Uttar Pradesh Rajarshi Tandon Open University

# Bachelor of Science

## UGEVS-101 (N)

# Energy Resources and Green Technology

# COURSE INTRODUCTION

The objective of this course is speared the knowledge of energy resources and green technology. The energy resources and green technology play are crucial role in the society that pursuit as sustainable sources of energy resources. However, we know as the global population continues to grow and energy demands increase, the need of clean and renewable energy resources becomes more pressing. Fortunately, advancements in green technology are providing innovative solution to address these challenges. This course provides detailed knowledge of energy production sources such about solar energy, fossil fuel energy and production of biomass energy. The energy conservation strategy and energy policies for energy production and conservation are also discussed.

**Block 1** covers the solar and fossil Fuel. Here you will learn solar energy and energy production from fossil fuels.

**Block 2** deals the biomass energy and energy polices, this block covers the production of biomass and en ergy policy of India.

**Block 3** describes in brief of energy conservation and green energy in Indian and other countries.

***Rajarshi Tandon Open University, Prayagraj***

**SBSEVS-01N**

# *Energy Resources and Green Technology*


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SBSEVS-01N

Energy Resources and Green Technology

# Block- I

# Solar and Fossil Fuel

## UNIT -1

## Sun as a Source of Energy

## UNIT-2

## Fossil Fuel

## UNIT-3

## Renewable Energy Resources

# Unit-1: Energy Resources and Green Technology

***Contents***



## 1.1. Introduction

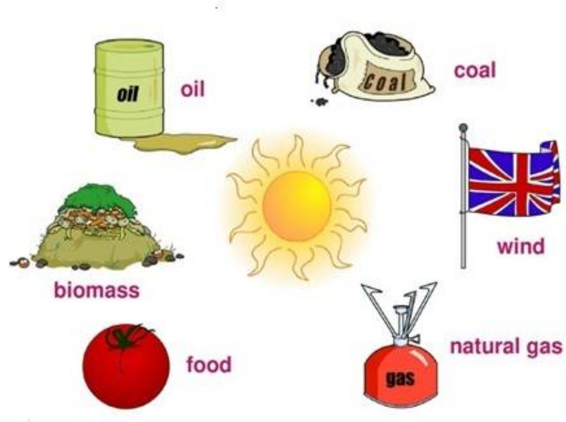
The sun is the closest star to our planet Earth and is the most important source of energy for life on Earth. Sun is regarded as ultimate source of energy for ecosystem on the earth. It is a massive, luminous ball of gas, mostly composed of hydrogen and helium, and generates energy through a process called nuclear fusion. In the process of fusion, the sun converts hydrogen into helium, releasing large amounts of energy in the form of heat and light. This energy is emitted in all directions in the form of electromagnetic radiations and it makes life on Earth possible. Without the sun's energy, our planet would be cold, dark and lifeless. The sun's energy is harnessed by various technologies to produce electricity and power our homes, businesses, and industries. Solar panels, for example, capture the sun's energy and convert it into usable electricity. The sun's energy also plays a crucial role in the Earth's climate and weather patterns. The visible part of electromagnetic spectrum called light is utilized by green plants in photosynthesis in which the radiant of sun energy is used to produce carbohydrate. The sun's energy drives the water cycle, which is responsible for the formation of clouds, rain, and snow. It also drives the winds and ocean currents, which in turn affect weather patterns and climate. Overall, the sun is an ultimate powerful and essential source of energy that has shaped the Earth's climate and provided life with the energy it needs to thrive.

**Objectives**

- To discuss the sun as source of energy
- To discuss the concept of energy
- To discuss the characteristics of solar energy
- To discuss the energy used as a historical perspective
- To discuss solar devices and solar radiation

## 1.2. Sun as source of energy

The sun is the closest star to our planet Earth and is the most important source of energy for life on Earth. It is a massive, luminous ball of gas, mostly composed of hydrogen and helium, and generates energy through a process called nuclear fusion. Through the process of fusion, the sun converts hydrogen into helium, releasing large amounts of energy in the form of heat and light. This energy is emitted in all directions in the form of electromagnetic radiations and is what makes life on Earth possible. Without the sun's energy, our planet would be cold, dark and lifeless. The sun's energy is harnessed by various technologies to produce electricity and power our homes, businesses, and industries. Solar panels, for example, capture the sun's energy and convert it into usable electricity. The sun's energy also plays a crucial role in the Earth's climate and weather patterns. The sun's energy drives the water cycle, which is responsible for the formation of clouds, rain, and snow. It also drives the winds and ocean currents, which in turn affect weather patterns and climate. In an ecosystem, energy flows through a food chain or food web from producers to consumers and ultimately to decomposers. The green plants which are primary producers performed photosynthesis and make their biomass.

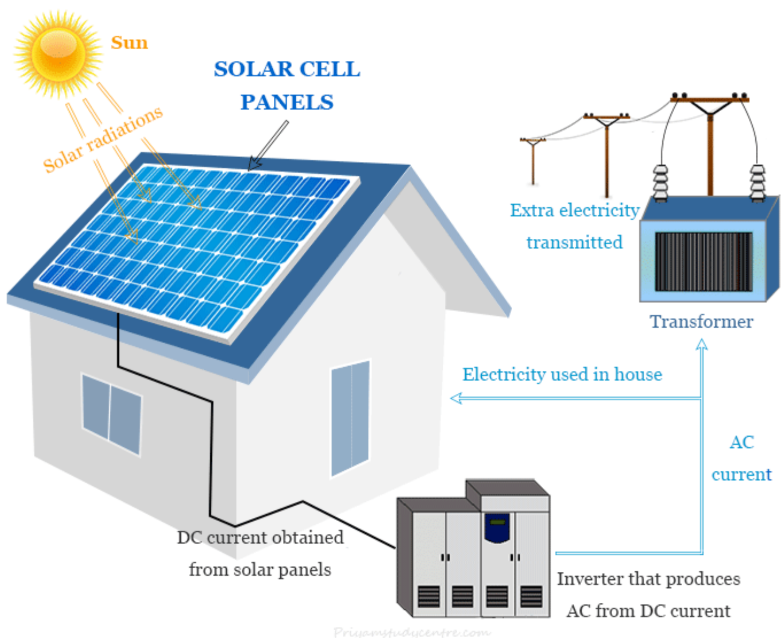



The primary source of energy in an ecosystem is the sun, which provides energy to plants through photosynthesis. Plants, also known as producers, use energy from the sun to convert carbon dioxide and water into glucose and oxygen. This process stores energy in the chemical bonds of glucose molecules. Consumers, such as herbivores, carnivores, and omnivores, obtain energy by consuming plants or other animals. When consumers eat, they break down the food molecules to release the energy stored in the chemical bonds of the food. This energy is then used to power the consumer's metabolism and life processes, such as growth, movement, and reproduction. Decomposers, such as bacteria and fungi, break down dead organic matter and return nutrients to the soil, completing the nutrient cycle. They also release energy stored in the chemical bonds of organic matter, making it available to other organisms in the ecosystem. Overall, the sun is a powerful and essential source of energy that has shaped the Earth's climate and provided life with the energy it needs to thrive.

## 1.3. Solar Energy

Solar energy is energy that is produced by the sun and can be harnessed and converted into usable electricity. The process of converting sunlight into electricity is achieved through the use of photovoltaic (PV) cells, which are typically made from silicon and other materials. These cells absorb sunlight and convert it into direct current (DC) electricity, which can then be converted into alternating current (AC) electricity and used to power homes and businesses to run various applications and machines.

The used of solar energy was initiated seventh century BC, when people used basic magnifying glasses to focus light from the sun to make fire. Over a century ago, a scientist in France used a solar collector to make steam to power an engine. However, it was not until the late 19th century that scientists began to explore the use of solar energy as a potential source of electricity. In 1876, William Grylls Adams and Richard Day discovered the photovoltaic effect, which involves the generation of electricity when certain materials are exposed to light. This discovery laid the foundation for the development of modern solar photovoltaic technology. In the early 20th century, solar energy was primarily used for heating water and cooking food in remote areas. The use of solar energy has continued to grow, driven by advancements in technology, decreasing costs, and increasing concerns about climate change.




Today, solar energy is used in a variety of applications, from small-scale residential systems to large-scale commercial and industrial systems. The future of solar energy is bright, with continued advancements in technology and decreasing costs expected to drive further growth. Solar energy has the potential to play a significant role in meeting global energy demand also reducing greenhouse gas emissions with other harmful pollutants. The scope of solar energy is vast and covers a wide range of applications.

- The most common use of solar energy is for electricity generation, either through on-grid or off-grid systems.
- It is used for heating and cooling, through the use of solar thermal technology

- It is used to transportation, lighting, water pumping and also in different types of appliances.
- It has been used to power satellites and other spacecrafts for several decades.

### 1.3.1. How Solar Energy Works?

Solar energy works through the use of photovoltaic (PV) cells, which are typically made from silicon and other materials. These cells absorb sunlight and convert it into direct current (DC) electricity, which can then be converted into alternating current (AC) electricity and used to power homes and businesses.

**Limitations:-**

1. Energy reach in the surface is very much diffused and so the direct utility is limited.
2. It is not available uniformly all the times and at all the places.
3. It is not available in night.
4. Cloud formation may obstruct the reflection.
5. In solar panels various used components can produce toxic chemicals and can generate greenhouse gas emissions.
6. The efficiency of solar energy systems can vary depending on the type of technology used and the location of the system.
7. In some areas, the amount of sunlight may be insufficient to generate enough electricity to meet demand.
8. Solar energy systems require large area of land, which can be a challenge in urban areas where space is limited

### 1.3.2. Advantages of Solar Energy:

There are several advantages of using solar energy, including:

- Solar energy is a renewable energy source, which means that it is constantly replenished and will not run out like fossil fuels.
- Solar energy does not produce greenhouse gas emissions or other harmful pollutants, thus, making it an environmental friendly energy source.
- Solar energy has become increasingly cost-effective in recent years, with the cost of solar PV systems decreasing significantly. In addition, solar energy can help in reducing

energy bills over time, as it allows homeowners and businesses to generate their own electricity and reduce their reliance on the grid.

