

RENEWABLE ENERGY RESOURCES (KOE-074)

Kapil Gandhi
Electrical Engineering



SYLLABUS

Unit-1

- ❖ Introduction: Various non-conventional energy resources- Introduction, availability, classification, relative merits and demerits. Solar Cells: Theory of solar cells. Solar cell materials, solar cell array, solar cell power plant, limitations
- ❖ **CO1-** Understand various non-conventional energy resources and their availability along with knowledge on solar cells



SYLLABUS

Unit-2

- ❖ Solar Thermal Energy: Solar radiation, flat plate collectors and their materials, applications and performance, focusing of collectors and their materials, applications and performance; solar thermal power plants, thermal energy storage for solar heating and cooling, limitations.
- ❖ **CO₂**- Apply the concept of solar radiation on flat plate and focusing type collectors to convert solar energy into electrical energy.



SYLLABUS

Unit-3

- ❖ Geothermal Energy: Resources of geothermal energy, thermodynamics of geo-thermal energy conversion-electrical conversion, non-electrical conversion, environmental considerations. Magneto-hydrodynamics (MHD): Principle of working of MHD Power plant, performance and limitations. Fuel Cells: Principle of working of various types of fuel cells and their working, performance and limitations.
- ❖ **CO3-** Understand the concept of electrical energy generation from geothermal energy, magneto-hydro dynamics and fuel cells.



SYLLABUS

Unit-4

- ❖ Thermo-electrical and thermionic Conversions: Principle of working, performance and limitations. Wind Energy: Wind power and its sources, site selection, criterion, momentum theory, classification of rotors, concentrations and augments, wind characteristics. Performance and limitations of energy conversion systems
- ❖ **CO4-** Understand the concept of electrical energy generation from thermo-electrical, thermionic and wind energy conversions.



SYLLABUS

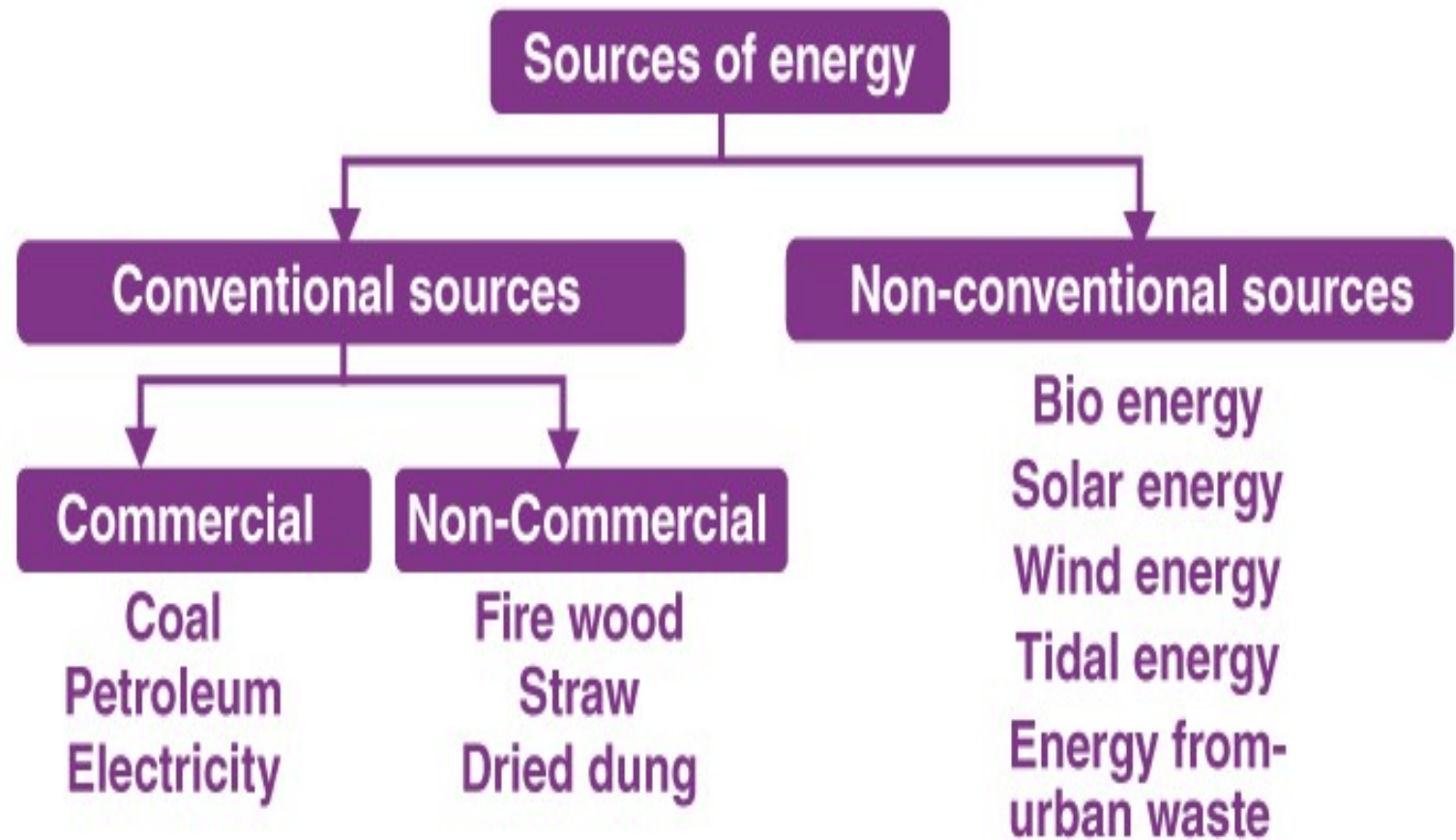
Unit-5

- ❖ Biomass: Availability of biomass and its conversion theory. Ocean Thermal Energy Conversion (OTEC): Availability, theory and working principle, performance and limitations. Wave and Tidal Wave: Principle of working, performance and limitations. Waste Recycling Plants.
- ❖ **CO5-** Understand biomass, ocean thermal, wave and tidal wave energy conversions



