


CMR INSTITUTE OF TECHNOLOGY		USN												
IAT-1														
Sub:	RENEWABLE ENERGY POWER PLANT								Code:	BME654B				
Date:	27-03-2025	Duration:	90 mins	Marks:	50	Sem:	6	Section::	CSE/ISE/AIDS /AIML					
Scheme of Evaluation and Solution														

Marks CO RBT

1	Discuss causes of energy scarcity and solution to energy scarcity.	5+5
2	Explain briefly energy resources and its classification.	4+6
3	Explain the types of Solar radiation. a) Diffused b) Direct and c) Global radiation with a neat sketch.	1+3+3+3
4	Explain the main components of flat plate solar collectors, explain the function of each.	5+5
5	Classify wind energy conversion system (WECS), with a simple line diagram explain main components of Horizontal axis wind turbine (HAWT)	2+4+4
6.	Explain extra terrestrial radiation and solar constant with a neat sketch, describing the construction and working principle of the pyranometer.	2+2+3+3
7.	What is the principle of solar photovoltaic power generation? What are the main elements of a PV system?	2+2+6

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Solution:

1. Causes of Energy Scarcity & Solutions

Causes:

- Depleting fossil fuels: Finite reserves of coal, oil, and gas cannot meet rising demand.
- Population growth: Increased energy consumption per capita strains resources.
- Inefficient infrastructure: Transmission losses (up to 30% in some grids) and outdated power plants.
- Geopolitical conflicts: Disruptions in fuel supply chains (e.g., Russia-Ukraine war impacting gas supplies).
- Climate policies: Phasing out coal without adequate renewable replacements.

Solutions:

- Renewable energy adoption: Solar/wind capacity expansion (global solar capacity reached 1.2 TW in 2023).
- Energy storage: Battery tech (e.g., lithium-ion) for grid stability.
- Smart grids: AI-driven demand-response systems to reduce wastage.
- Nuclear fusion: Projects like ITER aim for near-limitless clean energy.
- Behavioral changes: Promoting energy-efficient appliances (e.g., LED lighting saves 80% energy).

2. Energy Resources:

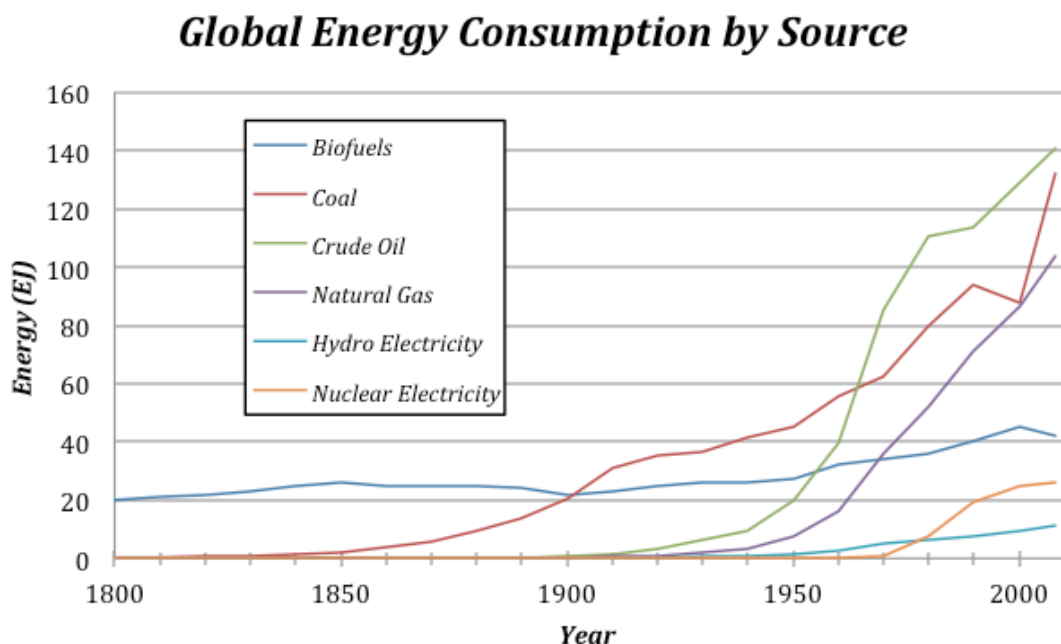
Primary sources like fossil fuels (coal, oil), renewables (solar, wind), and nuclear.