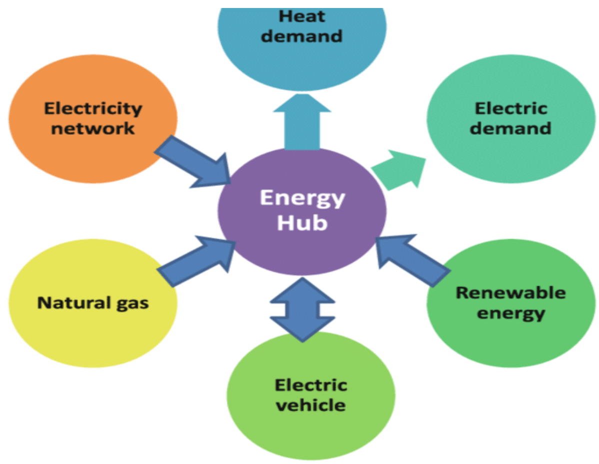
- Solar energy is a reliable source of energy, as long as there is sufficient sunlight available. This makes it a good option for areas that may experience power outages or grid instability.
- Solar energy can be used in a variety of applications, from small-scale residential systems to large-scale commercial and industrial systems.

### 1.3.3. Disadvantages of Solar Energy:

- Instead of having various advantages solar energy also has so many disadvantages such as
- Solar energy is an intermittent energy source, as it is dependent on sunlight. This means that solar energy systems may not produce electricity during periods of low sunlight, such as on cloudy days or at night.
- The upfront costs of installing a solar PV system can be high despite in recent years.
- Solar panels require a significant amount of space, which may be a challenge for homeowners or businesses with limited roof or ground space.
- While solar energy does not produce greenhouse gas emissions, the production of solar panels and other components can have adverse environmental impacts, due to as the use of rare earth metals and other materials in manufacturing.

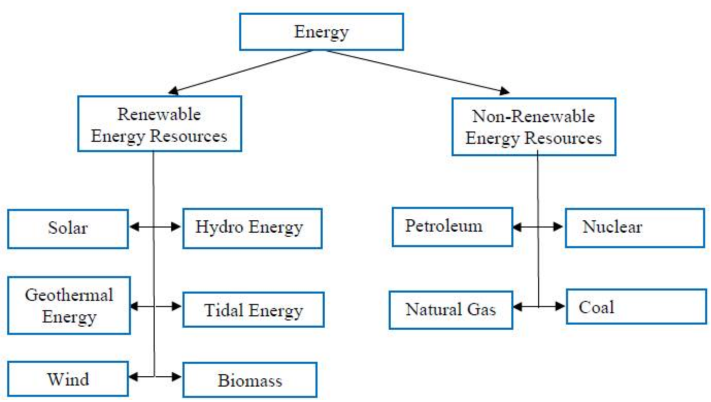
## 1.4. Concept of energy

Energy is a fundamental concept in physics and refers to the ability of a physical system to do work. In other words, energy is the capacity of a system to produce change or perform work on another system. Energy may have different forms, including kinetic energy (the energy of motion), potential energy (the energy stored in an object due to its position or configuration), thermal energy (the energy associated with the temperature of a system), chemical energy (the energy stored in chemical bonds), and electromagnetic energy (the energy associated with light and other forms of electromagnetic radiation). The total amount of energy in a closed system is conserved, meaning it cannot be created or destroyed, only transferred or converted from one form to another. This is known as the Law of Conservation of energy. Energy is a crucial concept in many areas of science and engineering, including thermodynamics, mechanics, electromagnetism, and quantum mechanics. It also plays a critical role in our daily lives, powering our homes, vehicles, and industries, and affecting the natural world around us through climate and weather patterns. Fossil fuels such as coal, oil, and gas are sources of energy generated from plants which were present on the Earth millions of years ago through a number of chemical reactions inside the Earth surface. In the world most of energy demand is fulfilled by the fossil fuel.




### 1.4.1. Source of energy

Any system from where energy can be trapped is called a source of energy. There are two main sources of energy that is conventional and non-conventional sources of energy.




- **Conventional/ non-renewable source:** - energy source which are being used traditionally for many years and are depleted over a period of time, are called conventional/ non-renewable source e.g. coal, petroleum, natural gas etc.

- **Non-conventional/ renewable source:-**energy sources which do not deplete and are scarcely used up by population are called non- conventional or renewable sources of energy e.g. solar energy, wind energy and tidal energy etc.

### 1.4.2. Characteristics of good sources of energy:-

**1** Should be capable of providing adequate amount of energy.

**2** Should be convenient to use & easy to store, handle & transport.

**3** Should be capable of giving desired quantity at required rate steadily over a long period.

**4** Should be easily accessible.

**5** Should be economical.

**6** Should release energy in mostly all forms in which the day-to-day requirement exists.

The energy exists in different forms in nature such as

- Muscular energy
- Heat energy
- Light energy
- Chemical energy
- Nuclear energy
- Solar energy
- Wind energy
- Tidal energy
- Geothermal energy
- Ocean energy etc.

## 1.5. Energy used as a historical perspective

Energy has played a significant role in human history, from the use of fire for cooking and heating to the development of advanced technologies that have transformed our society. This essay will provide a historical perspective on the use of energy over time, exploring how humans have harnessed different sources of energy to meet their needs.

### The Prehistoric Era

Humans have been using energy since prehistoric times, with the discovery of fire being a significant milestone in our evolution. The ability to control fire allowed our ancestors to cook food, provide heat and light, and ward off predators, greatly improving their chances of survival. In addition, the discovery of fire enabled the development of tools and weapons, as well as the creation of art and rituals. The use of fire as a source of energy continued throughout the prehistoric era, with early humans relying on wood, dried dung, and other combustible materials for fuel. The domestication of animals, such as horses, oxen, camels etc, also provided a new source of energy for humans, enabling them to transport goods and plow fields for agriculture.

**The Ancient Era**

As civilizations developed, new sources of energy were discovered and harnessed. In ancient Egypt, for example, the Nile River provided a reliable source of water for irrigation and transportation, while the wind was used to power sails on boats and mills for grinding grain. In ancient Greece, water was used to power waterwheels for grinding grain and sawing wood, while slaves and animals were used to provide energy for other tasks.

**The Medieval Era**

During the medieval era, new sources of energy were discovered and harnessed, including wind, water, and animal power. Windmills were used to grind grain and pump water, while waterwheels were used to power mills and other machinery. The use of animal power, such as horses and oxen, also continued, with the development of the horse collar and other innovations improving their efficiency.

**The Industrial Revolution**

The Industrial Revolution, which began in the 18th century, marked a significant turning point in human history, transforming the way we use energy and leading to rapid technological advancements. The invention of the steam engine, for example, allowed for the use of coal as a new source of energy, enabling the development of factories and the mechanization of industry. The use of steam power also enabled the development of new modes of transportation, such as steamships and railways, which revolutionized global trade and travel. In addition, the use of electricity, which was discovered in the 19th century, further transformed the way humans used energy, enabling the development of electric motors and lighting, as well as the creation of new industries, such as electronics and telecommunications.

**The Modern Era**

In the modern era, energy use has continued to grow, driven by increasing population and economic growth. Fossil fuels, such as coal, oil, and natural gas, have become the dominant sources of energy, powering our homes, businesses, and industries. However, the use of fossil fuels has also led to significant environmental problems, such as air pollution and climate change, creating the need for new, sustainable sources of energy.

## 1.6. Indian government policy on solar energy

The Indian government has implemented several policies and initiatives to promote the growth of solar energy in the country. Some of the key policies and initiatives are:

**National Solar Mission:** The National Solar Mission, launched in 2010, aims to promote the development of solar energy in India and achieve a target of 100 GW of solar power capacity by 2022. The mission has several components, including a grid-connected solar power program, off-grid solar applications, and research and development in solar energy.

**Solar Park Scheme:** The Solar Park Scheme was launched in 2014 to promote the development of large-scale solar parks across the country. Under this scheme, the government provides financial support for the development of solar parks, including land acquisition, power evacuation infrastructure, and transmission lines.

**Rooftop Solar Program:** The Rooftop Solar Program was launched in 2015 to promote the installation of solar panels on rooftops of residential, commercial, and industrial buildings. The program provides financial incentives and subsidies for rooftop solar installations.

**Net Metering:** The government has implemented net metering policies to encourage the installation of rooftop solar systems. Under net metering, surplus electricity generated by rooftop solar systems can be fed back into the grid, and consumers receive credit for the excess power generation.

**International Solar Alliance:**

India has played a key role in the formation of the International Solar Alliance, which aims to promote the use of solar energy in developing countries. The alliance has a target of 1,000 GW of solar energy capacity by 2030. The Indian government has implemented a range of policies and initiatives to promote the growth of solar energy in the country. These policies have helped India become a leader in solar energy, with significant growth in solar power capacity in recent years. However, there are still challenges to be addressed, including the need for additional infrastructure and improvements in grid integration.

## 1.7. Solar radiation

Solar radiation is the energy that comes from the sun and is responsible for sustaining life on Earth. Solar radiation includes visible light, ultraviolet (UV) radiation, and infrared (IR) radiation. Understanding the characteristics and behavior of solar radiation is important for many fields, including renewable energy, climate science, and agriculture.

### Properties of Solar Radiation

The properties of solar radiation can be described in terms of its wavelength, frequency, and intensity.

### Wavelength

Solar radiation can be thought of as waves of energy that travel through space. The wavelength of solar radiation refers to the distance between the peaks of these waves. The range of wavelengths in solar radiation is called the solar spectrum. The solar spectrum is divided into several regions based on wavelength, including:

- Ultraviolet (UV) radiation: Wavelengths shorter than 400 nanometers (nm)
- Visible light: Wavelengths between 400 and 700 nm
- Infrared (IR) radiation: Wavelengths longer than 700 nm

### Frequency

The frequency of solar radiation refers to the number of waves that pass a given point in a certain amount of time. The frequency of solar radiation is related to its wavelength through the speed of light, which is a constant value of 299,792,458 meters per second (m/s). The frequency of solar radiation is typically measured in hertz (Hz), which represents the number of waves per second.

### Intensity

The intensity of solar radiation refers to the amount of energy that is carried by the radiation per unit area per unit time. The intensity of solar radiation varies depending on several factors, including the angle of incidence, atmospheric conditions, and time of day. The intensity of solar radiation is typically measured in watts per square meter (W/m2).

### Behavior of Solar Radiation

Solar radiation behaves in different ways depending on its wavelength and the materials it interacts with. Some of the key behaviors of solar radiation include absorption, reflection, transmission, and scattering.

When solar radiation interacts with a material, some of the energy is absorbed by the material. The amount of energy that is absorbed depends on the properties of the material and the wavelength of the radiation. For example, materials that are good absorbers of UV radiation, such as certain types of glass and plastics, can be used to block UV radiation from the sun.