CO-PO Mapping

PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO-1	1			1		2	3			1		1		
CO-2	3			2		3	3			1		2		
CO-3	1			2		2	3			1		2		
CO-4	1			2		2	3			1		2		
CO-5	1			2		2	3			1		2		
Target Level	1.4			1.8		2.2	3			1		1.8		





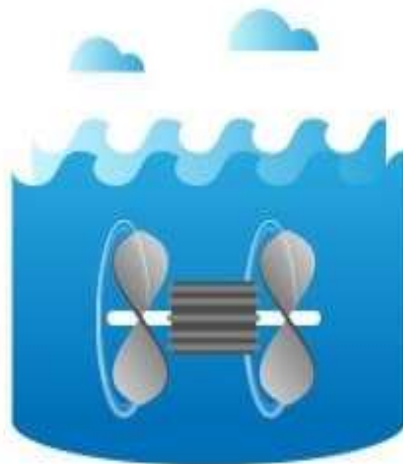
Non-conventional Energy Sources



Solar energy



Wind energy



Tidal energy



Geothermal energy



Biomass energy

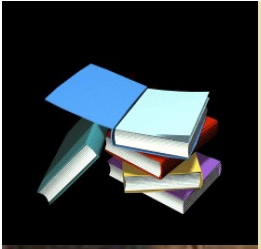


Non-Conventional Energy Resources

- ◆ Non-conventional energy resources, also known as renewable energy resources, are energy sources that are continuously replenished by natural processes and are not exhausted when used. These include solar, wind, geothermal, tidal, biomass, and small-scale hydroelectric energy.

Key Points:

- They are an alternative to conventional fossil fuels such as coal, oil, and natural gas.
- These energy sources are considered more sustainable and environmentally friendly.

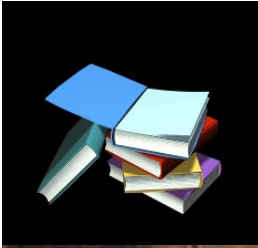


Importance in Today's Energy Landscape

Environmental Concerns

- ◆ **Climate Change:** Non-conventional energy resources play a critical role in reducing greenhouse gas emissions and combating climate change.
- ◆ **Pollution:** These resources typically produce less pollution compared to fossil fuels.



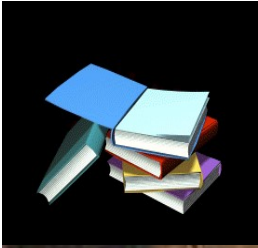


Importance in Today's Energy Landscape

Depleting Conventional Energy Resources

- ◆ **Finite Supply:** Conventional energy sources are finite and are being depleted at a rapid rate.
- ◆ **Energy Security:** Non-conventional resources provide energy security by reducing dependence on imported fuels.





Importance in Today's Energy Landscape

Global Energy Demand

- ◆ **Rising Demand:** With increasing industrialization and population growth, the global demand for energy is rising.
- ◆ **Sustainable Supply:** Non-conventional energy resources are essential for meeting future energy demands sustainably.





Role of Engineering in Non-Conventional Energy

- **Innovation and Development**

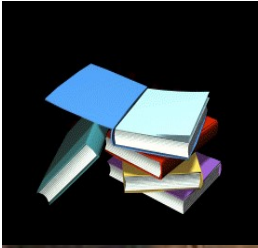
Engineers are at the forefront of developing new technologies and improving the efficiency of non-conventional energy systems.

- **Problem Solving**

Addressing challenges such as energy storage, efficiency, and integration with the grid.

- **Contribution to Global Goals**

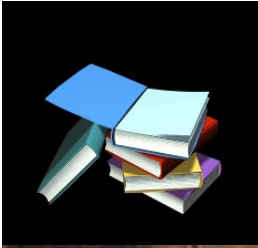
Engineering innovations contribute to global sustainability goals, such as the United Nations Sustainable Development Goals (SDGs), particularly in affordable and clean energy.



Types of Non-Conventional Energy Resources

◆ Solar Energy:

- **Definition:** Energy harnessed from the sun's rays using technologies such as photovoltaic (PV) cells and solar thermal systems.
- **Applications:** Solar power plants, rooftop solar panels, solar water heaters.
- **Advantage:** Abundant and available almost everywhere.



Types of Non-Conventional Energy Resources

◆ Wind Energy:

- **Definition:** Energy generated by converting wind currents into electricity using wind turbines.
- **Applications:** Onshore and offshore wind farms.
- **Advantage:** Clean and efficient with significant potential in windy regions.



Types of Non-Conventional Energy Resources

◆ Biomass Energy:

- **Definition:** Energy produced from organic materials (plant and animal matter), either by burning biomass directly or converting it into biofuels.
- **Applications:** Bioenergy plants, biodiesel, bioethanol.
- **Advantage:** Utilizes waste materials, reducing landfill use and methane emissions.



