**OEE351-RENEWABLE ENERGY SYSTEM**

**UNIT I - INTRODUCTION**

**1. Discuss the primary energy sources available globally and their significance.**

**Introduction**

Energy is essential for modern life. It powers homes, industries, vehicles, and technology. The sources we get energy from are called **primary energy sources**. They are classified as **non-renewable** and **renewable**, based on whether they can be naturally replenished in a short time or not.

**1. Non-Renewable Energy Sources**

**Definition:**

Non-renewable energy sources are those that come from **natural resources that take millions of years to form**. Once we use them, they **cannot be quickly replaced**. They are widely used but cause **pollution and environmental damage**.

**a) Fossil Fuel Energy**

**🔹 Coal**

1. **Coal is a solid black rock** formed from ancient plants that were buried and compressed over millions of years. It contains a lot of carbon, which releases energy when burned.
2. It is mainly used in **thermal power plants** to generate electricity by heating water to make steam, which spins turbines.
3. Coal is **cheap and widely available**, especially in countries like India and China, which still depend heavily on it.
4. However, burning coal produces **a lot of harmful gases**, like carbon dioxide and sulfur dioxide, leading to **air pollution and global warming**.

**🔹 Petroleum (Crude Oil)**

1. Petroleum is a **thick, dark liquid** found deep underground. It was formed from ancient sea plants and animals buried under sand and rock.
2. It is refined into fuels like **petrol, diesel, and kerosene**, which are used in cars, planes, and industries.
3. It powers most of the world’s **transport systems** and is also used to make plastics, chemicals, and cosmetics.
4. Oil spills in oceans can cause **serious harm to marine life**, and its burning releases **carbon monoxide and carbon dioxide**, polluting the air.

**🔹 Natural Gas**

1. Natural gas is a **cleaner fossil fuel** made mostly of methane. It is found near oil deposits and extracted through drilling.
2. It is used in **homes for cooking and heating**, in power plants for electricity, and in industries.
3. It produces **less carbon dioxide** than coal and oil, making it a better choice environmentally.
4. However, methane leaks during extraction and transport can cause **global warming**, as methane is a very powerful greenhouse gas.

**b) Water Power (Large Hydropower Dams)**

**Note: Though water is renewable, large hydroelectric dams are sometimes considered non-renewable due to their negative environmental impacts.**

1. Large dams are built to **store river water**, which is released to flow through turbines and generate electricity.
2. They are a **stable and clean energy source** and can run for decades once built.
3. These dams help in **controlling floods, supplying water for farming (irrigation)**, and creating reservoirs.
4. However, they can **displace people**, destroy forests and **affect fish and aquatic life** due to changes in river flow.

**c) Nuclear Energy**

**Definition:**

Nuclear energy is created by **splitting the nucleus of uranium atoms**, a process called **fission**. This releases a huge amount of heat used to produce electricity.

1. **A small amount of uranium** can generate a lot of electricity, making nuclear energy very efficient.
2. Nuclear power plants do not release greenhouse gases during electricity generation, which helps in **fighting climate change**.
3. But nuclear accidents (like in Chernobyl and Fukushima) can release **dangerous radiation**, harming people and the environment.
4. The **radioactive waste** produced remains dangerous for thousands of years and needs special storage.
5. **Building nuclear plants is very expensive**, and countries need strict safety systems to operate them.

**2. Renewable Energy Sources**

**Definition:**

Renewable energy comes from **natural sources** like sunlight, wind, water, and Earth’s heat, which are **replenished regularly**. These are **cleaner** and better for the environment than fossil fuels.

**a) Solar Energy**

**Definition:**

Solar energy is the energy we get from the **sun’s rays**. It is captured using **solar panels** made of special materials (photovoltaic cells).

1. Sunlight is **free and unlimited**, available almost everywhere on Earth.
2. Solar panels can be used to power **homes, schools, streetlights**, and even satellites in space.
3. Energy is only produced when the sun is shining, so **solar panels don’t work well at night or on cloudy days**.
4. To store energy for later use, **batteries are needed**, which can increase costs.
5. Solar technology is **getting cheaper and more popular**, especially in sunny countries like India.