When solar radiation interacts with a surface, some of the energy is reflected back into space. The amount of energy that is reflected depends on the properties of the surface, such as its reflectivity, or albedo. Light-colored surfaces, such as snow and ice, have a high albedo and reflect a large amount of solar radiation back into space, while dark-colored surfaces, such as forests and oceans, have a low albedo and absorb more solar radiation.

When solar radiation passes through a material, such as the atmosphere, some of the energy is transmitted through the material. The amount of energy that is transmitted depends on the properties of the material and the wavelength of the radiation. For example, the atmosphere is transparent to visible light but absorbs certain wavelengths of UV and IR radiation.

When solar radiation interacts with particles in the atmosphere, such as dust and air molecules, some of the energy is scattered in different directions. This can result in changes in the intensity and direction of the radiation. For example, when solar radiation passes through the atmosphere, some of the radiation is scattered in all directions, resulting in a diffuse sky radiation that contributes to daylight illumination.

Solar radiation varies over time and space due to several factors, including the angle of incidence, atmospheric conditions, and time of the day.

## 1.8. Solar shell

Solar shell is a theoretical construct that describes a hypothetical structure that could be built around a star to harness its energy. A solar shell would be a shell-shaped structure that surrounds a star and collects its energy. The structure would be composed of many small solar panels that are connected together to form a large, continuous shell. The solar panels would convert the energy from the star into usable electricity that could be transmitted to other locations in the galaxy. One of the main benefits of a solar shell is its potential to provide a nearly limitless source of energy. A star produces an enormous amount of energy, and a solar shell could capture a significant fraction of that energy and convert it into usable electricity. However, the construction of a solar shell would also have significant environmental and ethical implications. The resources required to build such a structure would be enormous, and the impact on the surrounding environment and ecology could be significant. Despite these challenges, the idea of a solar shell continues to be a topic of interest and debate in the scientific and science fiction communities. The concept raises important questions about the potential of space exploration and the future of energy production, and it highlights the immense challenges and opportunities that lie ahead for humanity in the coming decades and centuries.

The concept of a solar shell is a hypothetical structure that could be built around a star to harness its energy. The idea is based on the principle of a Dyson sphere, which was proposed by physicist Freeman Dyson in 1960. Dyson suggested that a civilization could construct a giant sphere around a star to capture its energy and use it for its own purposes. The idea of a Dyson sphere captured the imagination of many scientists and science fiction writers, and it has since become a popular concept in popular culture. However, the construction of a Dyson sphere is still considered to be purely theoretical, as it would require an enormous amount of resources and energy.

### 1.8.1. Characteristics of solar shell

As a hypothetical structure, a solar shell has not yet been constructed, so its characteristics are mostly speculative. However, there are certain assumptions and predictions that can be made about a solar shell based on the principles of Dyson spheres and existing solar power technologies.

- **Size:** A solar shell would need to be an enormous structure to encase an entire star. Its size would depend on the size of the star, but it could potentially be thousands of kilometers in diameter. The larger the shell, the more energy it could capture.
- **Material:** The material used to construct a solar shell would need to be incredibly strong and resistant to the extreme heat and radiation of the star. Some proposals suggest using a combination of advanced materials, such as carbon nanotubes, graphene, and diamondoids, to create a structure that can withstand the intense environment.
- **Solar panels:** A solar shell would be covered in solar panels designed to capture the energy of the star. These solar panels would need to be highly efficient, able to convert a large percentage of the star's energy into usable electricity.
- **Transmission:** The energy captured by the solar panels would need to be transmitted back to a central point for use or storage. The method of transmission is not yet clear, but some proposals suggest using lasers or other high-powered beams to transmit the energy across vast distances.
- **Environmental considerations:** A solar shell would need to be designed to minimize its impact on the surrounding environment. For example, it would need to be constructed in such a way that it doesn't block the light and heat from reaching other planets in the solar system. It would also need to be designed to avoid collisions with other objects in space.
- **Cost:** Building a solar shell would be an incredibly expensive undertaking, and it would require a significant investment of resources and energy. The cost of constructing a solar shell would depend on the materials used the size of the structure, and the method of construction.

- **Benefits:** Despite the challenges and costs involved in constructing a solar shell, the potential benefits could be significant. A solar shell could provide a nearly limitless source of energy, which could be used to power space exploration missions, support human settlements in space, and provide energy for Earth-based applications.
- It is important to note that a solar shell is still a purely theoretical concept, and it is not yet clear whether it is a feasible or practical solution to the energy needs of humanity. Nonetheless, the idea of a solar shell continues to spark the imagination of scientists and researchers, and it highlights the potential of space-based energy systems to transform the way we think about energy and sustainability.

## 1.9. Solar devices

Solar devices are devices that convert solar energy into usable forms of energy such as electricity, heat, or mechanical power. Solar devices have become increasingly popular over the years due to the growing concern over climate change and the desire to reduce dependence on fossil fuels.

- **Solar Photovoltaic (PV) Panels:** Solar PV panels are the most widely used solar device for generating electricity. These panels are made up of multiple solar cells that convert sunlight into direct current (DC) electricity. The DC electricity is then converted into alternating current (AC) electricity using an inverter, which can be used to power homes, businesses, and other electrical devices.
- **Solar Thermal Collectors:** Solar thermal collectors are used to convert solar radiation into heat. These collectors are typically used for space heating, water heating, and industrial process heat. There are two main types of solar thermal collectors: flat-plate collectors and evacuated tube collectors. Flat-plate collectors are typically used for residential and small commercial applications, while evacuated tube collectors are used for larger commercial and industrial applications.
- **Solar Water Pumps:** Solar water pumps are used to pump water in remote areas where there is no access to grid electricity. These pumps use solar panels to generate electricity, which is then used to power the pump. Solar water pumps are widely used in developing countries to provide access to clean water.

- **Solar Cookers:** Solar cookers are used to cook food using solar energy. These devices are typically made up of a reflective surface (such as a parabolic mirror) that concentrates sunlight onto a cooking pot. Solar cookers are widely used in developing countries where there is limited access to fuel and electricity.
- **Solar Air Conditioners:** Solar air conditioners are used to cool buildings using solar energy. These devices use solar panels to generate electricity, which is then used to power the air conditioner. Solar air conditioners are becoming increasingly popular in regions with high levels of solar radiation.
- **Solar Backpacks and Chargers:** Solar backpacks and chargers are portable devices that allow users to charge their electronic devices using solar energy. These devices typically include a small solar panel and a battery that can be used to store energy for later use.
- These are just a few examples of the types of solar devices that are currently available. As solar technology continues to improve, it is likely that new and more innovative solar devices will be developed to meet the growing demand for clean energy.

### 1.9.1. Limitation of solar devices

While solar devices have many advantages, there are also some limitations to their use. Here are some of the main limitations of solar devices:

- **Dependence on Sunlight:** Solar devices rely on sunlight to generate electricity, heat or other forms of energy. This means that they are only effective during daylight hours and may not work effectively in cloudy or overcast conditions.
- **Initial Cost:** The initial cost of installing solar devices, such as solar panels or solar thermal systems, can be high. While the long-term cost savings can be significant, the upfront cost may be a barrier for some people.
- **Maintenance:** Solar devices require regular maintenance to ensure that they are working effectively. This may include cleaning the solar panels, replacing batteries, and checking the system for any damage or malfunctions.
- **Space Requirements:** Solar panels require a large area of space to generate significant amounts of electricity. This can be a limitation in urban areas where space is limited.
- **Energy Storage:** Solar devices generate energy when the sun is shining, but this energy needs to be stored for use when the sun is not shining. While batteries can be used to store

energy, they can be expensive and may not be able to store enough energy for extended periods of time.

- **Environmental Concerns:** The production and disposal of solar devices can have environmental impacts. The manufacturing process requires energy and can generate waste, while the disposal of solar panels and batteries can also be a concern.
- **Intermittent Energy Supply:** Solar energy is an intermittent energy source, meaning that it is not available 24/7. This can be a challenge for power grids, which require a consistent supply of energy to meet demand.
- Despite these limitations, solar devices have many advantages and are becoming increasingly popular as a source of clean energy. As technology continues to improve, it is likely that many of these limitations will be addressed, making solar devices an even more attractive option for individuals and businesses looking to reduce their carbon footprint and energy costs.

### 1.9.2. Why solar device is useful

Solar devices are useful for a number of reasons, including:

- **Clean Energy:** Solar devices generate clean, renewable energy from the sun, which does not produce any harmful emissions or pollutants. This makes solar energy a much cleaner alternative to traditional fossil fuels, which adversely contribute to climate change and air pollution.
- **Cost Savings:** Once installed, solar devices can provide significant cost savings on energy bills, as they generate free energy from the sun. While there may be some upfront costs associated with installation, the long-term savings can be significant.
- **Energy Independence:** Solar devices provide a source of energy that is independent of the grid, which can be especially useful in remote areas or during power outages.
- **Versatility:** Solar devices can be used in a variety of applications, from powering homes and businesses to providing electricity for outdoor lighting or powering remote sensors.
- **Low Maintenance:** Solar devices require very little maintenance, as they have no moving parts and are designed to last for many years. This makes them a cost-effective and low-maintenance option for generating energy.

- **Government Incentives**: Many governments offer incentives, such as tax credits or rebates, to encourage the installation of solar devices. This can make them an even more cost-effective option for individuals and businesses.

Overall, solar devices are a useful and increasingly popular option for generating clean, renewable energy. As technology continues to improve and costs continue to decrease, it is likely that solar devices will become an even more attractive option for individuals and businesses looking to reduce their carbon footprint and energy costs.

## 1.10. Status of solar energy in India

India has made significant strides in the development and adoption of solar energy in recent years. The country is blessed with abundant sunshine, making it an ideal location for solar energy projects. In this article, we will explore the status of solar energy in India, including its current capacity, government policies, challenges, and future outlook.

**Current Capacity of Solar Energy in India:**

India has emerged as one of the world's largest and fastest-growing markets for solar energy. According to the Ministry of New and Renewable Energy, as of February 2022, the total installed solar capacity in India stood at 53.17 GW. Of this, 38.89 GW is grid-connected, and 14.28 GW is off-grid. This represents a significant increase from just 2.63 GW of installed solar capacity in 2014.

The majority of India's solar capacity comes from large-scale solar parks, which are being developed by both private and public entities. As of February 2022, India had 48 solar parks with a total capacity of 42.7 GW. The largest of these is the Pavagada Solar Park in Karnataka, which has a capacity of 2.05 GW.