Renewable:

- Solar*: Photovoltaic/thermal systems.
- Wind*: Onshore/offshore turbines.
- Hydropower*: Dams/tidal streams.

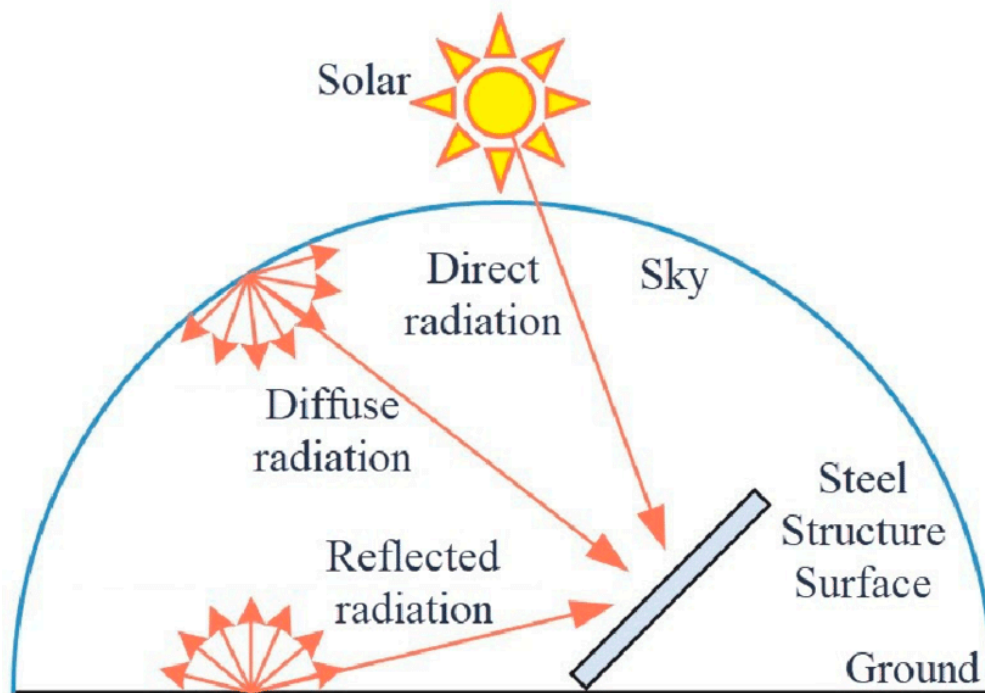
Non-renewable:

- Fossil fuels*: Coal (35% global electricity), natural gas.
- Nuclear*: Uranium-based fission.



3. Types of Solar Radiation

- a) Direct Radiation: Sunlight reaching Earth's surface without scattering (beam radiation).
- b) Diffuse Radiation: Scattered by atmosphere/clouds (20% of total).
- c) Global Radiation: Sum of direct + diffuse (measured in W/m^2).



4. Flat Plate Solar Collector Components

A Flat Plate Collector is a device acting as a heat exchanger. It converts solar power into thermal energy. It can gather solar energy and use it to heat water in the house for bathing, washing, etc. Also, it can be used to heat hot tubs and swimming pools.

