

Engineering

Year 1

SECTION

5

RENEWABLE ENERGY SOURCES



ENERGY SYSTEMS

Renewable Energy Systems

Introduction

Welcome to the section on Renewable energy sources. In this section, we will focus on Renewable energy which refers to energy derived from naturally replenished sources, such as sunlight, wind, water, and geothermal. The importance of renewable energy lies in its ability to address environmental challenges, reduce greenhouse gas emissions, combat climate change, and promote energy security by diversifying our energy mix. Renewable energy refers to energy sources that are naturally replenished and are considered sustainable over the long term. Unlike fossil fuels such as coal, oil, and natural gas, which are finite and non-renewable, renewable energy sources can be harnessed without depleting their availability for future generations. Sustainable Development Goals Related to Affordable and Clean Energy (SDG 7) aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Sustainable Cities and Communities (SDG 11) focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. It is crucial to compare various renewable energy sources concerning their availability, potential electricity generation, ease of energy production, cost of generation, technological maturity, and other relevant factors. This comparative analysis will help us better understand the strengths and limitations of different renewable energy options, aiding in informed decision-making for a sustainable energy future.

At the end of this section, you will be able to:

- List the sources of renewable energy
- Explain how renewable energy sources benefit humanity and contribute towards the attainment of the SDGs
- Explain how electricity is generated from water, wind, solar, biomass, and biogas energy sources.
- Compare the electricity generation from the various renewable energy sources with respect to availability of resource, quantity of electricity that could be generated, ease of energy generation, cost of generation, availability of technology, etc.

Key Ideas

- Renewable energy sources, solar, hydro and wind power, offer sustainable alternatives to fossil fuels. The utilisation of renewable energy sources to generate energy minimises environmental impact and secures a cleaner future for generations.
- The adoption of renewable energy sources offers various opportunities as well as challenges. Researchers around the world are working tirelessly to resolve some of these challenges to pave the way for their adoption and realisation of their full potential.
- Energy generation from renewable sources is clean, replenishable, and environmentally friendly.

SOURCES OF RENEWABLE ENERGY

Renewable energy refers to energy derived from naturally replenished sources, such as sunlight, wind, water, and geothermal heat. Unlike fossil fuels, which are finite and produce harmful emissions when burned, renewable energy sources offer sustainable and cleaner alternatives to meet our energy needs. The importance of renewable energy lies in its ability to address environmental challenges, reduce greenhouse gas emissions, combat climate change, and promote energy security by diversifying our energy mix. Some of the sources of renewable energy are discussed below.

1. Solar Energy

Solar energy is one of the most prominent renewable energy sources. It harnesses the sun's rays to generate electricity through photovoltaic cells, commonly known as solar panels. These solar panels contain semiconductor materials, typically made from silicon, which absorb sunlight and release electrons, creating an electric current.

Solar energy refers to energy from the sun that is harnessed using various technologies such as photovoltaics (PV), solar heating, concentrated solar power (CSP), and others. It is a renewable and sustainable source of energy that can be used to generate electricity, heat water, power homes, and even fuel cars.

The main advantages of solar energy include:

- a. **Renewable:** Solar energy is abundant and inexhaustible as long as the sun exists.
- b. **Environmentally Friendly:** It produces no greenhouse gas emissions or air pollutants during operation, unlike fossil fuels.
- c. **Low Operating Costs:** Once installed, solar energy systems generally have low maintenance and operating costs compared to conventional energy sources.
- d. **Versatility:** Solar energy can be used for a wide variety of applications, from small-scale residential systems to large-scale power plants.
- e. **Energy Independence:** It reduces dependence on imported fuels and enhances energy security.

Despite these advantages, solar energy also faces challenges such as intermittency (due to weather conditions), energy storage requirements, and initial installation costs, although the latter has been decreasing significantly over recent years.



Fig. 5.1: A picture of a Solar Generation Station

2. Wind Energy

Wind energy refers to the energy generated by harnessing the kinetic energy of wind through wind turbines. Wind turbines, commonly found in wind farms, are designed to capture the energy of the moving air. These turbines convert the wind's kinetic energy into mechanical power, which can then be used for various purposes, especially generating electricity.

Here are some advantages of wind energy:

- a. **Renewable and Sustainable:** Wind energy is renewable because it relies on the natural movement of air, which is replenished by solar radiation and the Earth's rotation. It does not deplete finite resources like fossil fuels.
- b. **Clean and Environmentally Friendly:** Wind power generation produces no greenhouse gas emissions or air pollutants during operation, contributing to lower carbon footprints and reduced air pollution compared to conventional fossil fuel power plants.
- c. **Cost-Effective:** The cost of wind energy has been decreasing significantly over the past few decades, making it increasingly competitive with traditional energy sources. Once turbines are installed, operational and maintenance costs are relatively low.
- d. **Scalability:** Wind energy can be harnessed on a wide range of scales, from small turbines for residential or rural applications to large offshore wind farms for utility-scale electricity generation.
- e. **Energy Security:** Wind energy can enhance energy security by diversifying energy sources and reducing reliance on imported fuels.

Despite its advantages, wind energy also faces challenges such as intermittency (the variability of wind speeds), land use concerns, potential visual and noise impacts, and the need for suitable wind resources. However, technological advancements and improved grid integration techniques are addressing many of these challenges.



Fig. 5.2: A picture of a Wind Energy Turbine

3. Hydroelectric Power

Hydroelectric power, often referred to simply as hydroelectricity, is electricity generated by harnessing the gravitational force of flowing or falling water. In the Hydroelectric Power generation, the rotating turbine shaft is connected to a generator. As the turbines spin, the generator converts the mechanical energy into electrical energy through electromagnetic induction, producing electricity. It is one of the oldest and most widely used renewable energy sources globally.

Here are advantages of hydroelectric power:

- a. **Renewable and Sustainable:** Hydroelectric power relies on the water cycle, which is continuously replenished by precipitation. If there is rainfall and runoff, hydroelectric power is considered renewable and sustainable.
- b. **Clean and Low Emissions:** Hydroelectric power generation produces minimal greenhouse gas emissions and air pollutants compared to fossil fuels. It contributes significantly to reducing carbon footprints and mitigating climate change.
- c. **Cost-Effective and Reliable:** Once a hydroelectric facility is built, the operational and maintenance costs are relatively low compared to other sources of electricity. Hydroelectric plants can operate for decades with proper maintenance.
- d. **Flexibility and Storage:** Hydroelectric dams can serve as water reservoirs, providing flexibility in electricity generation by adjusting water flow to meet demand. Some hydroelectric plants also offer energy storage capabilities, which is crucial for grid stability.

- e. **Large-scale Electricity Generation:** Hydroelectric plants can range in size from small-scale micro-hydro systems serving remote communities to large-scale facilities generating electricity for cities and regions.
- f. **Multi-Purpose Use:** Besides electricity generation, hydroelectric facilities can be used for flood control, irrigation, water supply, and recreation, providing additional societal benefits.

Despite its advantages, hydroelectric power faces challenges such as environmental impacts on aquatic ecosystems, displacement of communities due to dam construction, and potential changes in downstream water availability. Efforts to mitigate these impacts include improved dam design, environmental assessments, and ecosystem restoration projects.