**Government Policies Supporting Solar Energy:**

The Indian government has taken several measures to promote the adoption of solar energy in the country. One of the most significant is the Jawaharlal Nehru National Solar Mission (JNNSM), launched in 2010, which aims to achieve 100 GW of solar capacity by 2022. The mission has two main components: grid-connected solar power and off-grid solar applications. The grid-connected component aims to achieve 60 GW of solar capacity by 2022, while the off-grid component aims to achieve 40 GW.

The ISA was formed with the aim to promote solar energy in 121 member countries and to mobilise over $ 1 trillion of investment for development of solar energy at affordable cost. It is the first intergovernmental organization regard solar energy head quatered in India in Gurugram.

In climate adaptation submit 2021, Indian PM raised the importance of "globalised climate partnership" like International Solar Alliance (ISA) and thus pledged to follow Paris Agreement.

The government has also introduced several financial incentives to support the development of solar energy in India. These include a capital subsidy for solar projects, tax exemptions for solar equipment, and low-interest loans for renewable energy projects. In addition, the government has launched several schemes to promote the adoption of solar energy, such as the Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM) scheme, which aims to install 25.75 GW of solar pumps by 2022.

**Challenges Facing Solar Energy in India:**

Despite the significant progress made in the adoption of solar energy in India, there are still several challenges that need to be addressed. One of the main challenges is the high cost of solar energy compared to conventional sources of energy. While the cost of solar energy has decreased significantly in recent years, it still remains higher than the cost of coal-based power. This has led to concerns about the affordability and financial viability of solar projects. Another challenge facing solar energy in India is the lack of adequate infrastructure to support the growth of the sector. This includes the lack of sufficient transmission and distribution infrastructure, as well as the need for improvements in energy storage technology to address the intermittent nature of solar power.

## 1.11. Solar energy consumption

Solar energy consumption has been increasing rapidly around the world in recent years, as countries seek to transition to cleaner, more sustainable sources of energy. India is one of the countries that have been expanding its solar energy consumption, but it still lags behind many other countries in terms of total solar energy consumption. According to the International Energy Agency (IEA), the top five countries in terms of solar energy consumption in 2020 were China, the United States, Japan, Germany, and India. China was by far the largest consumer of solar energy, accounting for around 40% of global solar energy consumption in 2020. The United States was the second largest consumer, accounting for around 15% of global solar energy consumption.

India's solar energy consumption has been increasing rapidly in recent years, but it still accounts for a relatively small share of the global total. According to the IEA, India's solar energy consumption in 2020 was around 47 TWh, or around 3% of global solar energy consumption. This represents a significant increase from just a few years ago, when India's solar energy consumption was much lower. However, India has set ambitious targets for expanding its solar energy consumption in the coming years. The government has set a target of installing 100 GW of solar power capacity by 2022, which would make India one of the largest solar energy markets in the world. In addition, the government has set a target of reaching 450 GW of renewable energy capacity by 2030, including 280 GW of solar power capacity. Other countries around the world are also expanding their solar energy consumption.

In Europe, Germany has been a leader in solar energy consumption, with around 8% of its total electricity generation coming from solar energy in 2020. Other European countries such as Spain, Italy, and France have also been expanding their solar energy capacity in recent years. In Latin America, countries such as Brazil, Mexico, and Chile have been expanding their solar energy capacity, while in Africa, countries such as Morocco, Egypt, and South Africa are investing in solar energy as a way to meet their growing energy needs.

## 1.12. Summary

Solar energy is a form of renewable energy that is derived from the sun's rays. It is a clean and sustainable source of energy that can be harnessed through a variety of technologies and devices, such as solar panels and solar cells. Solar devices are designed to capture and convert solar energy into usable forms of energy, such as electricity or heat. There are many different types of solar devices, including solar panels, solar water heaters, and solar cookers, among others. Solar devices are often used in remote areas where there is no access to grid electricity, as well as in urban areas to supplement traditional sources of energy. The use of solar energy has many advantages, including its sustainability, its low environmental impact, and its potential to provide energy security and independence. However, there are also some limitations to solar energy, including its variability and intermittency, as well as its dependence on weather conditions and the availability of sunlight. In recent years, there has been a significant increase in the use of solar energy around the world, with many countries investing in solar energy as a way to reduce their dependence on fossil fuels and combat climate change. India, in particular, has been expanding its solar energy capacity in recent years, with ambitious targets for solar energy installation in the coming years.

## 1.13. Terminal questions

**Q.1.** What is energy? Discuss the different types of energy source.

**Answer**:------------------------------------------------------------------------------------------------

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**Q.2.** How sun is the only source of energy? Explain it.

**Answer**:------------------------------------------------------------------------------------------------

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**Q.3.** Discuss solar radiation. Also discuss the factor that affected solar radiation.

**Answer**:------------------------------------------------------------------------------------------------

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**Q.4.** Discuss the energy used as historical perspectives.

**Answer**:------------------------------------------------------------------------------------------------

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**Q.5.** What are solar shells? Discuss the characteristic of solar shells.

**Answer**:------------------------------------------------------------------------------------------------

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**Q.6.** Why should we use solar energy? Discuss the status of solar energy in India.

**Answer**:------------------------------------------------------------------------------------------------

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## 1.14. Further suggested readings


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3. Mahmood Zohoori, Advantages and Disadvantages of Green Technology; Goals, Challenges and Strengths, International Journal of Science and Engineering Applications, ISSN-2319-7560
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## Unit-2: Fossil Fuel

***Contents***

## 2.1. Introduction

Fossil fuels are non-renewable energy sources that are formed from the remains of plants and animals that died millions of years ago. Ancient sun-shine has become trapped in various forms of fissile fuels. The three main types of fossil fuels are coal, oil, and natural gas, and they are used to power most of the world's electricity generation, transportation, and industrial processes. Coal is formed from the remains of past plants that lived millions of years ago in swamps and bogs. Over time, the plant material was buried and compressed under layers of sediment, which caused it to undergo chemical and physical changes that transformed it into coal. Oil is formed from the remains of tiny marine plants and animals that lived in the ocean millions of years ago. When these organisms died, their remains sank to the bottom of the ocean and were covered by sediment. Over the time, the pressure and heat from the earth's crust transformed these remains into crude oil. Natural gas is also formed from the remains of ancient plants and animals, but it is created under different conditions than oil. Natural gas is typically found in underground rock formations, and it is formed when organic material is heated and pressurized over long period of time. Fossil fuels are finite resources, meaning that they will eventually run out. Additionally, their combustion releases carbon dioxide and other greenhouse gases into the atmosphere, contributing to climate change. Particularly due to global warming, as a result, there is increasing interest in finding alternative sources of energy that are renewable and sustainable.

**Objectives:**

- To discuss the fossil fuels and its utility
- To discuss coal and its types in India
- To discuss diesel fuel and crude oil
- To discuss the net and gross calorific values of different fuels

## 2.2. Fossil fuel Overview

Today, fossil fuels remain the dominant source of energy worldwide, accounting for over 80% of global energy consumption. However, concerns about the environmental impact of fossil fuels, particularly their contribution to climate change, have led to increased efforts to transition to renewable energy sources. The use of fossil fuels dates back to ancient times, with evidence of coal being used for heating and cooking in China as early as the 4th century BCE. However, the widespread use of fossil fuels did not begin until the Industrial Revolution in the late 18th and early 19th centuries. During this period, the demand for energy to power factories, transportation, and other industrial processes grew rapidly. Coal became the primary source of energy, and its use expanded throughout Europe and North America. The discovery of oil in the mid-19th century further accelerated the use of fossil fuels, and by the early 20th century, oil had become the dominant energy source. In the 20th century, the demand for fossil fuels continued to increase, particularly with the rise of automobiles and air travel. The development of new extraction techniques, such as hydraulic fracturing (fracking) for natural gas and oil sands for crude oil, also expanded the availability of fossil fuels.


Fossil fuels are formed from the remains of ancient plants and animals that died millions of years ago. The fossil fuels are found in deposits around the world, with some countries having larger reserves than others e.g. Middle East countries. The extraction and processing of fossil fuels can be expensive and challenging, particularly for resources located in remote or difficult-to-access areas. Coal and Oil presenting in virgin areas is possible by using paleolimnological indexing and stratigraphic correlation of rocks.

The three main types of fossil fuels and their sources are:

a) **Coal:** Coal is formed from the remains of plants that grew in swamps and bogs millions of years ago. Major Coal reservoirs are found in rocks of Carboniferous Period. Over time, the plant material was buried and compressed under layers of sediment, which caused it to undergo chemical and physical changes that transformed

b) **Oil:** Oil is formed from the remains of tiny prehistoric marine plants and animals that lived in the ocean. When these organisms died, their remains sank to the bottom of the ocean and were covered by sediment. Over the time, the pressure and heat from the earth's crust transformed these remains into crude oil.

c) **Natural gas**: Natural gas is also formed from the remains of ancient plants and animals, but it is created under different conditions than oil. Natural gas is typically found in underground rock formations, and it is formed when organic material is heated and pressurized over large geological period.

**The characteristics of fossil fuels are such as**

1. Fossil fuels are finite resources, which mean that they are not replenished naturally over time. They are formed from the remains of ancient plants and animals that took millions of years to form.
2. It has a high energy density, meaning that they contain a lot of energy in a relatively small amount of material. This makes them efficient for transportation and electricity generation.
3. They are primarily made up of carbon and hydrocarbons, which are compounds made up of carbon and hydrogen. When fossil fuels are burned, they release carbon dioxide and other greenhouse gases into the atmosphere, contributing to climate change.
4. The quality of fossil fuels can vary depending on factors such as their age, composition, and location. This can affect their energy content, as well as their suitability for different applications.
5. Fossil fuels can have significant environmental impacts, both in terms of their extraction and their use. Extraction techniques such as fracking can cause environmental damage, while the combustion of fossil fuels contributes to air pollution and climate change.
6. Fossil fuels are a major part of the global economy, with many countries relying heavily on their export and use. The price of fossil fuels can also have significant economic impacts, with fluctuations affecting industries such as transportation, manufacturing, and agriculture.

### 2.2.1. Physical properties of fossil fuels

The physical properties of fossil fuels can vary depending on their composition and sources. The physical properties of fossil fuels include their melting and boiling points, which can affect their processing and transportation. Fossil fuels also have different densities, which can affect their storage and handling. Finally, fossil fuels can contain various contaminants such as ash, sulfur, and heavy metals, which can affect their combustion and emissions. There are some general characteristics of fossil fuels such as:

**a) Coal**

Coal is a solid fuel that ranges in color from black to brown. It has a high carbon content, typically ranging from 45% to 90%, and a high energy density. Coal also contains various impurities such as sulfur, nitrogen, and trace metals, which can contribute to air pollution when the coal is burned. Coal has a relatively high density, ranging from 1.1 to 1.5 grams per cubic centimeter (g/cm3), depending on the type of coal. The density of coal can affect its handling and transportation. Coal is a relatively soft mineral with hardness on Moh's scale ranging from 1 to 2.5. However, higher rank coals tend to be harder than lower rank coals. Coal is a porous material, with pore spaces that can range in size from nanometers to millimeters. The porosity of coal can affect its storage and handling, as well as its susceptibility to moisture.