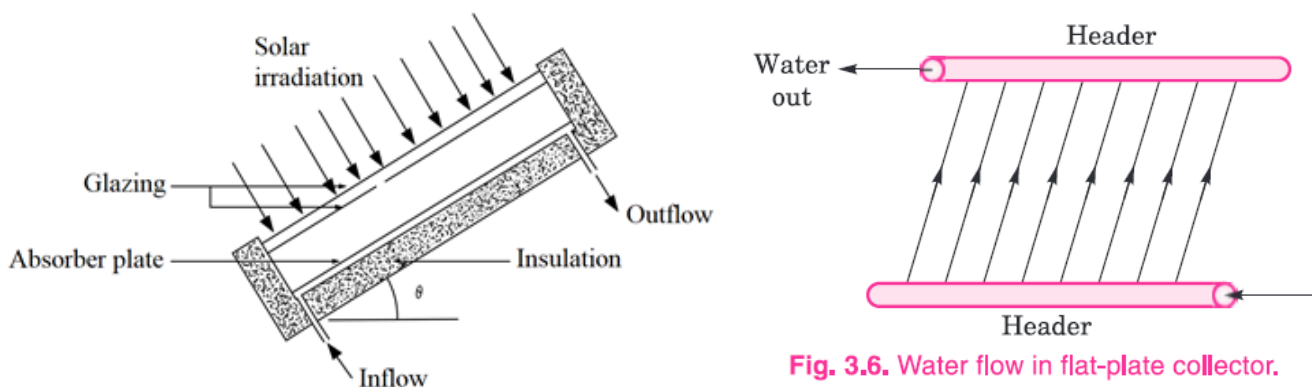


Fig. 3.6. Water flow in flat-plate collector.

1. Absorber Plate: Dark-coated metal (copper/aluminum) to maximize heat absorption.
2. Glazing Cover: Tempered glass reduces convective losses.
3. Insulation (Back/Sides): Minimizes heat loss (fiberglass/polyurethane).
4. Fluid Tubes: Circulate heat transfer fluid (water/glycol).
5. Casing: Aluminum frame for durability.

Sunlight passes through the glazing and is absorbed by the dark absorber plate.

The absorber plate heats up, and the heat is transferred to the fluid flowing through the pipes.

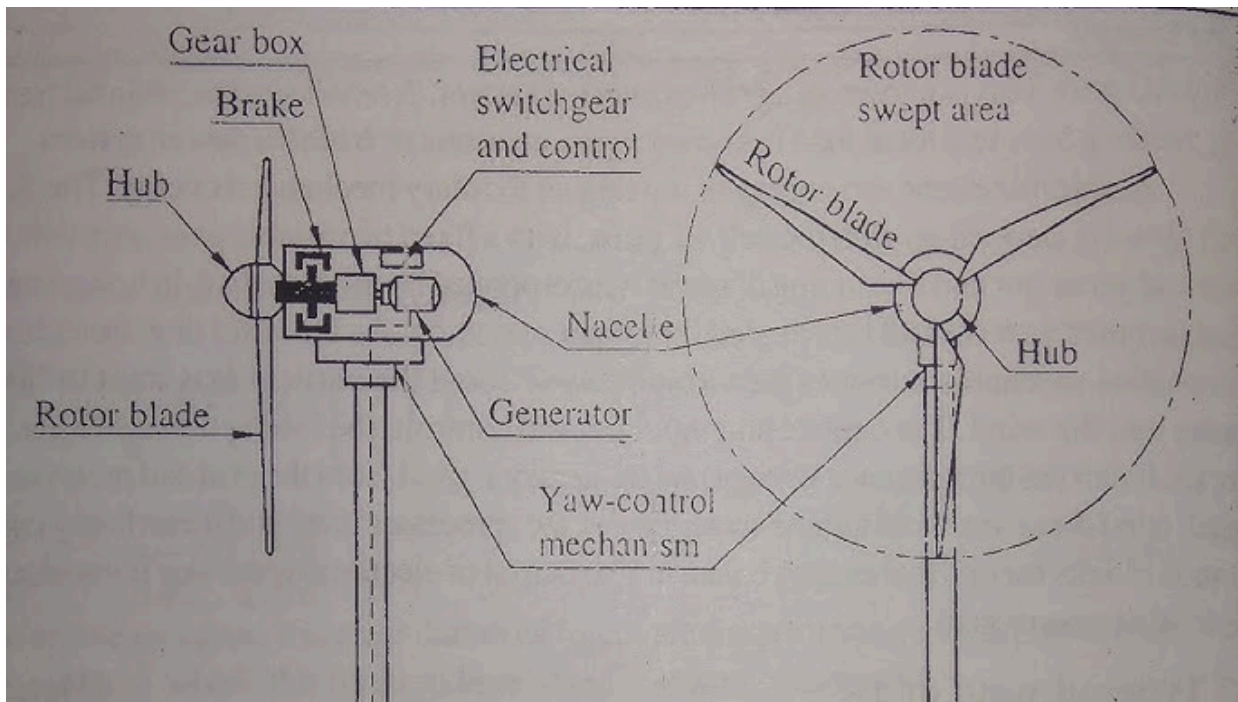
The heated fluid is then circulated to a storage tank or heat exchanger for use in heating water or space.