**b) Wind Energy**

**Definition:**

Wind energy is the power generated by **moving air**. Wind turbines turn this movement into electricity.

1. Wind turns the blades of a turbine, which spins a generator to make electricity.
2. It is **clean, safe**, and doesn’t produce any air or water pollution.
3. Wind turbines are often installed in **open areas**, on hills, or offshore where wind is strong and steady.
4. They require **a lot of space**, and some people don’t like the way they look or the noise they make.
5. Wind energy depends on the weather — **no wind means no power**, so it's often combined with other energy sources.

**c) Tidal Energy**

**Definition:**

Tidal energy is generated by using the **rise and fall of ocean tides**, which happen due to the moon's gravitational pull.

1. Tidal movements are **very regular and predictable**, so the energy is reliable.
2. Special turbines are placed in **coastal areas** to capture energy when tides go in and out.
3. Building tidal energy systems can be **expensive** and may affect **marine animals** and water movement.
4. Only a few places in the world have the right conditions for large-scale tidal energy.
5. Once built, these systems can generate **clean energy for many years**.

**d) Wave Energy**

**Definition:**

Wave energy is created by the **up and down movement of ocean waves**, and it can be captured using floating devices or underwater systems.

1. It is a **powerful and consistent energy source** in oceanic areas.
2. It can be used along coastlines to generate **electricity for local communities**.
3. Wave energy devices must be **strong enough to survive storms and saltwater corrosion**.
4. It's still **in development stages**, but has great potential for the future.
5. It is **non-polluting** and could work well in combination with wind or tidal systems.

**e) Geothermal Energy**

**Definition:**

Geothermal energy is the **natural heat inside the Earth**, found in hot rocks, geysers, and steam vents. It is used by drilling wells to access the heat.

1. It can provide **electricity and heating** all day and all year, unlike solar or wind.
2. It produces **almost no pollution** and needs little land space.
3. It works best in volcanic areas like **Iceland, New Zealand, and California**, where the heat is near the surface.
4. Drilling deep into the Earth is **costly**, and may sometimes cause **earthquakes or water contamination**.
5. It is ideal for **heating homes, greenhouses**, and running small power plants.

**f) Biomass Energy**

**Definition:**

Biomass energy comes from **burning organic material** like wood, crop waste, animal waste, or garbage to produce heat or electricity.

1. It is a **recycled energy source** because it uses waste products that would otherwise rot.
2. Biomass can also be converted into **biofuels** (like ethanol or biodiesel) used in cars and buses.
3. If plants are replanted after being used, biomass energy can be **carbon-neutral**.
4. Burning large amounts of biomass can still cause **air pollution**, especially indoors if not ventilated properly.
5. It helps reduce **waste in landfills** and provides energy in rural areas where electricity is limited.

**2. Compare and contrast renewable and non-renewable primary energy sources with examples.**

**1. Introduction**

Primary energy sources are the natural sources of energy that are used to generate power, heat, and electricity. These are broadly classified into two types:

* **Renewable energy sources**: Energy sources that are naturally replenished over short periods.
* **Non-renewable energy sources**: Energy sources that exist in limited quantities and take millions of years to form.

**2. Definition**

**Renewable Energy Sources**

Renewable energy sources are those that are continuously available in nature and can be replenished over time. They cause minimal environmental harm and are sustainable for future generations.

**Examples:** Solar energy, wind energy, tidal energy, wave energy, geothermal energy, and biomass energy.

**Non-Renewable Energy Sources**

Non-renewable energy sources are limited in supply and cannot be replaced once they are exhausted. These sources often lead to environmental pollution when used.

**Examples:** Coal, petroleum (oil), natural gas, nuclear energy, and large-scale hydroelectricity with ecological impacts.