Coal is a porous material, with pore spaces that can range in size from nanometers to millimeters. The porosity of coal can affect its storage and handling, as well as its susceptibility to moisture. Coal can contain various minerals and other inorganic materials that are left behind when the coal is burned. The ash content of coal can range from a few percent to more than 50%. Coal contains volatile hydrocarbons that can vaporize during combustion. The volatile matter content of coal can affect its combustion characteristics and emissions.

**b) Fuel Oil**

Fuel Oil is a liquid fuel that ranges in color from light yellow to black. It has a lower carbon content than coal, typically ranging from 83% to 87%, and a high energy density. Different types of oil can vary in viscosity and volatility, which can affect their suitability for different applications.

- Fuel oils have a relatively high density compared to other liquid fuels such as gasoline and diesel. This means that they are heavier and more viscous, which can affect their flow properties and make them more difficult to handle and transport.

- The viscosity of fuel oils refers to their resistance to flow. Fuel oils have a relatively high viscosity, which can make them difficult to pump and burn efficiently. The viscosity of fuel oils is usually measured in centistokes (cSt) or Saybolt Universal Seconds (SUS).
- The flash point of a fuel oil is the temperature at which it gives off enough vapor to ignite when exposed to a spark or flame. Fuel oils have relatively high flash points, which mean they are less volatile and less likely to ignite than other liquid fuels.
- The pour point of a fuel oil is the temperature at which it becomes too thick to flow. Fuel oils have relatively high pour points, which can make them more difficult to handle and transport in colder climates.
- The heating value of a fuel oil is the amount of heat that is produced when it is burned. Fuel oils have a high heating value, which makes them an efficient source of energy for heating and powering various types of machinery. The heating value of fuel oils is usually measured in British thermal units (BTUs) per gallon or per pound

**c) Natural gas**

Natural gas is a gaseous fuel that is primarily composed of methane ($CH_4$). It has a low carbon content, typically ranging from 70% to 90%, and a high energy density. Natural gas can also contain other hydrocarbons such as ethane, propane, and butane, as well as impurities such as nitrogen ($N_2$), carbon dioxide ($CO_2$), and hydrogen sulfide ($H_2S_2$).

- Natural gas is less dense than air and has a density of around 0.7 kg/m^3 at standard temperature and pressure (STP). This means that it tends to rise and disperse in the atmosphere when released.
- The boiling point of natural gas is -162°C (-260°F). This means that it remains in the gaseous state at normal temperatures and pressures.
- Natural gas is highly flammable and can ignite at relatively low temperatures. Its flammability range is between 5% and 15% in air.
- Natural gas is odorless, but an odorant (typically mercaptan) is added to it for safety purposes. The odorant gives natural gas a distinct, unpleasant smell, which allows people to detect leaks and take appropriate action.
- The heating value of natural gas is high, which makes it an efficient source of energy. The heating value of natural gas is usually measured in British thermal units (BTUs) per cubic foot or per cubic meter.

- Natural gas is highly compressible, which means that it can be compressed to a much smaller volume than its original state. This property makes it easier to store and transport natural gas over long distances through pipelines and other infrastructure.

### 2.2.2. Chemical properties of fossil fuels

Fossil fuels are hydrocarbons that formed from the remains of plants and animals that died millions of years ago. The three main types of fossil fuels are coal, oil, and natural gas.

**a) Coal**

Coal is primarily composed of carbon, along with small amounts of hydrogen, sulfur, oxygen, and nitrogen, as well as trace elements such as arsenic, mercury, and selenium. The chemical properties of coal are determined by its composition, and some of the most important properties include:

- Coal has a high calorific value, which means that it contains a large amount of energy per unit of weight. The calorific value of coal is typically measured in British thermal units (BTUs) per pound or per ton.
- Coal is reactive and can undergo a range of chemical reactions under different conditions. For example, coal can react with oxygen to form carbon dioxide and water vapor, or with sulfur to form sulfur dioxide.
- Coal has varying degrees of volatility depending on its composition. Volatility refers to the ability of a substance to vaporize or evaporate at a given temperature. High-volatile coal releases more gases when heated, while low-volatile coal releases fewer gases.
- Coal contains varying amounts of ash, which is composed of inorganic minerals such as silica, alumina, and iron. The ash content of coal can affect its combustion properties, such as the temperature at which it burns and the amount of heat that it produces.
- Coal can contain varying amounts of sulfur, which can contribute to environmental pollution when burned. Sulfur in coal can react with oxygen to form sulfur dioxide, which can contribute to acid rain and other forms of air pollution.
- The carbon content of coal is an important factor in determining its quality and heating value. Coal with higher carbon content generally has a higher heating value and burns more efficiently.

**Fuel oils**

Fuel oils are derived from crude oil and are primarily composed of hydrocarbons, with small amounts of other elements such as sulfur, nitrogen, and oxygen. The chemical properties of fuel oils can vary depending on their composition and grade, but some of the most important properties include:

- The carbon content of fuel oils is an important factor in determining their heating value and efficiency. Higher carbon content generally leads to a higher heating value and better combustion properties.
- Fuel oils contain varying amounts of sulfur, which can contribute to environmental pollution when burned. Sulfur in fuel oils can react with oxygen to form sulfur dioxide, which can contribute to acid rain and other forms of air pollution.
- Fuel oils contain small amounts of inorganic materials, such as ash, which can affect their combustion properties. Higher ash content can lead to greater amounts of residue and can increase the risk of fouling or corrosion in equipment.
- The viscosity of fuel oils refers to their resistance to flow. Fuel oils have a relatively high viscosity, which can make them difficult to pump and burn efficiently. The viscosity of fuel oils is usually measured in centistokes (cSt) or Saybolt Universal Seconds (SUS).
- The flash point of a fuel oil is the temperature at which it gives off enough vapor to ignite when exposed to a spark or flame. Fuel oils have a relatively high flash point, which means they are less volatile and less likely to ignite than other liquid fuels.
- Fuel oils have a relatively high density compared to other liquid fuels such as gasoline and diesel. This means that they are heavier and more viscous, which can affect their flow properties and make them more difficult to handle and transport.

**Natural Gas**

Natural gas is primarily composed of methane, with smaller amounts of other hydrocarbon gases such as ethane, propane, and butane. The chemical properties of natural gas are determined by its composition, and some of the most important properties include:

- Natural gas is highly flammable and burns cleanly, with very low emissions of sulfur dioxide and other pollutants. When burned, natural gas reacts with oxygen to produce carbon dioxide and water vapor.

- The methane content of natural gas is an important factor in determining its quality and heating value. Higher methane content generally leads to a higher heating value and better combustion properties.
- Natural gas can contain small amounts of impurities, such as sulfur, carbon dioxide, and nitrogen, which can affect its properties and combustion efficiency. Impurities can also contribute to corrosion and other forms of equipment damage.
- Natural gas is less dense than air and has a density of around 0.7 $kg/Sm^3$ at standard temperature and pressure (STP). This means that it tends to rise and disperse in the atmosphere when released.
- Natural gas is odorless, but an odorant (typically mercaptan) is added to it for safety purposes. The odorant gives natural gas a distinct, unpleasant smell, which allows people to detect leaks and take appropriate action.
- Natural gas is highly compressible, which means that it can be compressed to a much smaller volume than its original state. This property makes it easier to store and transport natural gas over long distances through pipelines and other infrastructure.

## 2.3. Coal

Coal mining is a major industry in India, with the country ranking as the third-largest coal producer in the world after China and the United States. Coal mining in India is mainly concentrated in the eastern and central regions of the country, with the states of Jharkhand, Odisha, Chhattisgarh, and West Bengal accounting for the majority of coal production.

The history of coal mining in India can be traced back to the early 19th century, with the first coal mines being established in the Raniganj coalfield in West Bengal. Since then, the coal mining industry in India has grown significantly, with the adoption of modern mining methods and the establishment of large coal mining companies such as Coal India Limited, which is the largest coal producing company in the world.

### 2.3.1. Types of coal in India

India's coal reserves are mainly located in the eastern and central parts of the country, with the states of Jharkhand, Odisha, Chhattisgarh, and West Bengal accounting for the majority of coal production. Some mines are also present in Tamil Nadu, Rajasthan and Jammu and Kashmir and Kerala. The quality of coal varies widely across different regions and mines in India, with some mines producing high-quality anthracite and bituminous coal, while others produce lower-quality sub-bituminous and lignite coal. India has a rich history of coal mining and is one of the largest coal producers in the world. The types of coal found in India can be broadly classified into four categories based on their rank and composition:

**Anthracite coal:** Anthracite coal is the highest rank of coal and is characterized by its high carbon content, low volatile matter, and high energy density. It is generally found in small quantities in India, primarily in the Jammu and Kashmir region.

**Bituminous coal:** Bituminous coal is the most common type of coal found in India and is used for a wide range of applications, including power generation, steel production, and cement manufacturing. It has high carbon content, moderate to high volatile matter, and a medium energy density.

**Sub-bituminous coal:** Sub-bituminous coal is a lower rank coal with a lower carbon content and higher moisture content than bituminous coal. It is typically found in the northeastern and eastern regions of India and is used primarily for power generation.

**Lignite coal**: Lignite coal is the lowest rank of coal and has a high moisture content and low carbon content. It is typically found in the southern and western regions of India Tamil Nadu, Rajasthan is used primarily for power generation.

### 2.3.2. Role of coal in energy production in India

Coal plays a significant role in energy production in India, accounting for the majority of the country's electricity generation. India has a large reserve of coal and is the world's third-largest producer of coal after China and the United States. Coal is used for power generation, steel production, cement manufacturing, and other industrial processes. In India, about 70% of the electricity is generated from coal-fired power plants. According to the Central Electricity Authority (CEA), as of March 2021, the installed capacity of coal-based power plants in India was about 198,995 MW, which accounted for about 54.8% of the total installed power capacity in the country. However, the share of coal in electricity generation is expected to decline in the coming years as the government focuses on increasing the share of renewable energy in the country's energy mix. Coal-based power plants in India are facing several challenges, including issues related to air pollution and the impact of coal mining on the environment and local communities. The Indian government has taken several measures to address these issues, including the introduction of stricter emission norms for power plants, the promotion of clean coal technologies, and the expansion of renewable energy sources.