Overall, hydroelectric power remains a significant contributor to the global energy mix, providing reliable and sustainable electricity generation while supporting economic development and environmental stewardship.



Fig. 5.3: A picture of a Hydro Energy Generation Station

4. Biomass Energy

Biomass energy is derived from organic matter such as agricultural residues, forestry waste, and energy crops primarily plants and animal waste. It involves converting the chemical energy stored in biomass into usable heat, electricity, or biofuels. It is a renewable energy source because biomass can be replenished relatively quickly through natural processes. Biomass can be used directly as fuel, converted into biofuels, or processed into biogas through anaerobic digestion.

Here are advantages of biomass energy:

- a. **Renewable and Abundant:** Biomass is derived from organic materials such as crop residues, wood chips, agricultural waste, and dedicated energy crops. These materials can be continuously replenished through sustainable forestry and agricultural practices.

- b. **Carbon Neutral:** When biomass is burned or converted into biofuels, it releases carbon dioxide (CO₂) into the atmosphere. However, this carbon dioxide was recently absorbed from the atmosphere by the plants during their growth cycle, making biomass energy carbon neutral in theory. This assumes that the biomass is harvested sustainably and does not lead to deforestation or other negative land use changes.
- c. **Versatile:** Biomass can be used for various applications, including heat and electricity generation, transportation fuels (biofuels), and bioproducts (such as biochemicals and bioplastics).
- d. **Local Resource:** Biomass resources are often available locally, which can reduce dependence on imported fossil fuels and enhance energy security.
- e. **Waste Management:** Biomass energy can help manage organic waste materials that would otherwise contribute to landfill emissions or air pollution if burned openly.

Biomass energy faces challenges such as competition with food production for agricultural land, potential impacts on biodiversity if not managed sustainably, and concerns about air quality if biomass combustion emissions are not properly controlled.

Efforts are ongoing to improve the efficiency and sustainability of biomass energy systems, including advancements in biomass conversion technologies (like gasification and pyrolysis) and ensuring sustainable biomass sourcing practices. Biomass energy plays a role in the transition to a more sustainable energy system, particularly in sectors where direct electrification or renewable energy alternatives are not yet viable.

Types of Biomass Energy

- a. **Solid Biomass:**
 - **Wood and Agricultural Residues:** Used directly for heating or converted to pellets and briquettes.
 - **Energy Crops:** Plants grown specifically for energy production, such as switchgrass and miscanthus.
- b. **Biogas:**
 - **Landfill Gas:** Methane produced from the decomposition of organic waste in landfills.
 - **Anaerobic Digestion:** Biogas produced from the digestion of organic materials, such as animal manure, food waste, and sewage sludge.
- c. **Liquid Biofuels:**
 - **Bioethanol:** Produced from the fermentation of sugars found in crops like corn and sugarcane.
 - **Biodiesel:** Produced from vegetable oils, animal fats, or recycled cooking grease through a chemical process called transesterification.



Fig. 5.4: A picture of a Biomass Energy Generation Station

5. Geothermal Energy

Geothermal energy is heat derived from the Earth's subsurface, usually from the thermal energy stored in the Earth's crust. It can be harnessed for various applications, including electricity generation, heating, and cooling.

Here are advantages of geothermal energy:

- a. **Renewable and Sustainable:** Geothermal energy is considered renewable because the heat extracted is continuously replenished by natural processes within the Earth's mantle.
- b. **Low Emissions:** Geothermal power plants emit very low levels of greenhouse gases and pollutants compared to fossil fuel-based power plants, contributing to cleaner air and reduced carbon emissions.
- c. **Reliable and Baseload Power:** Geothermal power plants can provide baseload electricity generation, meaning they can operate continuously, unlike some other renewable energy sources that depend on weather conditions (like wind and solar).
- d. **Direct Use Applications:** Beyond electricity generation, geothermal energy can be used directly for heating and cooling buildings (geothermal heat pumps), industrial processes, greenhouse agriculture, and spa and recreational facilities.
- e. **Resource Variability:** The availability and productivity of geothermal resources can vary depending on geological factors such as location, depth, and permeability of underground reservoirs. Enhanced geothermal systems (EGS) are being developed to expand the geographic range of economically viable projects.
- f. **Environmental Considerations:** While geothermal energy is generally environmentally friendly, there are potential concerns such as land subsidence, induced seismicity (earthquakes), and the release of trace gases and minerals from geothermal fluids.

- g. **Global Distribution:** Geothermal resources are distributed globally, with some regions having higher potential for development than others. Countries like Iceland, the United States, Philippines, and New Zealand have utilised geothermal energy extensively.

In recent years, advancements in technology and exploration techniques have made it possible to tap into deeper and hotter geothermal reservoirs, expanding the potential for geothermal energy development. Continued research and investment in geothermal energy could contribute significantly to achieving sustainable energy goals worldwide.



Fig. 5.5: A picture of a Geothermal Energy Generation Station

6. Tidal and Wave Energy

Tidal and wave energy are renewable sources that harness the kinetic energy of ocean and sea movements, primarily tides and waves. While both utilise the kinetic energy of water, they operate on different principles:

a. **Tidal Energy:**

- **Source:** Tidal energy is derived from the gravitational forces of the moon and sun acting on the Earth's oceans, causing tidal movements.
- **Technology:** Tidal energy is typically harnessed using tidal barrages, tidal stream generators, or tidal turbines placed in tidal currents.
- **Advantages:** Tidal energy is predictable and reliable due to the regularity of tidal cycles. It has low environmental impact once operational and can provide consistent electricity generation.

b. **Wave Energy:**

- **Source:** Wave energy comes from the movement of surface waves on the ocean, generated by wind blowing over the water's surface.
- **Technology:** Wave energy devices include oscillating water columns, point absorbers, attenuators, and overtopping devices, designed to capture the energy from wave motion.

- **Advantages:** Wave energy is abundant and predictable in coastal areas with consistent wave patterns. It has the potential to provide a steady source of renewable electricity.

Key Points of Both Tidal and Wave Energy:

- Renewable and Clean:** Both tidal and wave energy are renewable sources that produce little to no greenhouse gas emissions or air pollutants during operation.
- Challenges:** Both types of energy face technical and economic challenges. Tidal energy requires suitable locations with significant tidal range or flow velocities, while wave energy devices must withstand harsh marine environments and variable wave conditions.
- Resource Location:** Tidal energy is more predictable and easier to forecast, as tidal cycles are well understood. Wave energy, on the other hand, varies more with weather patterns and seasons, making wave resource assessment more complex.
- Development Status:** While both tidal and wave energy technologies are still in the early stages of commercial deployment, there are ongoing research and pilot projects aimed at improving efficiency, reducing costs, and demonstrating feasibility at scale.

Overall, tidal and wave energy have the potential to contribute to global renewable energy portfolios, providing reliable and clean electricity generation from the power of the ocean. Continued technological advancements and supportive policies will be essential to realise their full potential.