**3. 🔄 Comparison Table**

|  |  |  |
| --- | --- | --- |
| Aspect | Renewable Energy Sources | Non-Renewable Energy Sources |
| Availability | Unlimited supply; naturally replenished by the environment (sun, wind, water). | Finite supply; once used, cannot be easily replaced. |
| Environmental Impact | Low pollution; clean and eco-friendly. | High pollution; contributes to greenhouse gases and climate change. |
| Examples | Solar, wind, tidal, wave, geothermal, biomass. | Coal, petroleum (oil), natural gas, nuclear energy, large-scale hydro with environmental impacts. |
| Cost Over Time | Initially high setup cost but low operating costs and free fuel (e.g., sunlight, wind). | Lower setup costs but high and fluctuating fuel costs. |
| Sustainability | Highly sustainable when managed well. | Not sustainable in the long run due to depletion. |
| Energy Storage | Needs storage systems (like batteries) due to inconsistency in sources like sun and wind. | Easy to store and transport as fuels (coal, gas, oil). |
| Global Use | Increasing usage globally due to climate awareness and energy transition. | Still the dominant source in many countries, especially for transport and industrial power. |
| Land/Space Requirement | Often needs more space (solar farms, wind farms), but can be placed on rooftops or remote areas. | Less space required for extraction plants or refineries, but can be destructive to ecosystems. |
| Initial Setup | Installation of solar panels, wind turbines, etc., requires technology and investment. | Extraction and processing infrastructure are well-developed and widely available. |

**4. Detailed Differences**

**A. Environmental Impact**

* **Renewable** sources like wind and solar produce little to no air or water pollution.
* **Non-renewable** sources like coal and petroleum emit harmful gases like CO₂ and sulfur dioxide, leading to climate change and acid rain.

**B. Cost and Efficiency**

* **Renewable energy** requires high initial setup cost (e.g., solar panels), but operational cost is low as the energy is free.
* **Non-renewable energy** sources are cheaper to set up initially, but costs fluctuate with fuel prices and availability.

**C. Reliability**

* **Non-renewable sources** provide continuous power and are easy to store and transport.
* **Renewable sources** may be less reliable due to dependence on weather conditions (e.g., no sunlight at night or during cloudy days).

**D. Usage in the Modern World**

* The world is transitioning towards **renewable energy** due to environmental concerns.
* However, **non-renewable sources** still dominate in industrial and transport sectors due to infrastructure and availability.

**5. Examples for Clarity**

* **Solar energy**: Used in rooftops and solar farms to generate electricity without pollution.
* **Coal**: Burned in thermal power plants to generate electricity but emits large amounts of CO₂.
* **Wind energy**: Captured using wind turbines; highly effective in windy regions.
* **Petroleum**: Used in vehicles and machinery; emits toxic gases and contributes to global warming.

**6. Conclusion**

In conclusion, while non-renewable sources have powered human civilization for centuries, they are polluting and limited. Renewable energy sources, although requiring initial investment, are cleaner, safer, and sustainable for future generations. The shift to renewable energy is essential to combat climate change and ensure energy security.

**3. Analyze the current usage and future potential of renewable energy sources in India**

**1. Introduction**

India is one of the fastest-growing countries in terms of energy demand. As the population and economy grow, so does the need for energy. To reduce pollution, fight climate change, and improve energy security, India is focusing on **renewable energy**—which is clean, eco-friendly, and sustainable.

* **High energy demand:** India is the third-largest energy consumer in the world.
* **Environmental concern:** Renewable energy reduces dependence on fossil fuels and lowers pollution.
* **Sustainable development:** Clean energy supports long-term economic growth.
* **Government push:** Strong national policies support renewable energy development.

**2. Current Usage of Renewable Energy in India**

India has made great progress in adopting renewable energy. It has become a global leader in solar and wind power development.

**🔹 A. Installed Renewable Energy Capacity (as of 2024)**

1. **Solar Energy (~75 GW):**  
   Solar panels convert sunlight into electricity. India receives a lot of sunlight, making solar power highly suitable. Rooftop systems and large solar parks are growing fast.
2. **Wind Energy (~45 GW):**  
   Wind turbines capture wind energy. States like Tamil Nadu, Gujarat, and Karnataka have many wind farms due to strong coastal winds.
3. **Small Hydro Power (~10 GW):**  
   Small-scale hydro projects use rivers or streams to generate electricity. These are helpful in hilly and remote areas.
4. **Biomass and Waste-to-Energy (~12 GW):**  
   Agricultural waste, animal dung, and city garbage are used to generate power, especially in rural areas.

