

Chemical reaction takes place during electrolysis



Ideally, a voltage 1.23 -2 volts should be sufficient for the electrolysis of water at Normal Atmospheric conditions. Since the rate of hydrogen production is proportional to current strength. Theoretically 2.8kW-hr electric energy should produce 1 m^3 of hydrogen gas. However actual electrical energy requirement is about 3.9 to 4.6 kW-hr per m^3 . Hence electrolysis efficiency to produce hydrogen is about 60 to 70%.

Advantages of Hydrogen Energy:

1. Clean and Renewable:

- When hydrogen is used in a fuel cell, the only by-product is water vapor, making it a zero-emission energy source if produced from renewable sources like wind or solar.

2. Abundant Availability:

- Hydrogen is the most abundant element in the universe. Though not found in its pure form on Earth, it can be produced from a wide range of sources, including water, biomass, and natural gas.

3. Versatility:

- Hydrogen can be used in various sectors, including electricity generation, transportation (fuel-cell vehicles), and industrial processes (like steel production). It can also be stored and transported, making it flexible compared to some other renewable sources.

4. Energy Efficiency:

- Hydrogen fuel cells are more efficient than internal combustion engines in vehicles. Hydrogen energy conversion can also achieve high energy efficiency in power generation.

5. Energy Storage:

- Hydrogen can act as a form of energy storage, which is useful for balancing intermittent renewable energy sources like solar and wind. Excess electricity can be used to produce hydrogen (via electrolysis), which can then be stored for later use.

6. Reduces Dependence on Fossil Fuels:

- Hydrogen can reduce reliance on oil and natural gas, particularly in sectors like transportation and industry, where electrification is challenging.

Disadvantages of Hydrogen Energy:

1. Environmental Impact of Hydrogen Production from Fossil Fuels:

- Currently, most hydrogen is produced from natural gas through a process called steam methane reforming, which emits carbon dioxide. Without carbon capture and storage (CCS), this method contributes to greenhouse gas emissions.

2. Efficiency Losses:

- The full hydrogen energy cycle (production, storage, transportation, and usage) can suffer from efficiency losses. Energy is lost at each step, particularly in the conversion process from electricity to hydrogen and back to electricity.

Solar P V System:

A photovoltaic system is a special electrical system that produces energy from a renewable and inexhaustible source: the sun. Essentially, there are two types of photovoltaic systems: Grid connected systems are systems that are integrated with conventional residential and industrial electricity systems. The process of converting light (photons) to electricity (voltage) is called the solar photovoltaic (PV) effect.

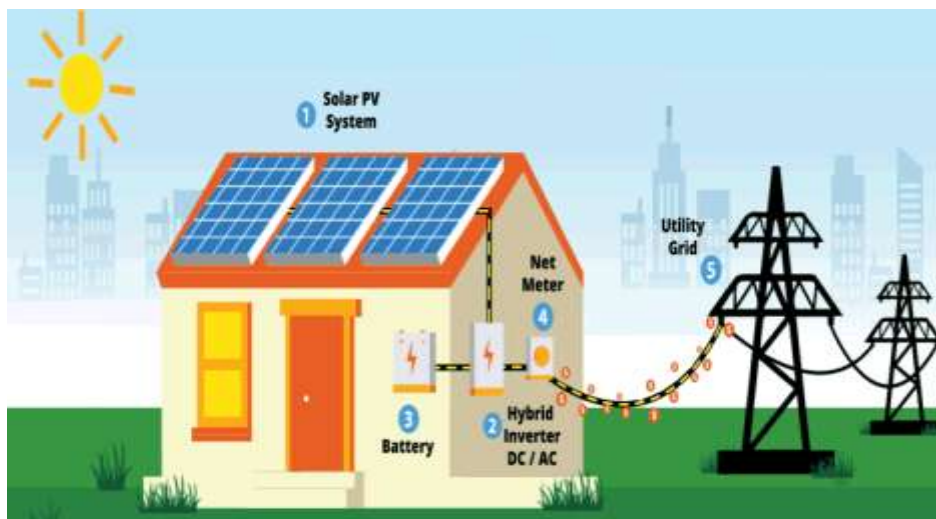


Figure 2. Solar P V System

Photovoltaic solar cells convert sunlight directly into solar power (electricity). They use thin layers of semi-conducting material that is charged differently between the top and bottom layers. The semi-conducting material can be encased between a sheet of glass and/or a polymer resin. When exposed to daylight, electrons in the semi-conducting material absorb the photons, causing them to become highly energized. These move between the top and bottom surfaces of the semiconducting material. This movement of electrons generates a current known as a direct current (DC). This is then fed through an inverter, which converts the power to alternating current (AC) for use in your home.