Fig. 5.6: A picture of a Tidal Energy Generation Station

BENEFITS OF RENEWABLE ENERGY SOURCES

Renewable energy sources benefit humanity and contribute towards the attainment of the SDGs. The Sustainable Development Goals (SDGs) are a set of 17 global objectives adopted by the United Nations in 2015, with the aim of addressing various interconnected challenges facing humanity and the planet. These goals were designed to guide efforts towards achieving a more sustainable and equitable future for all by 2030. The SDGs cover a wide range of issues, including poverty, hunger, health, education, gender equality, clean water, climate action, and more. They serve as a universal call to action, encouraging governments, businesses, civil society, and individuals to work collaboratively to create a better world.

Significance of the SDGs in Addressing Global Challenges

The SDGs are crucial in addressing global challenges because they provide a comprehensive and integrated framework for sustainable development. By focusing on interconnected issues, such as poverty, inequality, environmental degradation, and climate change, the SDGs recognise that tackling one problem often requires addressing its root causes and considering the broader implications.

Goals Related to Affordable and Clean Energy (SDG 7) and Sustainable Cities and Communities (SDG 11):

- SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. It targets improving energy efficiency, expanding renewable energy sources, and enhancing international cooperation in the energy sector. Access to clean and affordable energy is essential for eradicating poverty, supporting economic development, and promoting sustainable growth.
- SDG 11 focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. It addresses the challenges of urbanisation and aims to provide access to adequate and affordable housing, sustainable transportation, green spaces, and improved urban planning.

The following are the benefits of renewable energy to humanity:

1. Environmental Benefits of Renewable Energy

Renewable energy offers several environmental benefits compared to conventional fossil fuels. Here are some of the key environmental advantages:

- Reduced Greenhouse Gas Emissions:** Renewable energy sources such as solar, wind, hydro, and geothermal produce little to no greenhouse gas emissions during electricity generation. This significantly reduces the carbon footprint and helps mitigate climate change by decreasing the amount of CO₂ and other greenhouse gases released into the atmosphere.

- b. Improved Air Quality:** Unlike fossil fuel combustion, which emits pollutants such as sulphur dioxide, nitrogen oxides, particulate matter, and volatile organic compounds, renewable energy sources do not produce these harmful air pollutants. This leads to cleaner air and healthier environments for communities located near power plants and urban areas.
- c. Water Conservation:** Traditional power plants that rely on fossil fuels or nuclear energy consume large amounts of water for cooling purposes. In contrast, many renewable energy technologies require little to no water for operation, reducing water consumption and minimising impacts on aquatic ecosystems and water availability for agriculture and drinking purposes.
- d. Reduced Land and Habitat Degradation:** Renewable energy projects, such as solar and wind farms, generally have a smaller land footprint per unit of electricity generated compared to fossil fuel extraction, mining, and power plant infrastructure. This helps preserve natural habitats, biodiversity, and ecosystems that may otherwise be disrupted by industrial activities.
- e. Mitigation of Environmental Risks:** Renewable energy sources contribute to reducing environmental risks associated with fossil fuel extraction and transportation, such as oil spills, groundwater contamination, and habitat destruction. They also mitigate the environmental and health impacts of coal mining and ash disposal from coal-fired power plants.
- f. Long-Term Sustainability:** Renewable energy sources are sustainable over the long term because they rely on naturally occurring and continuously replenished resources, such as sunlight, wind, water, and geothermal heat. This contrasts with finite fossil fuel reserves, which are being depleted and contribute to environmental degradation and geopolitical tensions.
- g. Community and Social Benefits:** Renewable energy projects can bring economic benefits to local communities through job creation, tax revenues, and investment in infrastructure. They also empower communities to become more energy independent and resilient to fluctuations in energy prices and supply.

Overall, transitioning to renewable energy plays a crucial role in addressing environmental challenges, promoting sustainable development, and safeguarding the planet for future generations. Embracing renewable energy technologies and policies can lead to cleaner air, healthier ecosystems, and a more sustainable global energy system.

2. Transitioning from Fossil Fuels to Renewables

Transitioning from fossil fuels to renewable energy sources is imperative for protecting ecosystems and conserving biodiversity. Fossil fuel extraction and consumption have led to habitat destruction, water pollution, and ecosystem degradation. By minimising our reliance on fossil fuels, we can reduce these negative impacts and preserve vulnerable ecosystems, allowing nature to recover and flourish.

3. Energy Access and Equity

Renewable energy plays a crucial role in providing access to clean and affordable energy, especially for remote or underserved communities. Many remote areas lack access to centralised power grids, making it difficult for them to benefit from traditional energy sources. In such cases, decentralised renewable energy systems, like off-grid solar panels or small wind turbines, can offer a viable and sustainable solution.

4. Economic Opportunities and Job Creation

The transition to renewable energy offers significant economic opportunities and job creation potential. As the renewable energy sector expands, it generates employment across various stages, from manufacturing and installation to maintenance and research. This job growth stimulates local economies and contributes to overall economic development.

- a. **Job Creation:** The renewable energy sector is a significant source of job creation. Developing and operating renewable energy projects requires a diverse range of skills, from engineering and manufacturing to installation and maintenance.
- b. **Local Entrepreneurship:** The transition to renewable energy opens opportunities for local entrepreneurs to enter the market. Solar panel installation companies, wind turbine manufacturers, and biomass energy producers are examples of businesses that can thrive in a renewable energy-focused economy.
- c. **Investment Opportunities:** Renewable energy projects attract significant investments from various sources, including governments, private investors, and international organisations. These investments contribute to the growth of the renewable energy sector and can lead to attractive returns for investors.

5. Green Industries and the Transition to a Green Economy

- a. **Innovation and Technological Advancements:** Investing in renewable energy technologies drives innovation, leading to the development of more efficient and cost-effective solutions.
- b. **Green Job Market:** As green industries expand, there will be an increasing demand for professionals in various fields such as renewable energy engineering, environmental sciences, sustainable architecture, and green finance.
- c. **Export and Trade Opportunities:** Countries that excel in renewable energy technologies and infrastructure can become leaders in exporting clean energy solutions.

6. Energy Security and Independence

- a. **Reduced Dependence on Fossil Fuel Imports:** Relying on renewable energy sources reduces a country's dependence on fossil fuel imports.
- b. **Price Stability:** Renewable energy sources such as wind, solar, and hydropower have stable and predictable costs over the long term.

7. Decentralised Renewable Energy Systems

- a. **Resilient and Reliable Power Supply:** Decentralised renewable energy systems, such as distributed solar panels, small wind turbines, and microgrids, can enhance energy resilience and reliability. By generating power locally, these systems reduce the vulnerability of energy infrastructure to natural disasters, extreme weather events, and cyberattacks, ensuring continuous electricity supply even during emergencies.
- b. **Access to Energy in Vulnerable Regions:** Many remote and vulnerable regions lack access to centralised power grids. Decentralised renewable energy systems offer a viable solution to provide electricity to these areas, empowering communities and enabling economic development without relying on extensive and expensive grid infrastructure.