5. A Wind Energy Conversion System (WECS) converts kinetic energy from wind into electrical energy through a series of mechanical and electrical processes.

Types of WECS

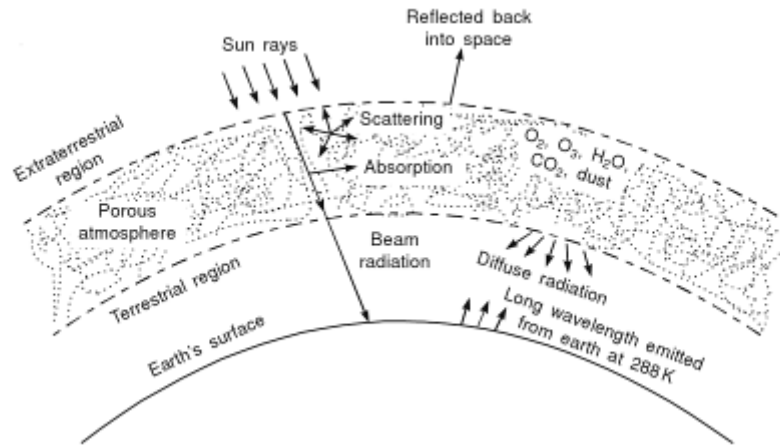
Horizontal Axis Wind Turbine (HAWT)

Vertical Axis Wind Turbine (VAWT)

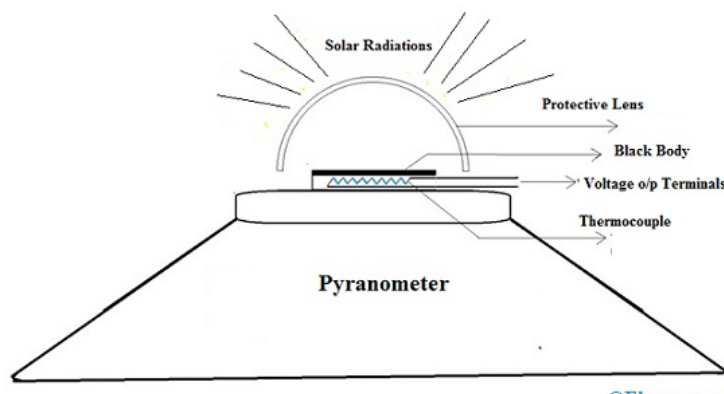


A Horizontal Axis Wind Turbine (HAWT) converts wind energy into electricity through aerodynamic and electromechanical processes. When wind flows over the airfoil-shaped blades, it creates a pressure difference that generates lift, causing the rotor to spin. The low-speed rotation (10–25 RPM) is either increased by a gearbox or directly fed into a generator in direct-drive systems. A yaw mechanism adjusts the nacelle to face the wind direction for optimal energy capture. The generator produces variable-frequency AC, which is converted to stable grid-compatible power via rectifiers and inverters. Control systems, including pitch adjustment and braking, ensure safe operation during high winds. HAWTs are highly efficient (35–45% of Betz limit) and scalable, making them ideal for onshore and offshore wind farms, though they require tall towers and careful positioning for maximum output.

6. Extraterrestrial radiation refers to the solar energy received at the top of Earth's atmosphere, characterized by the solar constant of approximately 1361 W/m^2 . This value represents the average irradiance at Earth's mean distance from the Sun, unaffected by atmospheric absorption or scattering. The measurement of solar radiation at Earth's surface is crucial for renewable energy applications, and this is where pyranometers play a vital role.



A pyranometer is a precision instrument designed to measure global solar radiation (both direct and diffuse components) reaching a horizontal surface. Its construction features a thermopile sensor with alternating black and white surfaces mounted beneath a hemispherical glass dome. The glass dome serves multiple purposes: it protects the sensor from environmental factors while transmitting solar radiation across a broad spectral range (typically 300-2800 nm). The black-coated surfaces absorb solar radiation and heat up, while the white surfaces remain relatively cooler, creating a temperature gradient across the thermopile junctions. This temperature difference generates a small voltage output (typically in the range of microvolts per W/m^2) that is directly proportional to the incident solar radiation.