Types of Non-Conventional Energy Resources

◆ Geothermal Energy:

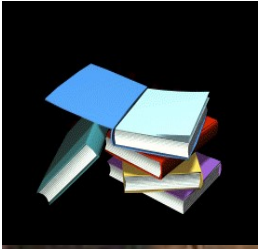
- **Definition:** Energy obtained by tapping into the earth's internal heat, typically from hot water or steam reservoirs beneath the earth's surface.
- **Applications:** Geothermal power plants, direct heating applications.
- **Advantage:** Reliable and available 24/7, not weather-dependent.



Types of Non-Conventional Energy Resources

◆ Hydroelectric Energy (Small-scale):

- **Definition:** Energy generated by small-scale hydroelectric systems that convert the energy of flowing water into electricity.
- **Applications:** Micro-hydro systems, small river turbines.
- **Advantage:** Provides a consistent and renewable energy source, especially in rural or remote areas.



Types of Non-Conventional Energy Resources

◆ Ocean Energy:

– Subtypes:

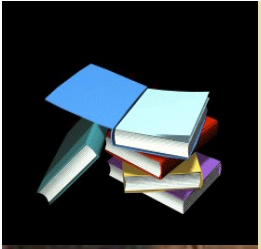
- **Tidal Energy:** Generated by harnessing the energy from tidal movements.
- **Wave Energy:** Produced by capturing the energy from surface waves on the ocean.

– **Applications:** Tidal power plants, wave energy converters.

– **Advantage:** Predictable and consistent energy source with significant potential.



Availability of Non Conventional Energy Resources

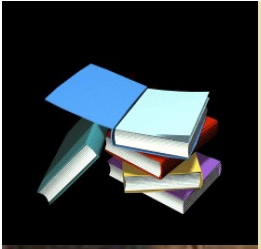


Global and Regional Availability

◆ Solar Energy:

- **Global Potential:** Solar energy is abundant and available globally, especially in regions with high sunlight exposure such as deserts, tropical, and subtropical regions.
- **Regional Examples:**
 - **High Potential Areas:** Middle East, North Africa, parts of the United States (e.g., California, Arizona), Australia.
 - **Lower Potential Areas:** Northern Europe, Alaska, and regions with high cloud cover.



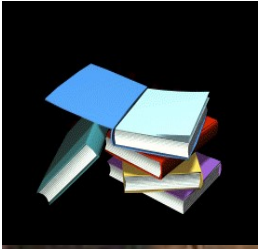


Global and Regional Availability

♦ Wind Energy:

- **Global Potential:** Wind energy potential is highest in areas with consistent and strong wind currents, often in coastal regions, open plains, and hilltops.
- **Regional Examples:**
 - **High Potential Areas:** Northern Europe (e.g., the UK, Denmark), central parts of the United States, coastal regions of China and India.
 - **Offshore Wind:** Particularly abundant in regions like the North Sea, the Baltic Sea, and off the coast of the northeastern United States.



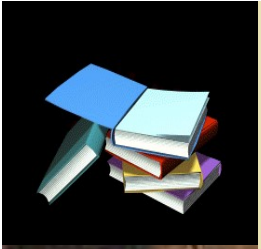


Global and Regional Availability

◆ Biomass Energy:

- **Global Potential:** Biomass is widely available, particularly in regions with abundant agricultural, forestry, and organic waste resources.
- **Regional Examples:**
 - **High Potential Areas:** Developing countries in Africa, Asia, and Latin America, where agricultural residue and organic waste are plentiful.
 - **Urban Areas:** Industrialized nations with well-established waste management systems.



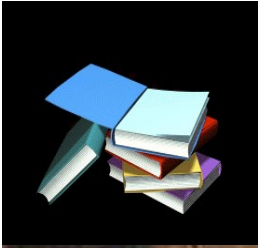


Global and Regional Availability

◆ Geothermal Energy:

- **Global Potential:** Geothermal energy availability is highest in regions with tectonic activity, such as the Ring of Fire.
- **Regional Examples:**
 - **High Potential Areas:** Iceland, New Zealand, the western United States (e.g., California, Nevada), Indonesia, and the Philippines.
 - **Challenges in Non-Volcanic Areas:** Limited access in regions without geothermal activity.



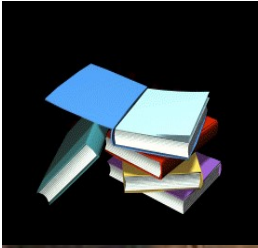


Global and Regional Availability

◆ **Hydroelectric Energy (Small-scale):**

- **Global Potential:** Small-scale hydroelectric systems are most viable in areas with flowing rivers and streams.
- **Regional Examples:**
 - **High Potential Areas:** Mountainous regions (e.g., the Himalayas, the Andes), rural areas with small rivers (e.g., parts of Africa, Southeast Asia).
 - **Sustainability Concerns:** Regions must consider environmental impacts on local ecosystems.



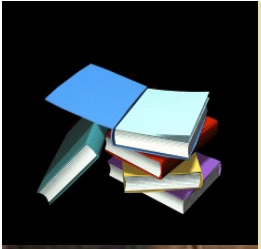


Global and Regional Availability

◆ Ocean Energy:

- **Global Potential:** Ocean energy is concentrated along coastlines with strong tidal currents or significant wave activity.
- **Regional Examples:**
 - **Tidal Energy:** High potential in the Bay of Fundy (Canada), the Severn Estuary (UK), and the coasts of France and South Korea.
 - **Wave Energy:** Abundant along the western coasts of Europe, North America, and parts of Australia.