8. Health and Well-being

- a. **Air Pollution Reduction:** Renewable energy sources produce little to no harmful air pollutants or greenhouse gas emissions during operation.
- b. **Improved Quality of Life:** Cleaner air and a healthier environment contribute to an overall improvement in the quality of life for communities. Reduced pollution levels mean fewer healthcare costs related to respiratory illnesses and improved productivity due to a healthier workforce.

9. Sustainable Development in Urban Areas

- a. **Rooftop Solar Panels:** Integrating rooftop solar panels into urban areas allows buildings to generate their electricity and reduce their reliance on the grid.
- b. **Smart City Initiatives:** By adopting renewable energy solutions and incorporating advanced energy management systems, cities can optimise their energy use, reduce carbon footprints, and create a more sustainable and liveable environment for residents.

Activity 5.1

1. List the various sources of energy and categorise them into renewable and non-renewable sources.
2. Discuss how renewable energy solutions can help developing countries leapfrog traditional fossil-fuel-based energy systems and accelerate progress towards achieving the SDGs.
3. Explain how investing in renewable energy infrastructure can promote sustainable economic development and create resilient communities, in line with the SDGs' aim of reducing inequalities.
4. Describe the potential environmental benefits of renewable energy sources in terms of land use, water conservation, and biodiversity conservation, with reference to the SDGs' focus on responsible consumption and production.

5. Watch video on the types of renewable energy sources (scan QR code or click on link)



<https://www.youtube.com/watch?v=44Wp3WE1AHs&t=2s>

Questions

- What type of renewable energy sources did you observe in the video?
- How important are these renewable energy sources to humans and the environment?

Activity 5.2

Build a Simple Solar Oven

Materials: Cardboard box, aluminum foil, plastic wrap, black construction paper, tape, thermometer.

Steps:

1. Line the inside of the box with aluminum foil.
2. Place black construction paper at the bottom of the box.
3. Cover the top opening with plastic wrap, taping it securely.
4. Place food items inside to cook, such as raw tomatoes.
5. Use a thermometer to measure the temperature inside the oven.

Questions

1. Why was black construction paper placed at the bottom of the box?
2. What happened to the food?
3. What is the temperature inside the oven?
4. How important is solar energy to humans?

Activity 5.3

Wind Energy Project: Create a Wind Turbine

Materials: Small motor (e.g., from a toy), cardboard, dowel rods, fan blades (made from cardboard or plastic), multimeter.

Steps:

1. Design and cut out blades for the turbine.
2. Attach the blades to a dowel rod connected to the motor.
3. Use a fan to simulate wind and generate electricity.
4. Measure the voltage produced with a multimeter or voltmeter.

Questions

1. What is your observation in this activity?
2. What is the voltage measured?
3. How can one make good use of wind?

Activity 5.4

Hydropower Demonstration: Build a Water Wheel

Materials: Cardboard, plastic spoons, glue, small water pump or large jug of water.

Steps:

1. Create a wheel using cardboard and attach plastic spoons around the edge.
2. Position the water wheel under a stream of water from a pump or jug.
3. Observe how the water movement generates mechanical energy.

Questions

1. What does this activity teach you?
2. How does hydroelectric power benefit humans?
3. Where in Ghana can we find hydroelectric power?

Activity 5.5

Biomass Energy Exploration: Biofuel Production from Kitchen Waste

Materials: Vegetable scraps, fruit peels, airtight container, water.

Steps:

1. Collect and chop kitchen waste.
2. Place waste in an airtight container with water to ferment.
3. After a few weeks, observe the production of biogas.
4. Discuss the potential and challenges of biofuel.

Questions

1. What are the sources of biomass that you know?
2. Why should the container be airtight?
3. What are the benefits and drawbacks to biomass?

Activity 5.6

Geothermal Energy Investigation: Model a Geothermal Power Plant

Materials: Large beaker, hot water, small container, steam turbine model, thermometer.

Steps:

1. Heat water in a large beaker to simulate geothermal energy.
2. Direct the steam produced through a small container to turn a steam turbine model.
3. Measure the temperature changes and discuss the conversion of heat to mechanical energy.

Questions

1. What are geothermal energy sources?
2. What are the measured temperature changes?
3. How is heat converted to mechanical energy?

Activity 5.7

Renewable Energy Survey: Conduct a Community Survey on Renewable Energy Awareness

Materials: Questionnaires, pens, clipboards.

Steps:

1. Design a questionnaire to assess community knowledge and attitudes towards renewable energy.
2. Conduct the survey in the local area.
3. Analyse the results and present findings in class.

Activity 5.8

Research and Presentation: Renewable Energy Source Research Project

Steps:

1. The teacher will allocate you or your group to a specific renewable energy source (solar, wind, hydro, geothermal, biomass).
2. Research and prepare a presentation on how it works, its advantages, and disadvantages.
3. Present findings to the class in five (5) minutes.

Activity 5.9

Renewable Energy Art Project: Create Art Representations of Renewable Energy Sources

Materials: Art supplies (paint, paper, clay, etc.)

Steps:

1. Create visual or sculptural representations of different renewable energy sources.
2. Display the art in a school exhibit and explain the science behind each piece.

Activity 5.10

Energy Audit: Perform a School Energy Audit

Materials: Energy audit checklist, measuring tools (e.g., watt meter).

Steps:

1. Evaluate the energy use in different parts of the school.
2. Identify areas where energy is wasted and suggest improvements.
3. Present recommendations to the school administration.

Questions

1. What is energy audit?
2. How important is energy audit?
3. How can energy waste be removed?

Activity 5.11

Field Trip: Visit a Local Renewable Energy Facility

Steps:

1. Organise a visit to a local solar farm, wind farm, or hydropower plant.
2. Learners prepare questions and take notes during the visit.
3. Discuss observations and learnings in a follow-up session.

Questions

1. What did you observe from the trip?
2. What excites you about the trip?
3. How is renewable energy being utilised as observed from the trip?

GENERATING ELECTRICITY IS FROM WATER, WIND, SOLAR, BIOMASS, AND BIOGAS ENERGY SOURCES

Renewable energy refers to energy sources that are naturally replenished and are considered sustainable over the long term. Unlike fossil fuels such as coal, oil, and natural gas, which are finite and non-renewable, renewable energy sources can be harnessed without depleting their availability for future generations.

1. Hydroelectric Power Generation

Hydroelectric power generation harnesses the energy of flowing water to produce electricity. It involves the construction of dams across rivers or other water bodies to create reservoirs, which store large quantities of water at an elevated level. When the water is released from the reservoir, it flows through turbines that convert the potential energy of the falling water into mechanical energy. Subsequently, the turbines are connected to generators that transform the mechanical energy into electrical energy.

Construction of Dams: Dams are constructed in locations with sufficient water flow and height difference to create a significant potential energy. The dam traps water in the reservoir, creating a large and stable water body.



Fig. 5.7: A picture of a hydroelectric dam

Turbines and Generators: The water released from the reservoir flows through large pipes called penstocks, which direct the water to strike the blades of the turbines. The force of the flowing water causes the turbines to rotate. These turbines are connected to generators, which are responsible for converting the rotational energy of the turbines into electrical energy. The generated electricity is transmitted through power lines to homes, businesses, and industries.