The instrument's working principle relies on the thermoelectric effect, where the voltage output varies linearly with the net radiation flux. Modern pyranometers incorporate temperature compensation and cosine correction to ensure accurate measurements across different solar zenith angles. Calibration against standard references maintains measurement traceability to the World Radiometric Reference. These devices are fundamental in meteorology, climatology, and solar energy system monitoring, providing essential data for photovoltaic system performance assessment and solar resource mapping. The glass dome requires regular cleaning to prevent measurement errors from dust accumulation, and proper installation (horizontal leveling and unobstructed exposure) is critical for obtaining representative solar radiation data.

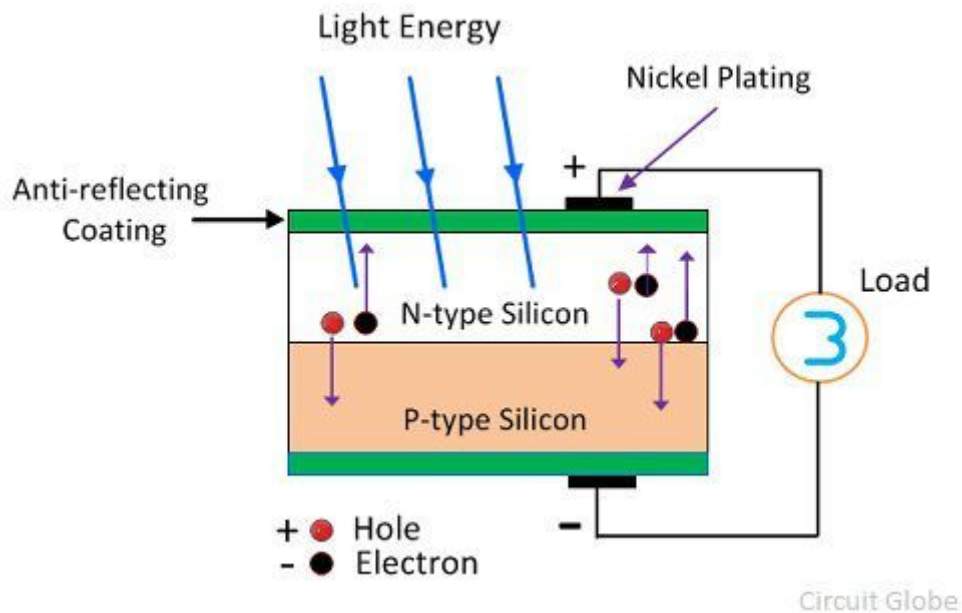
7. The fundamental principle behind solar photovoltaic (PV) power generation is the photoelectric effect, where sunlight (photons) is converted directly into electricity (electrons) using semiconductor materials. The working principle is explained below.

Photon Absorption: When sunlight strikes a PV cell (typically made of silicon), photons with sufficient energy (greater than the semiconductor's bandgap) are absorbed. This energy excites electrons in the semiconductor's valence band, freeing them to move into the conduction band, creating electron-hole pairs.

Electric Field Separation: A built-in electric field (created by a p-n junction in the cell) separates the electrons and holes. Electrons are forced to move toward the n-type layer, while holes move toward the p-type layer.

Current Generation: The movement of electrons creates a direct current (DC). Multiple PV cells are connected in series (for higher voltage) and parallel (for higher current) to form a PV module.

Power Output: The DC electricity generated is then conditioned for practical use via inverters (to convert DC to AC) and fed into the grid or stored in batteries.



A complete photovoltaic (PV) system consists of several key components:

1. **Solar PV Modules (Panels)** are made of interconnected solar cells (monocrystalline, polycrystalline, or thin-film). They generate DC electricity from sunlight.
2. **Mounting Structure** can be fixed or tracking systems (rooftop, ground-mounted, or floating). This ensures optimal tilt and orientation for maximum sunlight exposure.
3. **Inverter** Converts DC → AC for grid/load compatibility.
4. **Charge Controller** (For Off-Grid/Battery Systems) Regulates voltage/current to prevent overcharging batteries.
5. **Battery Storage** (Optional for Off-Grid/Hybrid Systems) Stores excess energy for use when sunlight is unavailable.

Common types: Lithium-ion, Lead-acid.

6. **Power Meter & Grid Connection** (For Grid-Tied Systems) Measures energy exported to or imported from the grid. Ensures synchronization with the utility grid.