## 2.4. Liquid fuel energy

Liquid fuels are a type of energy source that are derived from crude oil, natural gas, coal, or other organic materials. They are used extensively in transportation, as they are easy to store and transport, and can be burned efficiently in engines to produce energy. The most common types of liquid fuels are gasoline, diesel, and jet fuel.

### 2.4.1. Types of liquid fuel

There are various types of liquid fuels, but the most common ones are:

- **Gasoline:** Gasoline is a fuel made from crude oil and is commonly used in cars, motorcycles, boats, and small engines. It is a volatile, flammable liquid that is highly combustible and produces a large amount of energy when burned.
- **Diesel fuel:** Diesel fuel is also made from crude oil, but is denser and less volatile than gasoline. It is commonly used in trucks, buses, trains, and some cars. Diesel engines are generally more efficient than gasoline engines and produce less carbon monoxide, but more nitrogen oxides and particulate matter.
- **Jet fuel:** Jet fuel is a specialized type of liquid fuel that is used to power jet engines in airplanes. It is similar in composition to diesel fuel, but has a higher energy density and lower freezing point.
- **Biofuels**: Biofuels are liquid fuels that are derived from biomass, such as plants and waste materials. They can be produced from a variety of feed stocks, including corn, sugarcane, and algae, and can be used in place of traditional liquid fuels. Biodiesel production is gradually becoming common.
- **Kerosene:** Kerosene is a light, refined fuel that is commonly used as a heating fuel and as a fuel for lamps and stoves. It is similar in composition to jet fuel, but has a lower energy density.

- **Propane:** Propane is a liquid fuel that is commonly used for heating, cooking, and transportation.

### 2.4.2. Physical properties of liquid fuel

- The physical properties of liquid fuels can vary depending on the specific type of fuel, but some common properties include:
- Liquid fuels have a higher density than gases, which means that they are more compact and have a higher energy density per unit volume
- Viscosity is a measure of a fluid's resistance to flow. Liquid fuels generally have a higher viscosity than water, which can affect their performance in engines.
- The flash point is the lowest temperature at which a liquid can produce enough vapor to ignite in air. This property is important for safety considerations when handling and storing liquid fuels.
- The boiling point is the temperature at which a liquid turns into a gas. This property can affect the ease of evaporation and combustion of liquid fuels.
- The freezing point is the temperature at which a liquid turns into a solid. This property can affect the storage and transport of liquid fuels in colder climates.
- The energy content of liquid fuels is measured in units of energy per unit volume or mass, and can vary depending on the specific type of fuel. This property determines the amount of energy that can be extracted from the fuel through combustion.

### 2.4.3. Chemical properties of liquid fuel

- The chemical properties of liquid fuels can vary depending on the specific type of fuel, but some common properties include:
- Liquid fuels are typically composed of hydrocarbons, which are molecules made up of carbon and hydrogen atoms. The specific composition of hydrocarbons in a liquid fuel can affect its properties and performance.
- Liquid fuels undergo combustion when they react with oxygen to release energy in the form of heat and light. The combustion process produces carbon dioxide, water vapor, and other gases as byproducts.

- The energy content of a liquid fuel is determined by its chemical composition and can be measured in units of energy per unit volume or mass.
- The stability of a liquid fuel refers to its ability to resist chemical reactions and degradation over time. Factors such as exposure to air, light, and heat can affect the stability of a liquid fuel.
- Liquid fuels can be corrosive to certain materials, such as metals, and can cause damage to engines and storage tanks if not properly handled and stored.
- The combustion of liquid fuels releases carbon dioxide and other greenhouse gases, which contribute to climate change. Liquid fuels can also produce air pollution and can have negative impacts on human health and the environment.

## 2.5. Gasoline

Gasoline is a liquid fuel that is derived from petroleum and used primarily in internal combustion engines to power vehicles and equipment. Gasoline, also known as petrol, is a clear, volatile liquid that is used mainly as a fuel for internal combustion engines in cars and motorcycles. It is a mixture of hydrocarbons that are obtained from crude oil through refining. Gasoline has a high energy density, which means that it can produce a large amount of energy per unit volume. However, it is also a major source of air pollution, as its combustion produces carbon monoxide, nitrogen oxides, and other harmful emissions. The first practical use of gasoline as a fuel came in 1862, when the French engineer Etienne Lenoir developed an internal combustion engine that ran on a mixture of coal, gas and air. This engine was later modified to run on gasoline, and became the first commercially successful internal combustion engine. In the late 19th century, the development of the automobile spurred demand for gasoline as a fuel. In 1876, the German inventor Nikolaus Otto developed a four-stroke engine that was more efficient and reliable than previous designs, and in 1885, Karl Benz produced the first automobile powered by an internal combustion engine. The widespread adoption of the automobile in the early 20th century led to a boom in gasoline production and consumption, and fuelled the growth of the petroleum industry. The early production of gasoline was a crude and inefficient process, with little understanding of the chemical composition and properties of petroleum. In the early years of the petroleum industry, gasoline was produced as a byproduct of kerosene refining, and was largely discarded or sold as a low-value product. However, as demand for gasoline grew in the early 20th century, refineries began to focus on maximizing gasoline production and improving the quality of the fuel. The refining process for gasoline involves the separation of hydrocarbons from crude oil and the removal of impurities such as sulfur, nitrogen, and metals. This process is accomplished through a series of distillation, cracking, and reforming steps, which break down the complex molecules in crude oil into simpler compounds that are suitable for use as fuel. The resulting gasoline is a mixture of hydrocarbons with varying properties and energy content, depending on the specific refining process and the quality of the crude oil used.

### 2.5.1. Sources of gasoline

Gasoline is primarily derived from crude oil, a naturally occurring fossil fuel. Crude oil is extracted from underground reservoirs using drilling rigs and is transported to refineries for processing. The refining process involves several steps, including distillation, cracking, and blending, to produce gasoline and other products such as diesel fuel, jet fuel, and lubricants. There are also alternative sources of gasoline that are being developed, including biofuels and synthetic fuels. Biofuels are derived from renewable sources such as corn, sugarcane, or algae, and can be blended with traditional gasoline to reduce emissions. Synthetic fuels, also known as e-fuels, are produced using renewable energy sources such as wind or solar power to electrolyze water and generate hydrogen, which is then combined with carbon dioxide to produce a liquid fuel.

### 2.5.2. Types of gasoline

Gasoline can be broadly categorized into two types based on their octane rating: Regular and Premium gasoline.

i. **Regular Gasoline:** Regular gasoline typically has an octane rating of around 87-88. It is the most commonly used type of gasoline and is suitable for most cars and trucks that do not require higher-octane fuel. Regular gasoline is less expensive than premium gasoline and is widely available at gas stations.

ii. **Premium Gasoline:** Premium gasoline typically has an octane rating of around 91-94. It is designed for high-performance engines that require higher-octane fuel to prevent engine knocking and achieve optimal performance. Premium gasoline is more expensive than regular gasoline and is typically sold at select gas stations.

### 2.5.3. Chemical composition of gasoline

Gasoline is a complex mixture of hydrocarbons, which are compounds made up of hydrogen and carbon atoms. The exact chemical composition of gasoline can vary depending on the source of crude oil, the refining process, and the addition of other additives. The main components of gasoline include:

- **Paraffins**: These are straight-chain hydrocarbons with a low octane rating. They are typically found in low concentrations in gasoline.
- **Olefins**: These are unsaturated hydrocarbons with a higher octane rating than paraffins. They are typically found in low to moderate concentrations in gasoline
- **Naphthenes:** These are cyclic hydrocarbons that have a moderate to high octane rating. They are typically found in moderate to high concentrations in gasoline.
- **Aromatics:** These are cyclic hydrocarbons that contain a benzene ring. They have a high octane rating and are typically found in high concentrations in gasoline.

In addition to these main components, gasoline may also contain various additives that are added to improve performance and meet regulatory requirements such as:

- **Oxygenates:** These are compounds that contain oxygen, such as ethanol or methanol. They are added to gasoline to improve fuel efficiency and reduce emissions.
- **Detergents**: These are compounds that are added to gasoline to keep engines clean and prevent the buildup of deposits.
- **Corrosion inhibitors:** These are compounds that are added to gasoline to prevent corrosion of engine parts.
- **Anti-icing agents:** These are compounds that are added to aviation gasoline to prevent icing at high altitudes.

## 2.6. Diesel fuel

Diesel fuel, also known as diesel oil, is a type of fuel that is commonly used in diesel engines, which are found in a variety of vehicles and equipment such as trucks, buses, trains, ships, and construction equipment. The history of diesel fuel dates back to the late 19th century, when the German engineer Rudolf Diesel developed the diesel engine and designed it to run on vegetable oil. In 1892, Rudolf Diesel patented his invention of the diesel engine, which was designed to be more efficient than the gasoline engine. Unlike the gasoline engine, which uses spark ignition to ignite the fuel-air mixture, the diesel engine compresses the air inside the cylinder, which causes the air to heat up and ignite the fuel injected into the cylinder. This process, known as compression ignition, results in a higher thermal efficiency and better fuel economy than the gasoline engine. In the early 20th century, refineries began producing diesel fuel from crude oil, which became the primary source of diesel fuel. Diesel fuel has a higher energy density than gasoline, which makes it more efficient and provides better fuel economy. It is also more stable and has a longer shelf life than gasoline, which makes it a preferred fuel for transportation and heavy equipment.

### 2.6.1. Sources of Diesel

Diesel fuel is primarily derived from crude oil, a fossil fuel that is extracted from underground reservoirs using drilling rigs. The crude oil is then transported to refineries for processing, where it undergoes several steps to produce diesel fuel and other petroleum-based products. The refining process begins with the distillation of the crude oil, which separates the different components of the oil based on their boiling points. The heavier components, such as diesel fuel and heating oil, are separated from the lighter components, such as gasoline and jet fuel. In addition to petroleum-based diesel fuel, there are also alternative sources of diesel fuel that are being developed. Biodiesel, for example, is a renewable fuel that is made from vegetable oils, sun flower, Soybean palm oil and Jatropha Curcas, animal fats, or recycled cooking oils. It can be blended with petroleum-based diesel fuel to reduce emissions and improve air quality.