Fig. 5.8: A picture of a hydroelectric turbine

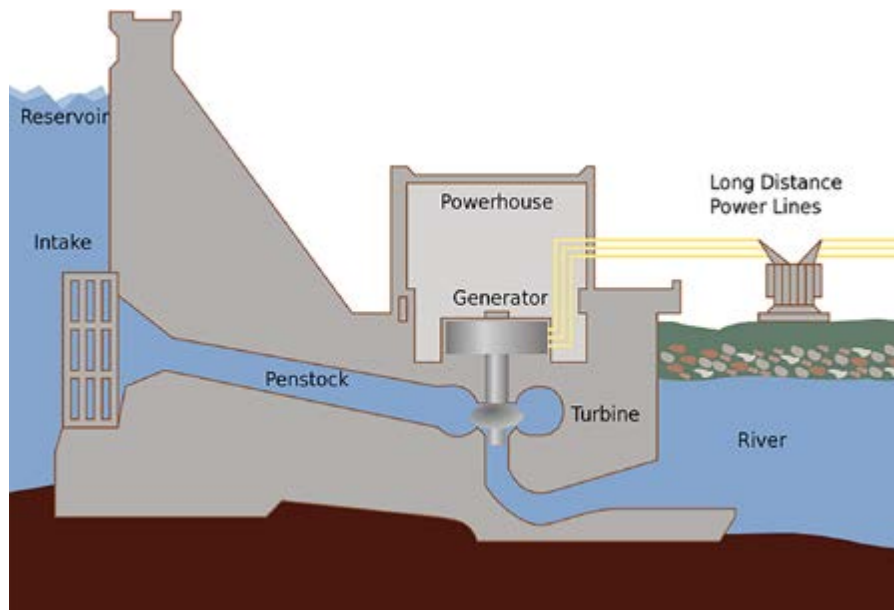


Fig. 5.9: A picture of how hydroelectric energy is generated

2. Wind Energy

Wind energy is harnessed from the kinetic energy of moving air. Where wind blows strongly, it becomes a major source of energy.

Wind Turbines: Wind energy is generated using wind turbines, which are tall structures with blades that rotate when wind blows. Wind turbines consist of large blades mounted on a tower. The blades act like an aeroplane wing, creating lift as the wind flows over them, causing them to turn. The turning blades spin a rotor connected to a main shaft. The main shaft is connected to a generator, which converts the mechanical energy from the rotating blades into electrical energy.



Fig. 5.10: A picture of a wind turbine

The basic working principle of wind turbines involves three main components: the blades, the shaft, and the generator. When the wind blows, it causes the blades to rotate

around the shaft. This rotation creates mechanical energy. The shaft is connected to a generator, which converts the mechanical energy into electricity.

Generator: The rotating blades are connected to a generator, which converts the kinetic energy of the wind into the mechanical energy of the rotating blades into electrical energy.

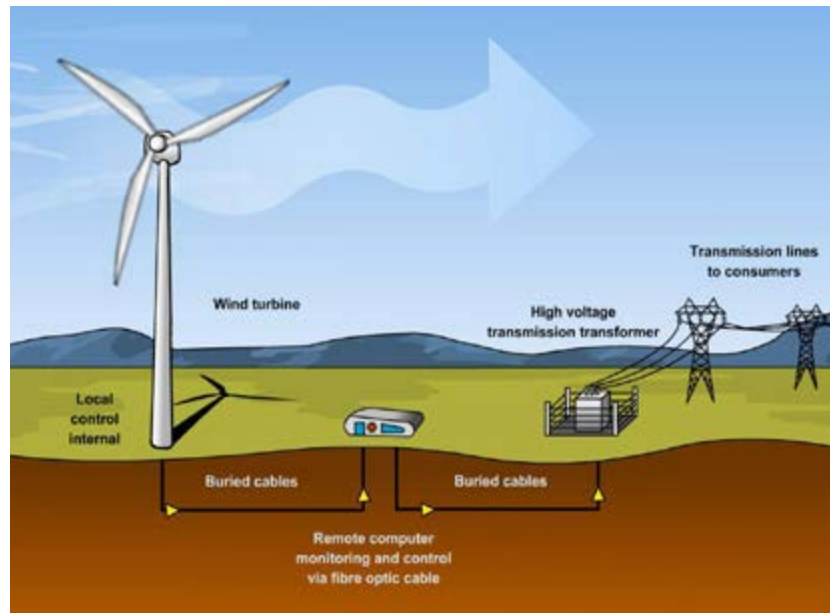


Fig. 5.11: A picture of how wind energy is generated

3. Solar Energy



Fig. 5.12: A picture of solar panel

Solar energy is obtained from the sun's radiation and can be converted into electricity through two main technologies: photovoltaic (PV) and solar thermal systems.

Photovoltaic (PV) Technology: Solar panels, made of semiconductor materials such as silicon, convert sunlight directly into electricity through the photovoltaic effect.

Concentrated Solar Power (CSP) plants use mirrors to focus sunlight onto a receiver, which generates steam to drive turbines and produce electricity.

How Photovoltaic Technology Works

When sunlight strikes the PV cell, it excites electrons in the semiconductor material, creating electron-hole pairs. The electric field in the PV cell drives these free electrons toward the front surface, creating a flow of electric current. Metal contacts on the top and bottom of the PV cell collect the current and transfer it to an external circuit, where it can be used or stored.

Components of a PV System

- PV Cells:** The basic building blocks of PV technology, usually made of semiconductor materials like silicon.
- PV Modules (Panels):** Multiple PV cells connected and encapsulated to form a durable and weather-resistant panel.
- Inverters:** Devices that convert the direct current (DC) electricity produced by PV panels into alternating current (AC) electricity used by most household appliances and the grid.
- Mounting Systems:** Structures that support and orient PV panels to maximise exposure to sunlight.
- Balance of System (BOS):** Includes wiring, switches, and other components necessary to integrate the PV system into the electricity grid or standalone systems.

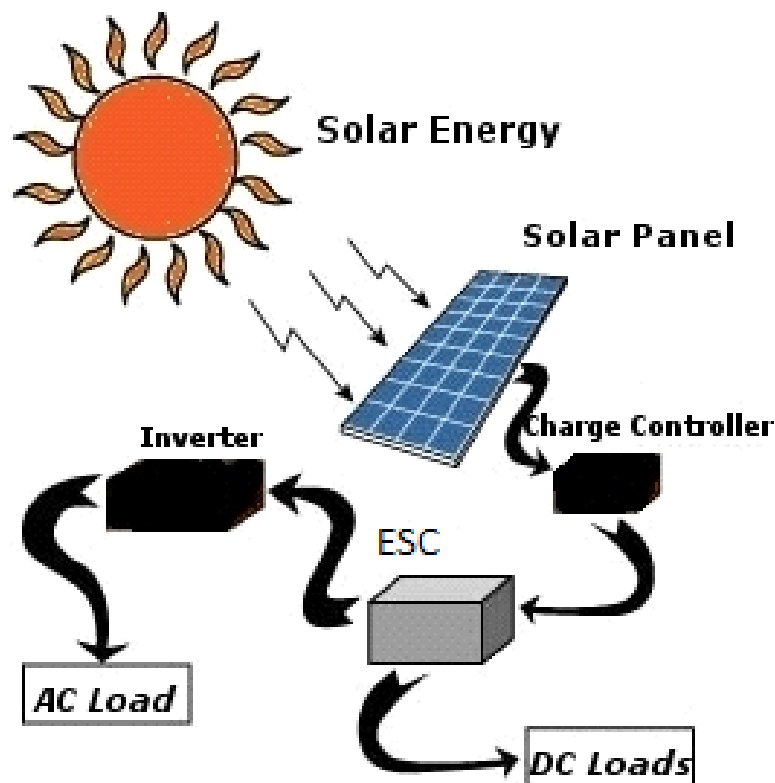


Fig. 5.13: A picture of how solar energy is generated

1. Biomass Energy

Biomass energy is derived from organic matter, including agricultural residues, forestry waste, and energy crops. It can be converted into biogas or burned to generate steam, which is then used to drive turbines for electricity production.