Working principle of Photovoltaic system:

The working principle of a Photovoltaic (PV) system involves the conversion of sunlight into electricity through the use of semiconductor materials in solar cells. Here's a step-by-step breakdown of how the process works:

Sunlight Absorption: Photovoltaic systems are designed to capture sunlight using solar panels, also known as photovoltaic modules. These panels are made up of semiconductor materials, often crystalline silicon.

Photovoltaic Effect: When sunlight (composed of photons) strikes the solar panels, the energy from the photons is absorbed by the semiconductor material. This absorption of energy excites electrons in the atoms of the semiconductor, causing them to become mobile.

Generation of Electron-Hole Pairs: As a result of the absorbed energy, electron-hole pairs are generated. Electrons gain energy and move to a higher energy state, leaving behind positively charged holes in their original positions.

Electric Current Generation: The movement of these excited electrons creates an electric current. The semiconductor material is carefully treated and structured to facilitate the flow of electrons, directing them in a specific direction.

Direct Current (DC) Output: The electric current generated is in the form of direct current (DC). This DC electricity is the result of the flow of electrons in a single direction within the solar cells.

Inverter Conversion: Since most appliances and the electrical grid use alternating current (AC), the DC electricity generated by the solar panels needs to be converted. This conversion is done by an inverter, which transforms DC electricity into AC electricity.

Usage or Grid Connection: The converted AC electricity can be used to power electrical appliances and equipment in homes or businesses. In grid-tied systems, any excess electricity can be fed into the electrical grid, and the user may receive credits or compensation for this surplus energy.

Optional: Energy Storage in Batteries: In some PV systems, particularly those in off-grid setups or areas with unreliable grid access, excess energy is stored in batteries. This stored energy can be used during periods when sunlight is not available.

Wind Energy

Wind energy can be described as the harnessing of moving air by wind turbines to produce electricity. Harvesting wind power isn't exactly a new idea – sailing ships, wind-mills, wind-pumps

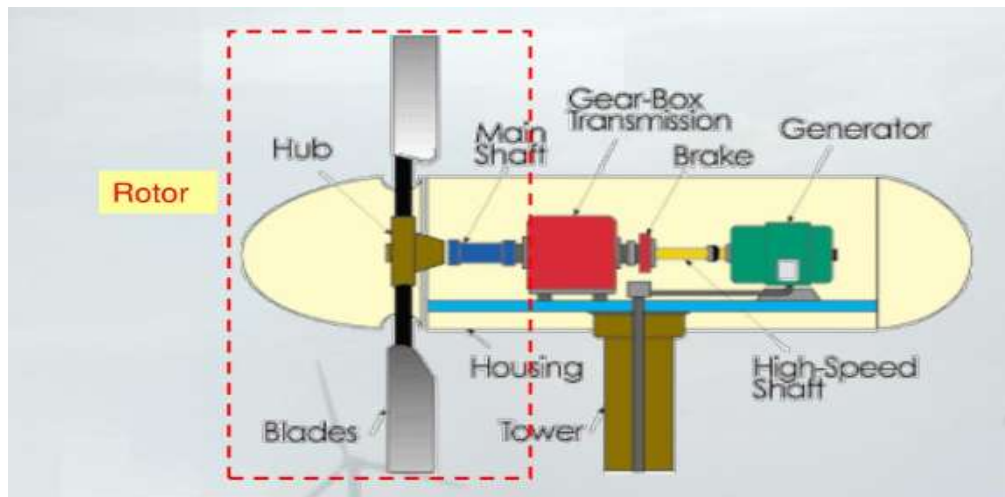


Figure 3. Parts of Wind Power Plant

Working of Wind Turbine:

- Wind is a moving stream of air caused by differences in atmospheric pressure. When wind blows across the turbine blades, it transfers some of its kinetic energy to the blades.
- The blades of a wind turbine are shaped like an airfoil (similar to an airplane wing), which allows them to capture the wind's energy efficiently. As wind passes over the blades, it creates a difference in air pressure between the two sides of the blade, generating lift and causing the blades to rotate around the central hub.
- The rotating blades are connected to a rotor. The rotor's rotation converts the wind's kinetic energy into mechanical energy.
- The gearbox is used to increase the rotational speed of the shaft connected to the generator. The gearbox converts the slow rotation of the rotor into a faster rotation suitable for the generator. However, direct-drive turbines skip the gearbox and directly connect the rotor to the generator.
- The rotating shaft from the rotor (or gearbox) drives a generator. Inside the generator, the mechanical energy is converted into electrical energy through electromagnetic induction. This process involves the rotation of a coil within a magnetic field, which induces an electric current in the coil.
- The electrical energy generated is then transmitted to a substation, where it is transformed to higher voltages for long-distance transmission through the electrical grid.