**🔹 B. Off-Grid Systems**

1. **Used in remote villages** where grid electricity is unavailable.
2. **Solar lanterns, home systems, and solar pumps** help meet rural needs.
3. **Mini-grids powered by solar/wind/biomass** are becoming popular.
4. Supports **irrigation, lighting, and small industries** in villages.

**🔹 C. Key Government Schemes**

1. **National Solar Mission:** Promotes large-scale and rooftop solar projects.
2. **PM-KUSUM:** Supports solar pumps for farmers to irrigate land without using diesel.
3. **UJALA Scheme:** Promotes use of energy-saving LED bulbs and solar systems.
4. **Green Energy Corridors:** Help transmit renewable energy from rural areas to cities.

**3. Future Potential of Renewable Energy in India**

India has huge potential to grow its clean energy sector due to natural advantages and government support.

**🔹 A. Solar Energy**

1. **Huge sunlight availability:** Most regions get sunlight 300+ days a year.
2. **Rooftop solar potential:** Urban homes, factories, and schools can install solar panels.
3. **Solar parks:** The government is building large-scale solar plants in deserts and open lands.

**🔹 B. Wind Energy**

1. **High potential in coastal states:** Tamil Nadu, Gujarat, and Maharashtra have steady winds.
2. **Onshore wind farms** already exist and are being expanded.

**🔹 C. Biomass and Bioenergy**

1. **Plenty of agricultural waste** like rice husks, wheat straw, and sugarcane bagasse.
2. **Biogas plants** can turn cow dung and food waste into fuel for cooking and electricity.
3. **Bio-CNG and biofuels** can be used in vehicles and industries.

**4. Challenges in Renewable Energy Growth**

Despite the potential, India faces some problems in renewable energy adoption.

1. **High initial costs:** Solar panels and wind turbines need large investments.
2. **Land acquisition issues:** Large projects need land, which is hard to get in populated areas.
3. **Weather dependence:** Solar and wind energy are not available all the time (night or no wind).
4. **Grid stability:** Managing power from multiple renewable sources is technically complex.

**4. Elaborate on the development of renewable energy technologies in India and their impact on power production.**

**Introduction**

Renewable energy means electricity that is made from natural things like the **sun, wind, water, and plants**. These natural sources will never run out. They are better than coal, petrol, or diesel because they **do not cause pollution** and are **good for the Earth**. India is a large country, and more people need electricity every day. So, India is now **using more renewable energy** to meet its power needs in a clean and smart way.

**Types of Renewable Energy in India:**

**1. Solar Energy (Energy from the Sun)**

* India gets **a lot of sunlight** for most of the year, so it is perfect for solar energy.
* **Solar panels** are used to capture sunlight and turn it into electricity.
* In 2010, the government started the **National Solar Mission** to make solar energy popular.
* **Big solar parks** have been built in deserts and open lands in **Rajasthan, Gujarat, Madhya Pradesh**, and more.
* People also put **solar panels on rooftops** of homes, schools, and shops to save electricity costs.
* Solar power is now one of the **cheapest and cleanest** ways to produce electricity in India.

**2. Wind Energy (Energy from Wind)**

* Wind energy is created when **strong winds** turn big windmills (called turbines), and that motion creates electricity.
* India started wind power in the **1990s** and is now **one of the top countries** in wind energy.
* States like **Tamil Nadu, Gujarat, Karnataka**, and **Maharashtra** have many **wind farms** where wind energy is made.
* Wind turbines work well in open areas and **coastal regions** where there is **strong wind**.
* Wind energy is clean, fast-growing, and works well along with solar.

**3. Hydropower (Energy from Water)**

* Hydropower is made by using the **force of flowing water**, usually in rivers and dams.
* Water turns large machines called **turbines**, which then produce electricity.
* States like **Himachal Pradesh, Uttarakhand, and Sikkim** have many dams for this.
* Hydropower is reliable and produces electricity day and night, but building big dams can **harm the environment** and nearby people.

**4. Biomass and Waste-to-Energy (Energy from Plants and Waste)**

* This type uses **plant waste, food waste, cow dung, and garbage** to make electricity or **biogas**.
* It helps in **reducing waste** and also gives us useful energy.
* Many villages and small towns use **biogas plants** for cooking and small power needs.
* This also helps farmers earn money by selling waste materials.