Here is an overview of how biomass energy is used to generate electricity:

Process:

- a. **Feedstock:** Biomass materials, such as wood chips, agricultural residues (like straw), or energy crops (such as switchgrass), are burned in a boiler or furnace.
- b. **Heat Generation:** The combustion process heats water in a boiler to produce steam.
- c. **Steam Turbine:** The steam drives a turbine connected to a generator, converting mechanical energy into electrical energy.
- d. **Electricity Generation:** The generator produces electricity, which can be used on-site or transmitted to the electrical grid.

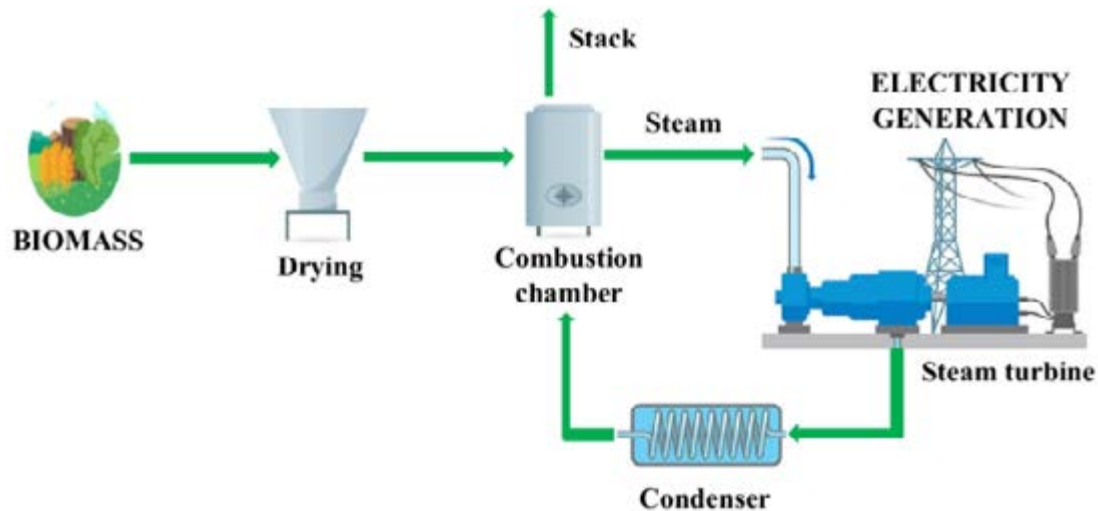


Fig. 5.14: A picture of how biomass energy is generated

2. Biogas Energy

Biogas is produced through the anaerobic digestion of organic waste materials, such as food scraps, agricultural waste, and animal manure. It mainly consists of methane and can be used as a fuel for generating electricity in gas turbines or combustion engines.

Process of Generating Electricity from Biogas

- a. **Biogas Production:** Organic materials are collected and placed in an anaerobic digester, a sealed container where bacteria break down the material in the absence of oxygen. This fermentation process produces biogas.
- b. **Biogas Composition:** Biogas typically contains around 50-70% methane (CH_4), which is the main combustible component, making it suitable for energy generation.

- c. **Cleaning and Conditioning:** Before biogas can be used for electricity generation, it undergoes cleaning and conditioning processes to remove impurities such as moisture, hydrogen sulphide (H_2S), and other contaminants that could damage equipment or reduce efficiency.
- d. **Conversion to Electricity:** Once cleaned, biogas is fed into a combustion engine, turbine, or combined heat and power (CHP) unit. The combustion engine or turbine burns the biogas, converting its chemical energy into mechanical energy.
- e. **Electricity Generation:** The mechanical energy is then used to drive an electric generator, which produces electricity. This electricity can be used on-site to power equipment, buildings, or be fed into the electrical grid for wider distribution.

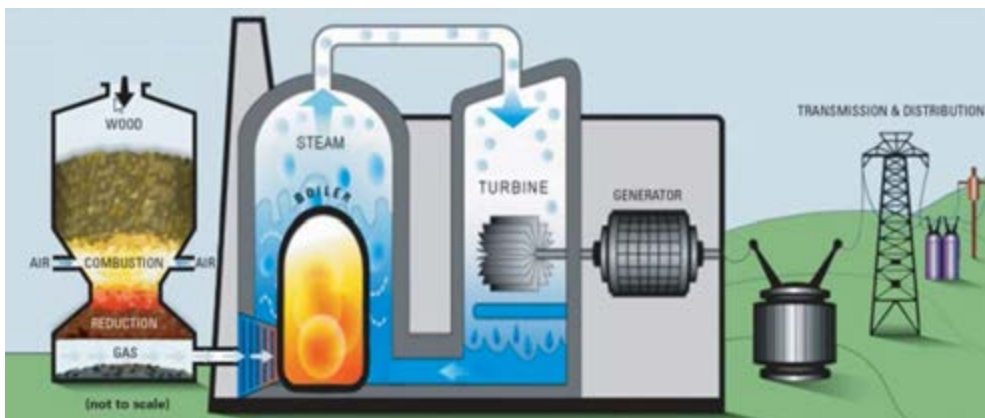


Fig. 5.15: A picture of how biogas energy is generated

3. Tidal Energy

Tidal energy is a form of renewable energy that harnesses the kinetic energy of ocean tides and currents to generate electricity. It is a type of marine energy technology that takes advantage of the predictable and reliable nature of tidal movements. There are two main methods used for generating electricity from tides: tidal stream systems and tidal range systems.

Tidal stream systems refer to the use of underwater turbines or generators placed in areas of strong tidal currents to harness the kinetic energy of moving water. Here is an overview of how tidal stream systems are used to generate electricity in renewable energy development:

How Tidal Stream Systems Work

- a. **Tidal Currents:** Tidal currents are caused by the gravitational forces of the moon and sun, and they flow in and out with the tides. These currents can reach significant speeds in narrow channels, straits, or coastal areas.
- b. **Tidal Turbines:** Tidal stream systems typically involve underwater turbines or generators like those used in wind farms but designed to operate underwater. These turbines are placed in areas where tidal currents are strong and predictable.