Resource Distribution

◆ Factors Affecting Availability:

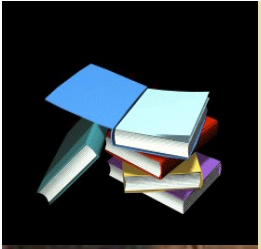
- **Geography:** The geographical location significantly influences the potential of each non-conventional energy resource.
- **Climate Conditions:** Solar energy depends on sunlight exposure; wind energy requires consistent wind patterns.
- **Technological Development:** The availability and feasibility of harnessing these resources also depend on the technological infrastructure in place.





Resource Distribution

- ◆ **Examples of Leading Regions/Countries:**
 - **Solar Energy Leaders:** China, the United States, and India are leading in solar installations.
 - **Wind Energy Leaders:** Denmark, Germany, and the United States have significant wind energy capacity.
 - **Geothermal Energy Leaders:** Iceland and the Philippines are top producers of geothermal energy.



Resource Distribution

◆ Examples of Leading Regions/Countries:

- **Biomass Energy Leaders:** Brazil (bioethanol), the United States, and Europe are leading in biomass energy production.
- **Hydroelectric Energy Leaders:** Norway, Canada, and Brazil have extensive hydroelectric resources.
- **Ocean Energy Leaders:** The UK and France are pioneers in ocean energy projects.





Classification of Non- Conventional Energy Resources



- ◆ **Solar Energy:** Continuously available as long as the sun shines.
- ◆ **Wind Energy:** Generated from wind, which is a naturally recurring phenomenon.
- ◆ **Geothermal Energy:** Utilizes the Earth's internal heat, which is essentially inexhaustible over human timescales.
- ◆ **Biomass Energy:** Produced from organic materials, which can be replanted and regrown.
- ◆ **Hydroelectric Energy (Small-scale):** Relies on the natural water cycle, making it renewable.
- ◆ **Ocean Energy:** Derived from the consistent movement of ocean waves and tides.



Solar Energy

Merits:

- ◆ **Abundant and Renewable:** Sunlight is plentiful and inexhaustible.
- ◆ **Low Operating Costs:** After the initial investment in solar panels and infrastructure, the cost of generating electricity is relatively low.
- ◆ **Environmentally Friendly:** Solar energy generation does not produce air pollution or greenhouse gases.
- ◆ **Scalability:** Solar systems can be deployed at various scales, from small home installations to large utility-scale farms.
- ◆ **Energy Independence:** Reduces dependency on fossil fuels and enhances energy security.



Solar Energy

Demerits:

- ◆ **Intermittent:** Solar power generation depends on sunlight, which is not available at night or on cloudy days.
- ◆ **High Initial Costs:** Installation costs can be high, although they are decreasing over time.
- ◆ **Space Requirements:** Requires large areas for large-scale power generation.
- ◆ **Energy Storage:** Effective storage solutions (like batteries) are needed to ensure a steady power supply when sunlight is not available.



Wind Energy

Merits:

- ◆ **Renewable and Clean:** Wind is an abundant and renewable source of energy that generates no emissions.
- ◆ **Cost-Effective:** The cost of wind power has decreased significantly, making it competitive with fossil fuels.
- ◆ **Quick to Install:** Wind farms can be constructed relatively quickly compared to other types of power plants.
- ◆ **Land Use Efficiency:** Land used for wind turbines can often still be used for agriculture or other purposes.



Wind Energy

Demerits:

- ◆ **Intermittency:** Wind is not always predictable or constant, leading to fluctuations in energy production.
- ◆ **Visual and Noise Impact:** Wind turbines can be considered unsightly and may generate noise, affecting nearby residents.
- ◆ **Wildlife Threats:** Turbines can pose a threat to birds and bats.
- ◆ **Geographic Limitations:** Effective only in areas with sufficient wind speeds, which limits their placement.



Hydropower

Merits:

- ◆ **Reliable and Consistent:** Provides a stable, continuous source of electricity.
- ◆ **Low Operating Costs:** After initial construction, the cost of maintenance and operation is relatively low.
- ◆ **Energy Storage Capability:** Hydropower plants can store potential energy in the form of water reservoirs, making them suitable for load balancing.
- ◆ **Multi-Purpose Use:** Reservoirs created for hydropower can also be used for water supply, irrigation, and recreation.



Hydropower

Demerits:

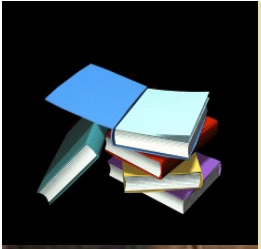
- ◆ **Environmental Impact:** Dams can disrupt local ecosystems, fish migration, and water quality.
- ◆ **High Initial Costs:** Construction of dams and related infrastructure is expensive.
- ◆ **Displacement:** Large-scale hydropower projects can displace local communities and wildlife.
- ◆ **Dependence on Water Availability:** Relies on consistent water flow, which can be affected by droughts and climate change.



Geothermal Energy

Merits:

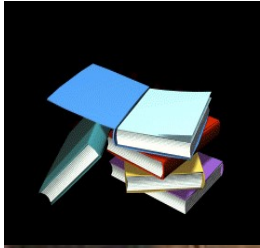
- ◆ **Reliable and Constant:** Provides a steady source of energy that is not dependent on weather conditions.
- ◆ **Low Emissions:** Produces minimal greenhouse gas emissions.
- ◆ **Small Land Footprint:** Geothermal plants generally require less land compared to other renewable energy sources.
- ◆ **Base Load Energy:** Can provide continuous, 24/7 power generation.