**Government Support and Plans**

The Indian government is doing a lot to **support renewable energy**. Some of the main steps are:

* Giving **subsidies** (financial help) to people who install solar panels or biogas plants.
* Allowing **foreign companies** to invest in renewable energy in India.
* Launching helpful schemes like:
  + **PM-KUSUM**: Helps farmers get solar pumps for farming.
  + **International Solar Alliance (ISA)**: India leads this group of over 100 countries to promote solar energy around the world.
  + **Green Energy Corridors**: These are special electric lines to send solar and wind power from remote areas to cities.
* India has set a **big target** – to produce **500 GW of renewable energy by 2030**. This will make India one of the **greenest countries in the world**.

**Impact on Power Production in India**

1. **Less Air Pollution**
   * Renewable energy does not produce smoke or harmful gases.
   * It helps keep the **air cleaner** and people **healthier**.
2. **Less Use of Coal and Oil**
   * India doesn’t need to buy as much fuel from other countries.
   * This saves **a lot of money** and makes India **energy-independent**.
3. **Cheaper Electricity**
   * Solar and wind energy costs have gone **down a lot**.
   * People can now get electricity at a **lower price**, especially in villages.
4. **More Jobs**
   * Jobs are created in making, installing, and repairing solar panels and wind turbines.
   * **Young people** are getting new work opportunities in this field.
5. **Electricity in Remote Areas**
   * Places that are far from cities can now get electricity using small solar panels.
   * This helps in **improving the lives** of people in rural areas.

**Challenges in Renewable Energy**

1. **Weather Problems**
   * Solar power doesn’t work at night or during rainy/cloudy days.
   * Wind energy works only when there is enough wind.
2. **Energy Storage is Costly**
   * To use solar or wind power when it's not sunny or windy, we need **batteries**, which are **still expensive**.
3. **Electric Grid Needs Upgrades**
   * The current power system in India is made for regular power, not variable power.
   * It needs to be **modernized** to handle energy from different sources like solar and wind.

**Conclusion**

India is doing an **amazing job** in growing its renewable energy capacity. Solar and wind energy are becoming **more popular**, and the government is helping with good schemes and support. More villages are getting electricity, the air is getting cleaner, and people are getting jobs. Even though there are some problems like weather and storage, India is moving fast towards a **green and clean energy future**. If this continues, India will soon become a **global leader** in renewable energy.

**5. Evaluate the benefits and challenges of transitioning from non-renewable to renewable energy sources in India.**

**Introduction**

India's energy needs are growing rapidly, but most of our electricity comes from **non-renewable energy sources** like **coal, oil, and gas**. These are **limited** and cause **pollution**. So, India is moving towards **renewable energy** like **solar power, wind power**, and **hydropower** to create cleaner, more sustainable electricity.

This shift is good for the environment, economy, and society, but it also brings some **challenges**. Let's look at both the **benefits** and **challenges** of using renewable energy in India.

**Benefits of Renewable Energy in India**

**1. Cleaner Environment – Less Pollution**

* **Non-renewable energy** like coal burns and releases **smoke** and **carbon dioxide (CO₂)**, which **pollutes the air** and causes **global warming**.
* **Example**: In cities like **Delhi**, burning coal for electricity creates a **lot of smoke**, leading to **health problems** like asthma.
* **Renewable energy** like **solar** and **wind power** doesn’t produce any harmful gases.
* **Example**: **Solar panels** on rooftops help in producing clean electricity with **no pollution**.

**2. Saves Money – Reduces Dependency on Imported Fuel**

* India imports **oil and gas** from other countries, which costs **billions of rupees** every year.
* **Example**: If India uses **solar energy** or **wind energy**, it won't need to **buy expensive oil** from other countries.
* By using **renewable energy**, India can **save money** and become more **self-reliant**.

**3. Unlimited and Free Energy**

* **Solar energy** comes from the sun, and **wind energy** comes from the wind. These are **natural**, **free**, and available **every day**.
* **Example**: You don’t need to pay to use **sunlight** or **wind**. Once you install solar panels or wind turbines, the cost of electricity is **very low**.
* Unlike coal, which takes years to form and is **running out**, these energy sources are **unlimited** and will **never run out**.