- c. **Generation of Electricity:** As tidal currents flow past the turbines, they cause the blades to rotate, like wind turbines. This rotational movement drives generators to produce electricity.
- d. **Grid Connection:** The electricity generated by tidal stream systems is transmitted to shore via underwater cables and integrated into the electrical grid for distribution to consumers.

Tidal range systems, also known as tidal barrage or tidal impoundment systems, harness the potential energy stored in the difference in height (range) between high and low tides. Here is an overview of how tidal range systems are used to generate electricity in renewable energy development:

How Tidal Range Systems Work

- a. **Tidal Range:** Tidal range systems operate by exploiting the vertical difference in water level between high tide and low tide in coastal areas.
- b. **Barrages or Dams:** Tidal barrages or dams are constructed across estuaries or bays with a large tidal range. These structures incorporate sluice gates, turbines, and associated infrastructure.
- c. **Generation of Electricity:** During high tide, water is allowed to flow into the basin behind the barrage through sluice gates. As the tide falls, the stored water behind the barrage is released through turbines, like hydroelectric dams, generating electricity.
- d. **Two-Way Generation:** Tidal range systems generate electricity during both incoming (flood) and outgoing (ebb) tidal flows, maximising energy capture.
- e. **Grid Connection:** The electricity generated by tidal range systems is transmitted to the grid via onshore connections, providing a stable and predictable source of renewable energy.

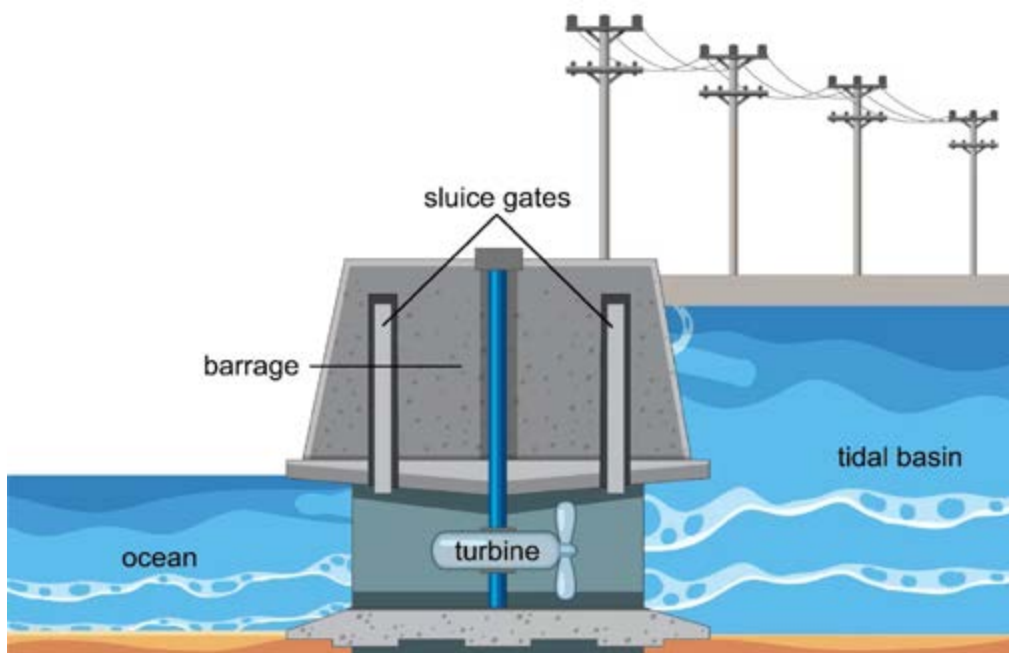


Fig. 5.16: A picture of how tidal energy is generated

COMPARING ELECTRICITY GENERATION FROM THE VARIOUS RENEWABLE ENERGY SOURCES

It is crucial to compare various renewable energy sources concerning their availability of resources, potential electricity generation, ease of energy production, cost of generation, technological maturity, and other relevant factors. This comparative analysis will help us better understand the strengths and limitations of different renewable energy options, aiding in informed decision-making for a sustainable energy future.

1. Resource Availability

- a. **Solar Energy:** Sunlight is widely available across the globe, with varying intensity based on geographical location and time of day/year. It is abundant in regions close to the equator, but solar panels can be installed in most places, including urban areas with rooftops and solar farms in open spaces.
- b. **Wind Energy:** Wind resources are location-specific and depend on factors like topography, altitude, and proximity to large water bodies. Windy regions, such as coastal areas and high altitudes, have greater potential for wind energy generation. However, wind turbines can be set up both onshore and offshore, offering flexibility in utilisation.
- c. **Hydroelectric Power:** Hydroelectric power relies on the availability of water bodies, such as rivers and reservoirs. Regions with significant water flow and elevation changes can harness hydroelectric power effectively. Large-scale projects are often located in specific areas with suitable geography.
- d. **Biomass Energy:** Biomass resources come from organic materials, including agricultural residues, wood, and dedicated energy crops. It is available in most regions where agricultural and forestry activities occur, making it widespread.
- e. **Biogas Energy:** Biogas is produced from organic waste, including animal manure, food waste, and sewage. The availability depends on the amount of organic waste generated, making it accessible in both urban and rural areas.
- f. **Tidal Energy:** Depends on coastal locations with significant tidal movements.

2. Quantity of Electricity Generation

- a. **Solar and Wind Energy:** The energy density of sunlight and wind varies, impacting the potential capacity for electricity generation. Wind turbines can achieve high-capacity factors in windy areas, while solar panels may have lower capacity factors but can be deployed widely.
- b. **Hydroelectric Power:** Hydroelectric plants can generate significant electricity with high-capacity factors, but the availability is constrained by suitable locations and environmental considerations.
- c. **Biomass and Biogas Energy:** The quantity of electricity generated from biomass and biogas depends on the availability of feedstock and the efficiency of conversion technologies.
- d. **Tidal Energy:** Potential is substantial due to predictable and powerful tidal flows.

3. Ease of Energy Generation

- a. **Solar Energy:** Solar installations are straightforward, especially for small-scale applications like rooftop solar panels. Larger solar farms require more planning and land use considerations.
- b. **Wind Energy:** Wind turbines require specialised infrastructure and careful siting to maximise wind exposure, but they are mature technologies.
- c. **Hydroelectric Power:** Large-scale hydroelectric projects involve complex engineering and environmental considerations, while small-scale installations may be simpler.
- d. **Biomass and Biogas Energy:** Generating electricity from biomass and biogas can be simple, especially in decentralised applications.
- e. **Tidal Energy:** Tidal energy requires specialised infrastructure and can be challenging to implement.

4. Cost of Generation

- a. **Solar Energy:** Solar panel costs have been decreasing in cost, making it more cost-effective over time. Installation and maintenance costs vary based on scale and location.
- b. **Wind Energy:** Wind turbine costs have also decreased, but installation and maintenance can be expensive, especially for offshore projects.
- c. **Hydroelectric Power:** Large-scale hydroelectric projects can have high initial costs, but operational expenses are relatively low.
- d. **Biomass and Biogas Energy:** Costs depend on the availability and transportation of feedstock, and larger projects may be more economically viable.
- e. **Tidal Energy:** Initial costs can be high due to the harsh marine environment and complex technology.