Geothermal Energy

Demerits:

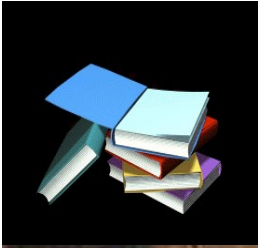
- ◆ **Geographic Limitations:** Viable only in regions with significant geothermal activity, such as tectonic plate boundaries.
- ◆ **High Initial Costs:** Exploration and drilling can be expensive and risky.
- ◆ **Environmental Risks:** Potential for groundwater contamination and surface instability (e.g., earthquakes) in some cases.



Biomass Energy

Merits:

- ◆ **Renewable:** Biomass is derived from organic materials like plant and animal waste, which can be replenished.
- ◆ **Utilizes Waste:** Converts waste materials into energy, helping to reduce landfill use.
- ◆ **Carbon Neutral:** Biomass can be considered carbon neutral because it releases the same amount of carbon dioxide that the plants absorbed during growth.

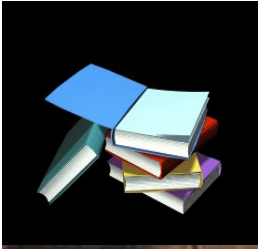


Biomass Energy

Demerits:

- ◆ **Air Pollution:** Burning biomass can release particulates and other pollutants, though cleaner technologies are being developed.
- ◆ **Land Use:** Growing biomass crops can compete with food production and may lead to deforestation if not managed sustainably.
- ◆ **Energy Efficiency:** Lower energy output compared to other renewables like wind and solar.

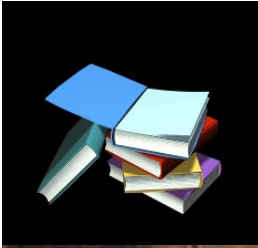




Tidal and Wave Energy

Merits:

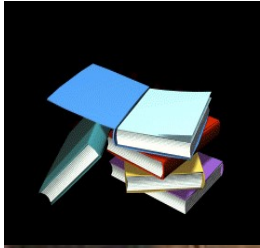
- ◆ **Predictable:** Tidal and wave patterns are predictable and reliable, providing a consistent source of energy.
- ◆ **Low Environmental Impact:** Minimal emissions and pollution once operational.
- ◆ **High Energy Density:** Tides and waves have a higher energy density compared to wind and solar.



Tidal and Wave Energy

Demerits:

- ◆ **High Initial Costs:** Expensive to build and maintain due to the harsh marine environment.
- ◆ **Limited Locations:** Only viable in coastal areas with significant tidal ranges or wave activity.
- ◆ **Environmental Concerns:** Potential impacts on marine ecosystems and navigation.