### 2.6.2. Physical properties of diesel

Diesel fuel is a type of liquid fuel that is used in diesel engines, which are commonly found in trucks, buses, trains, and some cars. Here are some of the physical properties of diesel fuel:

i. Diesel fuel is usually light yellow or clear in color, although it can also be green or red depending on the type of dye that is added to it for identification purposes.
ii. The density of diesel fuel is typically around 0.85 grams per milliliter, which means that it is less dense than water.

iii. Diesel fuel is more viscous (thicker) than gasoline, which means that it flows more slowly. The viscosity of diesel fuel is usually measured in centistokes (cSt) and is typically around 2.5 to 4.5 cSt at 40°C.

iv. The flash point of diesel fuel is the temperature at which it gives off enough vapor to ignite in the presence of a spark or flame. The flash point of diesel fuel is typically around 52°C to 96°C.

v. Diesel fuel is a mixture of hydrocarbons with different boiling points. The boiling point of diesel fuel ranges from about 150°C to 380°C.

vi. The pour point of diesel fuel is the temperature at which it becomes too thick to flow. The pour point ( the lower temperature at which the oil will pour or flow when cooled without stirring) of diesel fuel is typically around -15°C to -30°C, depending on the type of diesel fuel and its additives.

vii. The cetane number of diesel fuel is a measure of its ignition quality. The higher the cetane number ( a measurers of quality or performance of fuel) the more easily the fuel ignites. The cetane number of diesel fuel is typically around 40 to 55.

### 2.6.3. Chemical composition of diesel

Diesel fuel is a complex mixture of hydrocarbons that are derived from crude oil through a refining process. The exact chemical composition of diesel fuel can vary depending on the source of the crude oil, the refining process used, and the additives that are added to the fuel. However, most diesel fuels contain the following chemical compounds. The chemical composition of diesel fuel is important to consider in terms of its combustion properties and emissions. The different types and amounts of hydrocarbons, as well as the presence of additives, can affect the fuel's energy content, ignition quality, and emissions of pollutants such as particulate matter, nitrogen oxides, and carbon monoxide.

- **Alkanes:** Diesel fuel is primarily made up of saturated hydrocarbons known as alkanes, which have the general chemical formula $C_nH_2$n+2. The most common alkanes found in diesel fuel are heptane ($C_7H_{16}$), octane ($C_8H_{18}$), and nonane ($C_9H_{20}$).
- **Aromatics:** Diesel fuel also contains a smaller amount of unsaturated hydrocarbons known as aromatics, which have a cyclic structure and are more reactive than alkanes. The most

common aromatics found in diesel fuel are benzene ($C_6H_6$), toluene ($C_7H_8$), and xylene ($C_8H_{10}$).

- **Olefins**: Diesel fuel may also contain some unsaturated hydrocarbons known as olefins, which have a double bond between two carbon atoms. Olefins are less stable than alkanes and can react with other chemicals to form harmful byproducts.
- **Oxygenates:** Some diesel fuels may contain oxygen-containing compounds known as oxygenates, which can improve the fuel's performance and reduce emissions. Common oxygenates found in diesel fuel include alcohols such as methanol ($CH_3OH$) and ethanol ($C2H_5OH$), as well as ethers such as methyl tert-butyl ether (MTBE).

## 2.7. Crude Oil

Crude oil is a complex mixture of hydrocarbons, with its physical properties varying depending on the specific composition of the oil. Many types of crude oil used for energy production, with varying characteristics and properties. Some of the most commonly used types of crude oil are Brent Crude, West Texas Intermediate (WTI) Crude, Dubai Crude, Nigerian Bonny Light Crude, Venezuelan Crude, Canadian Oil Sands and Russian Urals Crude. The choice of crude oil for energy production depends on a variety of factors, including availability, cost, and the specific needs of the end user.

However, some general physical properties of crude oil include

- Crude oil is less dense than water, meaning it floats on top of water. The density of crude oil can vary depending on the specific type of oil, with lighter oils being less dense than heavier oils.
- Crude oil is less dense than water, meaning it floats on top of water. The density of crude oil can vary depending on the specific type of oil, with lighter oils being less dense than heavier oils.
- Crude oil can range in color from light yellow to dark brown or black. The color of crude oil can be an indication of its quality or purity.
- The boiling point of crude oil varies depending on the specific type of oil. Crude oil has a boiling point range of about 150 to 350 degrees Celsius.

- The flash point is the lowest temperature at which a liquid gives off enough vapor to ignite in air. The flash point of crude oil can vary depending on the specific type of oil and its composition.
- Crude oil is insoluble in water but can dissolve in other liquids such as alcohol, gasoline, and diesel fuel.
- Crude oil can have a distinct odor, which can vary depending on the specific type of oil and its composition.

**The crude oil has some chemical properties such as**

Crude oil is primarily composed of hydrocarbons, which are compounds made up of carbon and hydrogen atoms. The chemical properties of crude oil are determined by the specific composition of these hydrocarbons, as well as the presence of other elements and compounds.

- The carbon content of crude oil varies depending on the specific type of oil. Generally, crude oil contains between 83 and 87 percent carbon.
- Crude oil contains between 10 and 14 percent hydrogen.
- Sulfur is often present in crude oil in the form of sulfur compounds, such as hydrogen sulfide, mercaptans, and sulfides. The sulfur content of crude oil can range from less than 0.1 percent to over 5 percent.
- Nitrogen is also present in crude oil, often in the form of organic compounds such as amines and amides. The nitrogen content of crude oil is generally less than 1 percent.
- Crude oil also contains small amounts of oxygen, usually less than 1 percent. Oxygen can be present in the form of organic compounds such as alcohols, ketones, and carboxylic acids.
- The density of crude oil can vary depending on the specific type of oil. The density of crude oil is typically measured in degrees API, with higher API values indicating lighter, less dense oils.
- The acid value of crude oil is a measure of the amount of acidic compounds present in the oil, such as carboxylic acids. The acid value can vary depending on the specific type of oil and its composition.

## 2.8. Gaseous fossil fuels

There are different types of natural gas, each with their own unique characteristics and applications. The natural gas used and its application depend on factors such as availability, cost, and regulatory requirements in different regions and industries. Here are some of the most common types of natural gas such as Methane, Ethane, Propane and Butane are mostly for heating, cooking, and electricity generation. In addition, some other natural gases are Liquefied natural gas (LNG), compressed natural gas (CNG) and Hydrogen etc. NG is natural gas that has been converted to a liquid state for ease of transportation and storage. It is used primarily for electricity generation, heating, and as a transportation fuel for ships and trucks. CNG is natural gas that has been compressed to a high pressure for use as a transportation fuel in vehicles such as buses, taxis, and cars. Hydrogen can be produced from natural gas and is used in fuel cells to produce electricity for transportation and other applications

### 2.8.1. Classification of gaseous fossil fuels

Gaseous fossil fuels can be classified into two main categories: natural gas and liquefied petroleum gas (LPG).

#### 2.8.1.1. Natural Gas:

Natural gas has a long history of use as a source of energy, dating back to ancient times when it was used by the Chinese to produce salt. However, it wasn't until the 19th century that natural gas began to be used on a large scale for energy production. Natural gas is a mixture of hydrocarbons, primarily methane, but may also contain small amounts of other gases like ethane, propane, butane, nitrogen, and helium. It is found in underground reservoirs or associated with oil deposits. The first natural gas well was drilled in the United States in 1821, but it wasn't until the 20th century that natural gas became a significant source of energy. With the discovery of large natural gas reserves in the United States, Canada, and other countries, natural gas became an important fuel for heating, cooking, and industrial processes. Today, natural gas is one of the most widely used sources of energy in the world, with a wide range of applications in the residential, commercial, and industrial sectors. It is used for heating homes and buildings, powering industrial processes, generating electricity, and as a fuel for vehicles. Natural gas can be further classified into three types:

1) Associated Gas: Gas found in association with oil deposits.

2) Non-Associated Gas: Gas found in underground reservoirs not associated with oil deposits.
3) Shale Gas: Gas trapped in shale rock formations.

**Sources of natural Gas**

Natural gas is a fossil fuel that is formed deep within the Earth over millions of years. It is typically found in underground reservoirs, often in association with oil deposits. The primary sources of natural gas include:

- ***Conventional natural gas***: This is natural gas that is extracted from underground reservoirs using conventional drilling and production techniques. Conventional natural gas is typically found in porous rock formations, such as sandstone and limestone, and is often associated with oil deposits.
- ***Unconventional natural gas***: This includes natural gas that is found in shale rock formations, coal seams, and tight sandstones. Unconventional natural gas is extracted using techniques such as hydraulic fracturing (fracking) and horizontal drilling.
- ***Associated natural gas:*** This is natural gas that is found in association with oil deposits. When oil is extracted from underground reservoirs, natural gas often comes to the surface along with it.
- ***Non-associated natural gas:*** This is natural gas that is found in underground reservoirs that do not contain oil. Non-associated natural gas is typically found in deeper rock formations than conventional natural gas.

**Physical properties of Natural gas**

- Natural gas is colorless and odorless in its pure form, making it difficult to detect leaks. For safety reasons, a chemical called mercaptan is added to natural gas to give it a distinct odor.
- Natural gas is highly flammable and combustible, meaning it can burn easily when exposed to a spark or flame.
- Natural gas is lighter than air, which means it will rise and disperse quickly if released into the atmosphere
- Natural gas has a low density compared to other fossil fuels, such as oil and coal. This makes it easier to transport and store, as it requires less space.

- Natural gas produces fewer emissions and pollutants than other fossil fuels when burned, making it a cleaner and more environmentally friendly energy source

**Chemical properties of natural Gas**

- Methane ($CH_4$) is the primary component of natural gas, typically making up around 70-90% of the gas. Methane is a colorless, odorless gas that is highly flammable and combustible.
- Ethane ($C_2H_6$) is a hydrocarbon with two carbon atoms and six hydrogen atoms. It is typically present in natural gas in small amounts, usually less than 10%. Ethane is also a colorless, odorless gas that is highly flammable and combustible.
- Propane ($C_3H_8$) is a hydrocarbon with three carbon atoms and eight hydrogen atoms. It is typically present in natural gas in small amounts, usually less than 5%. Propane is a colorless gas that is easily liquefied, making it a popular fuel for heating and cooking.
- Butane ($C_4H_8$) is a hydrocarbon with four carbon atoms and ten hydrogen atoms. It is also present in natural gas in small amounts, usually less than 2%. Butane is a colorless gas that is easily liquefied, and it is commonly used as a fuel for camping stoves and lighters.
- In addition to these hydrocarbons, natural gas can also contain small amounts of non-hydrocarbon gases such as carbon dioxide ($CO_2$), nitrogen ($N_2$), and hydrogen sulfide ($H_2S$). These gases can affect the chemical properties of natural gas, such as its heating value and combustion properties.