**4. Job Creation and Economic Growth**

* The renewable energy sector creates **many jobs** for people.
* **Example**: If a large **solar farm** is built in a rural area, people will be needed to **install panels, maintain the farm**, and **work in the factory** making solar panels.
* This helps create **job opportunities** for **engineers, technicians, and workers** in both **urban and rural areas**.

**5. Electricity for Remote Areas**

* Many **villages in India** do not have access to electricity.
* **Example**: Small **solar panels** can be installed on homes in remote villages. This way, families can **light their homes, use fans**, and even charge **mobile phones**.
* **Solar power** helps bring electricity to places that are **far from the national grid**

**6. Energy Security – Consistent Power Supply**

* With **renewable energy**, India will not need to worry about **fuel shortages** or **price increases** in the future.
* **Example**: If India relies more on **solar power**, we don’t need to depend on other countries for **oil or gas**.
* This helps India **secure its energy supply** for the future and avoid **blackouts**.

**7. Promotes Innovation and Research**

* Shifting to **green energy** encourages scientists and companies to **develop better technologies**.
* **Example**: India’s **ISRO** (Indian Space Research Organization) is already working on new **solar power technologies** that can be used in both space missions and on Earth.

**Challenges of Renewable Energy in India**

**1. Dependence on Weather Conditions**

* **Solar power** only works when the sun is shining and **wind power** needs strong winds to produce electricity.
* **Example**: If it is **cloudy** or **rainy**, **solar panels** will produce **less electricity**. Similarly, on **calm days**, **wind turbines** may not produce enough energy.
* This makes renewable energy **unstable** and hard to rely on **all the time**.

**2. High Initial Costs**

* Setting up **solar panels**, **wind turbines**, and the required infrastructure is **expensive**.
* **Example**: Installing solar panels on a roof can cost **thousands of rupees** at first. This can be difficult for people who do not have enough money.
* However, in the long run, the cost of using **renewable energy** is **very low** compared to paying for traditional electricity every month.

**3. Energy Storage is Expensive**

* Solar power and wind power don’t work at night or on cloudy days, so we need to **store energy** in **batteries** for later use.
* **Example**: Batteries like **lithium-ion** are expensive and **need to be replaced** every few years.
* This makes storing renewable energy **costly** for both individuals and companies.

**4. Need for Skilled Workers**

* **Renewable energy technologies** require **specialized skills** to install and maintain.
* **Example**: A person who installs **solar panels** must be trained in understanding how **electricity flows**, how to **safely set up equipment**, and how to repair it if it breaks.
* **India** needs to invest more in **training workers** and **educating students** in the fields of **solar, wind, and energy storage technologies**.

**5. Old Power Grid System Needs to Be Updated**

* India’s current **electricity grid** was made for big **coal power stations**. Renewable energy comes from **many small sources** like individual solar panels or wind turbines, which the old grid can’t handle well.
* **Example**: The grid needs to be **updated** to carry power from **thousands of small solar panels** installed on homes and factories.
* This **requires a lot of money** and effort.

**6. Land Use Issues**

* Large renewable energy projects, like **solar parks** and **wind farms**, need a lot of **land**.
* **Example**: A **solar farm** may need to use **large fields** that could have been used for **farming** or **growing trees**.
* This can lead to conflicts between **farmers**, **environmentalists**, and the **government**.

**7. Lack of Awareness**

* Many people in India don’t know how **solar energy** works or why it’s good for the environment.
* **Example**: In rural areas, people may not understand the benefits of **solar panels** because they haven’t seen it used much.
* The government needs to **educate people** about the **advantages** and **cost savings** of renewable energy.

**Conclusion**

In conclusion, moving from non-renewable energy to renewable energy is very important for India’s future. The **benefits** include:

* Cleaner air and environment
* Reduced dependency on foreign oil
* **Unlimited** energy from sun and wind
* Job creation and rural development
* Energy security and innovation

However, there are also challenges such as high costs, dependency on weather, and lack of infrastructure. By addressing these issues through **better technology**, **government policies**, and **public awareness**, India can **successfully shift to renewable energy** and become a leader in the global clean energy movement.