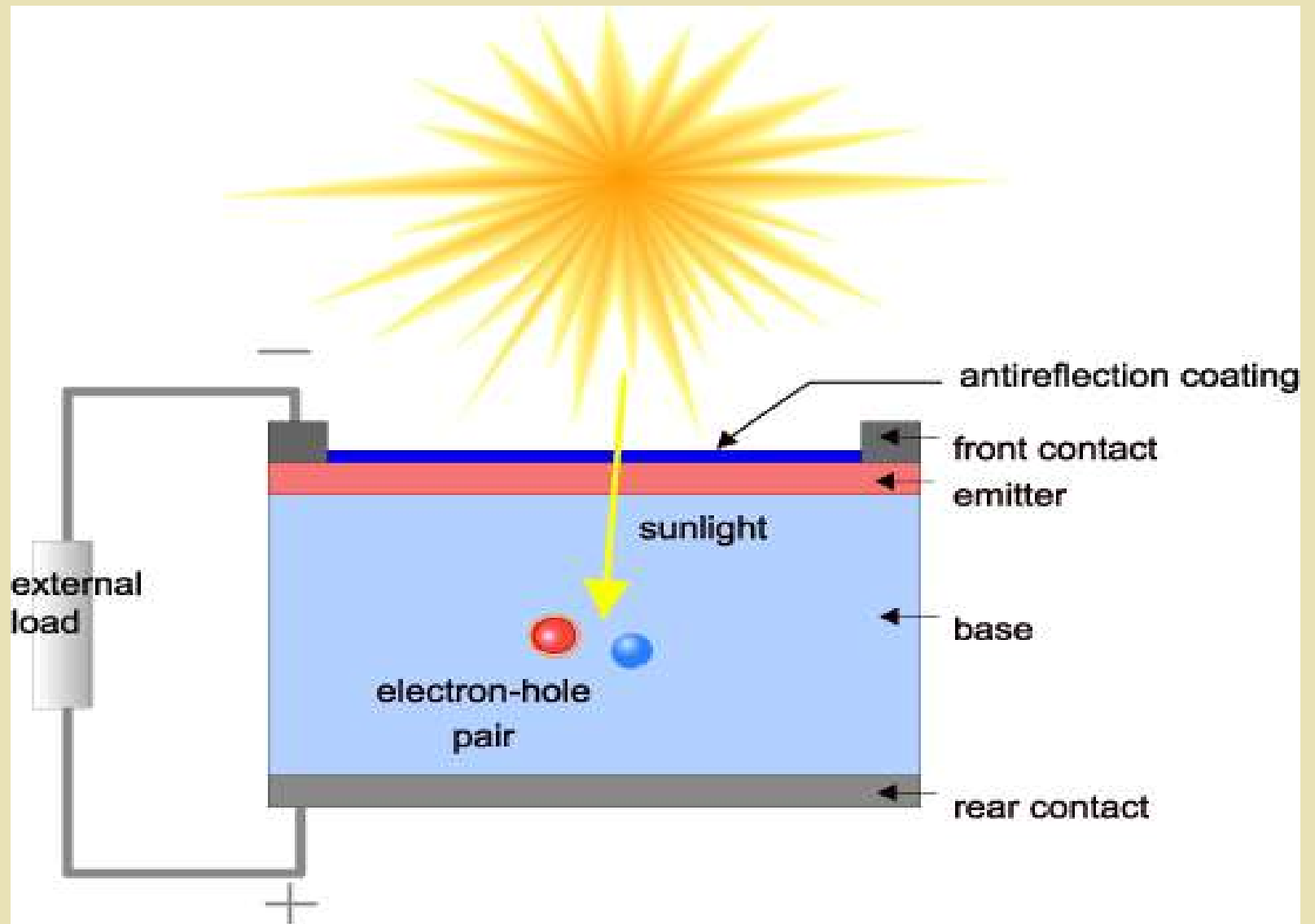
Solar Cell

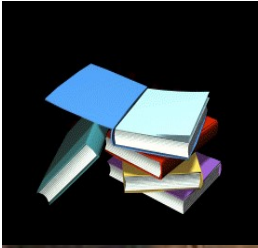
- Solar cells, or photovoltaic (PV) cells, are devices that convert light energy directly into electrical energy through the photovoltaic effect.
- When sunlight strikes a solar cell, it energizes electrons, creating an electric current.

Components of Solar Cell:

- **Photovoltaic Material:** Typically silicon, which absorbs photons and releases electrons.
- **Electric Field:** Created within the cell to direct the flow of electrons.
- **External Circuit:** Allows the generated current to be used as electricity.

Block Diagram of Solar Cell





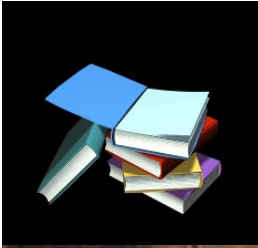
Block Diagram of Solar Cell

Anti-Reflective Coating:

- This thin layer is applied on top of the solar cell to reduce the reflection of sunlight. Without this coating, a significant amount of sunlight would bounce off the surface, reducing efficiency. The coating ensures more sunlight is absorbed into the cell.

N-Type Semiconductor:

- This layer is made of a semiconductor material (like silicon) that has been doped (added) with elements such as phosphorus, which has extra electrons. This "doping" process creates an excess of free electrons in this layer, making it negatively charged.



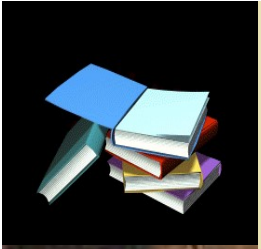
Block Diagram of Solar Cell

P-Type Semiconductor:

- This layer is also made of a semiconductor material, but it is doped with elements like boron, which have fewer electrons than silicon. This creates "holes," or spaces where electrons are missing, giving this layer a positive charge.

PN Junction:

- The junction where the n-type and p-type semiconductors meet. This is the core area where the conversion of light to electricity takes place. When photons hit the solar cell, they excite electrons in this region, allowing them to flow across the junction, creating an electric current.



Block Diagram of Solar Cell

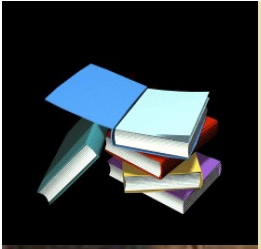
Metal Contacts:

- ◆ **Front Contact (Grid Lines):** Metal lines or fingers on the top surface of the solar cell, allowing light to enter while providing a path for the generated electrons to flow out.
- ◆ **Back Contact:** A metal layer on the back of the solar cell that completes the electrical circuit, allowing electrons to return to the front contact via an external circuit.



Working Principle of Solar Cells

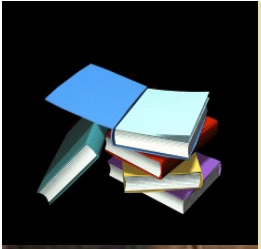
- **Photon Absorption:** When photons hit the solar cell, they can transfer energy to electrons in the semiconductor material.
- **Generation of Electron-Hole Pairs:** Absorbed energy excites electrons from the valence band to the conduction band, creating electron-hole pairs.
- **Separation by Electric Field:** The built-in electric field at the p-n junction separates these charge carriers, pushing electrons to the n-side and holes to the p-side.
- **Electric Current Flow:** The separated charges are collected by electrodes, creating a flow of current in an external circuit.



Solar Cell Materials

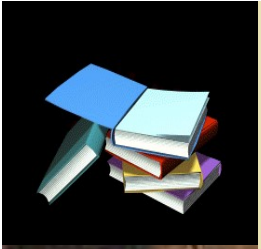
- Solar cell materials are the substances that make up the active layers of solar cells, where the conversion of light into electricity takes place.
- These materials are critical for determining the efficiency, cost, and overall performance of solar cells.