5. Availability of Technology

- a. **Solar and Wind Energy:** Solar panels and wind turbines are well-established technologies with widespread accessibility.
- b. **Hydroelectric Power:** Hydroelectric technology is mature, but large-scale projects face challenges due to environmental and social impacts.
- c. **Biomass and Biogas Energy:** Biomass and biogas technologies are accessible and have various applications, but they require careful management of feedstock.
- d. **Tidal Energy:** Developing technology with a smaller number of commercial-scale installations.

Table 5.1: Summary Table

Energy Source	Availability of Resource	Quantity of Electricity Generated	Ease of Energy Generation	Cost of Generation	Availability of Technology
Solar Energy	High (sunny regions)	Moderate to High	Moderate	Decreasing	High
Wind Energy	High (windy regions)	High	Moderate	Decreasing	High
Hydropower	High (water-rich areas)	Very High	High	Low to Moderate	High
Biomass Energy	High (widespread)	Moderate	Moderate	Moderate	High
Geothermal Energy	High (geothermal regions)	Moderate	Moderate	Moderate to High	High

Activity 5.12

Answer the following questions

1. Describe how wind turbines convert the kinetic energy of wind into electrical energy.
2. Explain the basic principle behind hydropower generation and how it harnesses the energy of flowing water.
3. Evaluate the environmental impacts associated with large-scale hydropower projects, considering both advantages and disadvantages.
4. Explain the factors that influence the efficiency of wind turbine operation, including wind speed and turbine design.
5. Elaborate on the photovoltaic (PV) effect and how solar panels use it to convert sunlight into electricity.
6. Compare and contrast solar thermal and solar photovoltaic systems, highlighting their respective working principles and applications.
7. Discuss how resource availability influences the choice of renewable energy for a location.
8. List the various considerations in evaluating the choice of renewable energy.
9. Discuss how electricity is generated from the various renewable energy sources (water, wind, solar, biomass, and biogas)
10. Compare the electricity generation from the various renewable energy sources with respect to availability of resources, quantity of electricity that could be generated, ease of energy generation, cost of generation, availability of technology, etc.

11. Discuss the appropriateness of each of the renewable energy sources in terms of resource availability, cost, and quantity of electricity supplied.
12. Investigate the cost of generating electricity from solar and wind sources. How have technological advancements affected the cost-effectiveness of these renewable energy options?
13. Compare the availability of technology for wave energy and solar energy. How does the level of technological development impact the feasibility of harnessing energy from each source?
14. Examine the environmental impacts of hydropower and biomass energy generation. How do these impacts vary, and what are the implications for long-term sustainability?
15. Evaluate the potential for wind energy and geothermal energy in regions with varying climate conditions. How do climatic factors influence the efficiency and reliability of these energy sources?
16. Discuss the role of government policies in promoting the adoption of renewable energy sources like solar and tidal power. How can policy decisions impact the growth of these industries?

Activity 5.13

Research and Presentation Project: Research and Compare Renewable Energy Sources

Steps:

1. The teacher will divide you into groups, each focusing on a different renewable energy source (solar, wind, hydropower, biomass, geothermal).
2. You will be provided with a set of questions to guide your research.
3. Then create a presentation based on your findings and present them to the class.

Questions:

1. What is the primary resource for this type of energy generation?
2. How readily available is this resource in different regions?
3. What is the potential quantity of electricity that can be generated from this source?
4. How easy or difficult is it to generate electricity using this source?
5. What are the initial and ongoing costs of generating electricity from this source?
6. What is the current state of technology for this energy source? Are there any recent advancements?
7. What are the environmental impacts of using this energy source.

Activity 5.14

Model Building and Demonstration: Build Models of Different Renewable Energy Generators

Materials: Solar cells, small wind turbines, water wheel kits, biomass combustion models, geothermal model kits.

Steps:

1. Each group is provided with materials to build a small-scale model representing a different renewable energy source.
2. Assemble the models and use them to generate electricity.
3. Measure and record the output of each model using a multimeter.
4. Compare the results and discuss the findings.

Questions

1. How much electricity was generated by your model?
2. What factors affected the efficiency of your model?
3. How easy or difficult was it to construct and operate your model?
4. How do the costs and materials for your model compare to those of the other groups?
5. What real-world challenges might exist for scaling up this technology?

Activity 5.15

Field Trip and Case Study Analysis: Visit Renewable Energy Facilities and Analyse Case Studies

Steps:

1. Visit a local renewable energy facility, such as a solar farm, wind farm, or hydropower plant.
2. You will be given background information and questions to ask during the visit.
3. After the visit, you will be provided with case studies of different renewable energy projects for analysis.
4. Discuss the findings in class.

Questions

1. What technologies did you observe at the renewable energy facility?
2. How much electricity does the facility generate, and what factors affect this output?
3. What are the costs associated with the facility's operation and maintenance?
4. How does the availability of resources affect the facility's performance?
5. What environmental and social impacts did the facility have on the local area?

Activity 5.16

Energy Audit and Proposal: Conduct a School Energy Audit and Propose Renewable Solutions

Materials: Energy audit tools (e.g., watt meters, thermometers), school energy bills.

Steps:

1. Conduct an energy audit of your school to identify energy usage patterns and areas for improvement.
2. Research different renewable energy options that could be implemented in the school.
3. In your group create a proposal for integrating a specific renewable energy source into your school's energy system.
4. Present and discuss the proposals.

Questions

1. What were the major findings of your school's energy audit?
2. Which areas of the school could benefit most from renewable energy solutions?
3. How much electricity could be generated by implementing your proposed renewable energy source?
4. What are the estimated costs for installing and maintaining your proposed solution?
5. How are the necessary technologies available for your proposal?
6. What environmental benefits would your proposal bring to the school?

Activity 5.17

Debate and Discussion: Debate on Renewable Energy Policies

Steps:

1. You will be assigned different roles, such as government officials, environmentalists, industry representatives, and community members.
2. Research your role's perspective on renewable energy.
3. In the debate discuss the benefits and challenges of different renewable energy sources.
4. Reflect on the debate in a class discussion.

Questions

1. What are the main arguments for and against each renewable energy source from your assigned perspective?

2. How do resource availability and technology affect the feasibility of each energy source?
3. What are the economic and environmental implications of adopting different renewable energy policies?
4. What compromises or solutions can be proposed to address the concerns of different stakeholders?
5. How do current policies and regulations impact the development and adoption of renewable energy technologies?

Review Questions

1. List four (4) sources of renewable energy, and how each one generates electricity
2. How does the availability of the resource impact the effectiveness of each renewable energy source?
3. State the typical costs associated with generating electricity from each renewable energy source, both initial and ongoing?
4. How does the current availability of technology affect the adoption of each renewable energy source?
5. How does the use of renewable energy sources help in reducing greenhouse gas emissions and combating climate change?
6. In what ways do renewable energy projects contribute to job creation and economic growth?
7. How does increasing access to renewable energy improve health outcomes and support sustainable cities and communities?
8. How does the deployment of renewable energy technologies ensure sustainable management of natural resources and support the transition to affordable and clean energy?

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