Purpose of Solar Cell Materials

- ◆ **Light Absorption:** To absorb sunlight efficiently and convert it into usable electrical energy.
- ◆ **Charge Separation and Transport:** To separate the generated electrical charges (electrons and holes) and transport them to external circuits for use.
- ◆ **Durability and Longevity:** To withstand environmental conditions such as UV radiation, moisture, and temperature variations while maintaining performance over time.

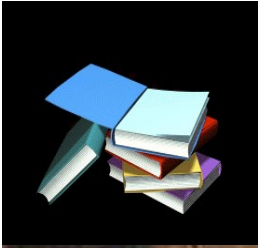


Importance of Material Choice

Impact on Efficiency:

- ◆ Different materials absorb sunlight and convert it into electricity with varying levels of efficiency. For example, monocrystalline silicon is highly efficient (20-24%), while some thin-film materials like amorphous silicon have lower efficiencies (around 6-8%).



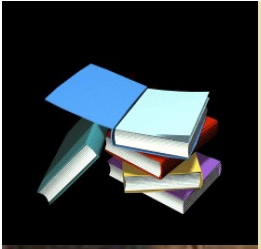


Importance of Material Choice

Cost Considerations:

The choice of materials affects the overall cost of solar cells. While silicon-based materials may be more expensive due to the energy-intensive manufacturing process, newer materials like perovskites are potentially cheaper to produce.



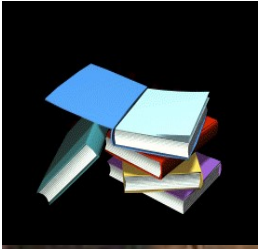


Importance of Material Choice

Durability and Longevity:

Materials must withstand environmental conditions such as UV radiation, temperature changes, and mechanical stress. Durable materials like monocrystalline silicon last longer, often over 25 years, while emerging materials may have shorter lifespans until further developed.



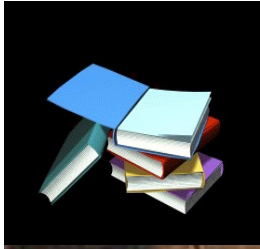


Importance of Material Choice

Environmental Impact:

Materials can have different environmental footprints based on their availability, extraction process, and recyclability. For example, Cadmium Telluride (CdTe) involves toxic elements, while silicon is abundant and relatively less harmful.





Types of Solar Cells

Monocrystalline Silicon Solar Cells:

- ◆ Made from a single continuous crystal structure.
- ◆ Known for high efficiency (up to 22-24%) and long lifespan but typically more expensive.



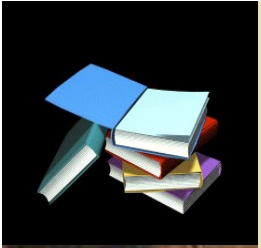


Types of Solar Cells

Polycrystalline Silicon Solar Cells:

- ◆ Composed of multiple silicon crystals.
- ◆ Generally less efficient (around 15-18%) but more cost-effective due to simpler manufacturing processes.





Types of Solar Cells

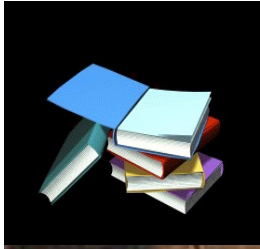
Thin-Film Solar Cells:

- ◆ Includes materials like Cadmium Telluride (CdTe) and Copper Indium Gallium Selenide (CIGS).
- ◆ Thinner layers of light-absorbing materials deposited on substrates, making them lightweight and flexible.
- ◆ Typically lower in efficiency (10-12%) but cheaper to produce and versatile for different applications.



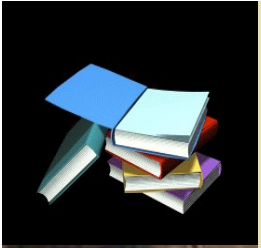
Comparison of Solar Cells

Solar Cell Type	Efficiency Range	Cost	Applications
Monocrystalline Silicon	High (20-24%)	Higher cost	Residential, commercial, and utility-scale solar panels; ideal for areas with limited space due to high efficiency.
Polycrystalline Silicon	Moderate (15-18%)	Moderate cost	Residential and commercial solar installations; suitable for larger areas where lower cost is prioritized.
Thin-Film (CdTe, CIGS)	Lower (10-12%)	Lower cost	Flexible and lightweight applications, such as building-integrated photovoltaics (BIPV), portable solar devices, and large-scale solar farms.



Solar Cell Arrays

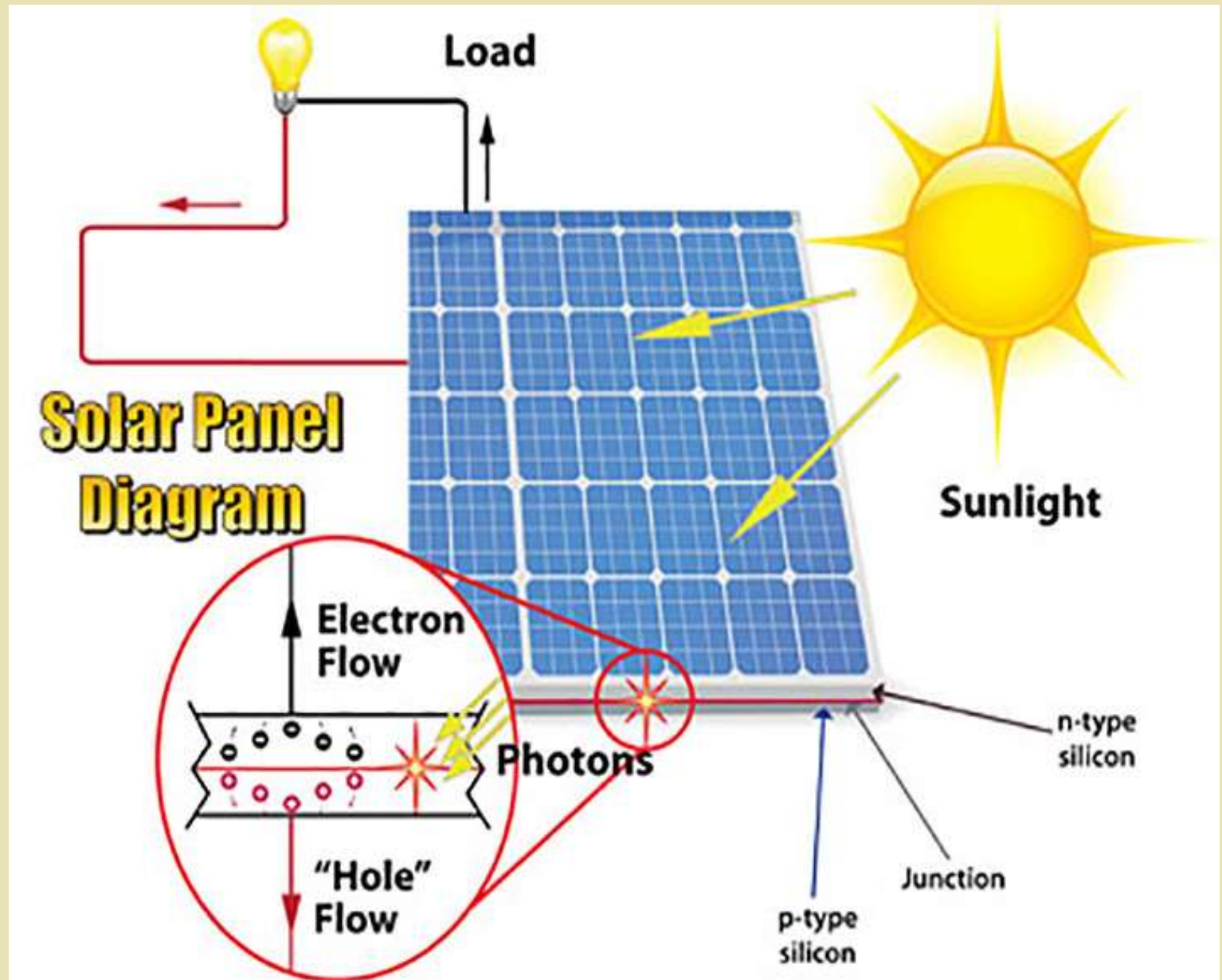
- A solar cell array is a collection of multiple solar cells connected together in a series or parallel configuration to increase the voltage or current output.
- It is used to generate electricity from sunlight at a scale sufficient for practical applications like powering homes, businesses, or electrical grids.
- Applications: Found in residential, commercial, and utility-scale solar power installations.

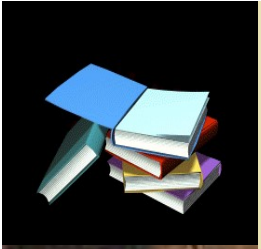


Components of a Solar Cell Array

- **Solar Cells:** The fundamental units that convert sunlight into electricity.
- **Modules:** Solar cells grouped together and encapsulated to form a solar panel or module.
- **Arrays:** Multiple modules connected together to form an array.
- **Inverter:** Converts the direct current (DC) electricity generated by the array into alternating current (AC) used by most appliances.
- **Mounting System:** Supports and positions the solar panels for optimal sunlight exposure.







Working of a Solar Cell Array

Energy Conversion:

- Solar cells absorb sunlight and convert it into DC electricity.
- The cells are connected in series or parallel to achieve desired voltage and current levels.

Power Distribution:

- Inverter converts the generated DC into AC.
- AC electricity is then either used locally or fed into the electrical grid.

Grid Connection: Explain the concept of net metering where excess electricity generated can be fed back to the grid.



Solar cell power plant

- A solar cell power plant (or solar farm) is a large-scale facility that uses an array of interconnected solar panels to generate electricity from sunlight.
- Used** to produce electricity on a commercial scale, supplying power to the grid or specific areas.

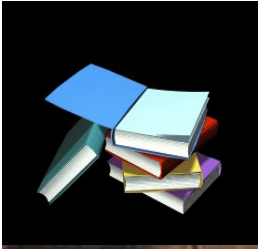
Types:

- Photovoltaic (PV) Power Plants:** Convert sunlight directly into electricity using solar panels.
- Concentrated Solar Power (CSP) Plants:** Use mirrors or lenses to concentrate sunlight to generate heat, which then produces electricity.



Components of a Solar Cell Power Plant

- Solar Panels:** Thousands of solar panels (modules) arranged in arrays to capture sunlight and convert it to DC electricity.
- Inverters:** Convert the DC electricity generated by the panels into AC electricity, which can be used by the grid.
- Transformers:** Step up the voltage of the electricity to match the grid requirements.



Components of a Solar Cell Power Plant



- Mounting Systems:** Racks or tracking systems that hold panels in place and optimize the angle for sunlight.
- Monitoring and Control Systems:** Track performance, detect faults, and ensure optimal operation.
- Connection to the Grid:** Substations and transmission lines to distribute generated power to the grid



Thank You !