**2.8.1.2. Liquefied Petroleum Gas (LPG):**

Liquefied petroleum gas (LPG) has been used as a fuel for over a century, but its popularity has increased in recent decades due to its many advantages as a clean and efficient source of energy. LPG is a mixture of propane and butane gases that are liquefied under pressure. It is produced during the refining of crude oil or extracted from natural gas streams. LPG is stored in tanks and cylinders and is used for heating, cooking, and transportation fuel. LPG was first discovered in 1910 when natural gas was being extracted in the United States. The first LPG plant was established in 1935 in the United States and since then, the production of LPG has grown rapidly. The gas was initially considered a nuisance as it was flammable and caused explosions in the gas fields. It was not until the 1920s that LPG was first produced commercially in the United States, when it was extracted from natural gas and used as a fuel for vehicles.

Today, LPG is produced from natural gas processing and crude oil refining, and is stored and transported in pressurized containers. It is used as a clean and efficient fuel for cooking, heating, and as a transportation fuel for vehicles. LPG has several advantages over other fossil fuels, including. LPG is a clean-burning fuel that produces fewer emissions of harmful pollutants and greenhouse gases compared to other fossil fuels. It is versatile fuel that can be used for a variety of applications, including residential, commercial, and industrial uses. It is readily available in many countries around the world, and is often a more cost-effective fuel compared to other options. LPG is expected to continue to grow in the coming years, as countries around the world seek to reduce their reliance on fossil fuels and transition to cleaner and more sustainable sources of energy. LPG is considered an important component of the energy mix, particularly for developing countries where access to clean and affordable energy is critical for economic development.

In India, LPG is primarily used as a cooking fuel in households. The government of India has implemented various schemes to increase the availability of LPG to households across the country, especially in rural areas. The Pradhan Mantri Ujjwala Yojana is one such scheme that provides free LPG connections to households below the poverty line. The scheme aims to replace traditional fuels such as wood, coal, and kerosene with cleaner and more efficient LPG. LPG plays a crucial role in the energy mix of India, providing clean and efficient energy for various applications. The government and oil companies continue to invest in the development of LPG infrastructure and the promotion of LPG usage to ensure its availability and affordability for all.

**Sources of LPG**

It is extracted from natural gas and crude oil wells and is processed through a refining process to separate it from other hydrocarbons. The refining process involves separating LPG from other gases and hydrocarbons through a process called fractional distillation. Once LPG has been separated, it is transported via pipelines or shipped in specially designed tankers to storage facilities or directly to end-users. In some cases, LPG is also produced from the processing of natural gas liquids (NGLs) in gas fields. LPG is also produced as a byproduct of oil and gas extraction activities. In such cases, the gas is separated from the oil and transported in pipelines or tankers to processing facilities. LPG can also be produced from the processing of natural gas or from the refining of crude oil.

**Types of LPG**

LPG (Liquefied Petroleum Gas) is a generic term used for propane and butane gases, which are commonly used as fuel. There are primarily two types of LPG based on the percentage composition of propane and butane:

- **Propane-based LPG**: This type of LPG is primarily composed of propane gas and is commonly used as a domestic and industrial fuel. Propane has higher energy content than butane and is more suitable for use in cold climates. Propane-based LPG is also used as a fuel for vehicles and in the manufacturing industry.
- **Butane-based LPG:** This type of LPG is primarily composed of butane gas and is commonly used in portable cylinders for camping, outdoor activities, and as a fuel for cooking and heating. Butane has a lower boiling point than propane and is more suitable for use in warm climates. Butane-based LPG is also used in the production of gasoline and as a refrigerant.

**Physical properties of LPG**

- LPG is a colorless, odorless gas in its natural state. However, to aid in detection, a strong odorant (such as ethanethiol) is added to the gas so that leaks can be detected by smell.
- LPG is a mixture of propane and butane gases that are stored under pressure in a liquid state. The boiling point of propane is -42°C, while the boiling point of butane is -0.5°C.
- LPG is lighter than air, with a density of about 1.5 $kg/m^3$ (at 15°C and 1 atm pressure). This means that in the event of a leak, LPG will rise and disperse into the air rather than pooling on the ground.
- LPG is not soluble in water, but it can dissolve in some organic solvents.
- LPG is highly flammable, and can ignite easily when it comes into contact with a spark or open flame. This makes it important to handle LPG with care and store it in a safe location.
- LPG has a high heat content, which makes it an effective fuel for a variety of applications. The heat content of LPG can range from about 46 MJ/kg for propane to 49 MJ/kg for butane.

- LPG is typically stored in pressurized tanks or cylinders, with a pressure of about 7 bar at room temperature.

**Chemical properties in LPG**

LPG (Liquefied Petroleum Gas) is a hydrocarbon gas mixture consisting primarily of propane and butane. Its chemical properties depend on its composition, which can vary depending on the source and the processing methods used.

- Propane, which makes up a significant portion of LPG, is a colorless and odorless gas with the chemical formula $C_3H_8$. It has a boiling point of -42°C (-44°F) and is easily liquefied under moderate pressure. Propane is highly flammable and combustible, making it an excellent source of energy for various applications.
- Butane, which is another component of LPG, has the chemical formula $C_4H_{10}$. It is a colorless and odorless gas with a boiling point of -1°C (30°F) and can also be easily liquefied under moderate pressure. Butane is also highly flammable and combustible, making it a popular choice for fuel in outdoor appliances such as camping stoves and portable heaters.
- LPG is also often treated with various chemicals to give it distinct odor and facilitate detection in case of leaks. Ethyl mercaptan is one such compound that is added to LPG to give it a characteristic odor.

## 2.9. Gross calorific values of different fuels

The approximate calorific values of different fuels are varying and it depending on factors such as the quality of the fuel, the method of production, and the conditions under which it is burned. Additionally, different countries may use different units of measurement for energy, such as British Thermal Units (BTUs) or megajoules (MJ). The approximate calorific values of some common fuels are

- Coal: 5000-7000 kcal/kg
- Diesel: 10,000-11,000 kcal/kg
- Gasoline (petrol): 11,000-12,000 kcal/kg
- LPG (propane): 46,000-50,000 kJ/kg
- Natural gas: 45,000-55,000 kJ/kg
- Biomass (wood, etc.): 3,500-5,500 kcal/kg

- Hydrogen: 120-142 kJ/g
- Ethanol: 29,000-30,000 kJ/kg
- Biodiesel: 37,000-40,000 kJ/kg

## 2.10. Net calorific values of different fuels

The Net calorific values of different fuels are varying and it depending on factors such as the quality of the fuel, the method of production, and the conditions under which it is burned. Additionally, different countries may use different units of measurement for energy, such as British Thermal Units (BTUs) or calories. The Net calorific values of different fuels are

- Coal: 20-28 MJ/kg
- Diesel: 42-45 MJ/kg
- Gasoline (petrol): 42-44 MJ/kg
- LPG (propane): 46.4 MJ/kg
- Natural gas: 45-55 MJ/kg
- Biomass (wood, etc.): 15-19 MJ/kg
- Hydrogen: 120-142 MJ/kg
- Ethanol: 26.4 MJ/kg
- Biodiesel: 36-38 MJ/kg

## 2.11. Oil reservoir and reserve in world

An oil reservoir refers to an underground formation that contains oil or gas in a porous rock, while oil reserves refer to the amount of oil or gas that can be technically and economically extracted from the reservoir. An oil reservoir is typically made up of a porous rock formation, such as sandstone or limestone that has been buried deep beneath the earth's surface. Over the time, oil or gas accumulates in the pore spaces within the rock, forming a reservoir. The size and shape of the reservoir, as well as the properties of the rock, will affect how much oil or gas can be extracted from it. Oil reserves are the estimated amount of oil or gas that can be recovered from a reservoir using current technology and economic conditions. Gas reservoirs are similar to oil reservoirs in that they are both formed by geological processes over millions of years. The gas is typically trapped in porous rock formations that act as a natural storage tank. Like oil reservoirs, gas reservoirs can vary greatly in size, shape, and quality, depending on factors such as the type of rock, the depth of the reservoir, and the pressure and temperature conditions. Gas reserves are typically categorized into three levels: proved, probable, and possible reserves. Proved reserves are those that are highly likely to be recovered using current technology and economic conditions. Probable reserves are less certain, while possible reserves are even less certain and may require additional exploration and testing. The amount of Oil and Gas reserves can change over time, as new technology is developed, economic conditions change, or more accurate estimates are made based on additional data. India has several oil and gas reservoirs, both onshore and offshore. Some of the major oil reserves in India are located in the states of Assam, Gujarat, and Rajasthan. The Mumbai High field, located offshore in the Arabian Sea, is the largest oil field in India and accounts for a significant portion of the country's oil production. As of January 2021, India's total proven oil reserves were estimated to be around 600 million metric tons (MMT), which is equivalent to about 4.4 billion barrels. However, it's important to note that proven reserves refer to the amount of oil that can be extracted using current technology and at current prices, and do not necessarily represent the total amount of oil that exists in a particular region.

According to the BP Statistical Review of World Energy 2021, the world's proved natural gas reserves were 205.4 trillion cubic meters (tcm) at the end of 2020, which is enough to last for 58 years at current production rates. The countries with the largest proved natural gas reserves are:

Russia: 38.8 tcm

Iran: 33.5 tcm

Qatar: 24.7 tcm

United States: 14.9 tcm

Turkmenistan: 9.9 tcm

India : 1.4 tcm

Here are some examples of oil and gas reservoirs and reserves in the world and India:

**World:**

a) **Ghawar Field, Saudi Arabia:** This is the largest oil field in the world and holds an estimated 70 billion barrels of oil.

b) **Kashagan Field, Kazakhstan:** This is one of the largest oil fields discovered in the last 40 years and holds an estimated 13 billion barrels of oil.

c) **Groningen Field, Netherlands:** This is the largest natural gas field in Europe and has produced more than 2,800 billion cubic meters of natural gas.

d) **Saudi Arabia:** Saudi Arabia is the world's largest oil producer and exporter, and has an estimated 266 billion barrels of oil reserves. The oil is mainly located in the Ghawar oil field, the largest oil field in the world.

e) **Canada:** Canada has an estimated 169 billion barrels of oil reserves, mostly located in the oil sands in Alberta. The oil sands contain heavy crude oil that requires specialized extraction techniques.

**India:**

a) **Bombay High, Mumbai:** This offshore oil field was discovered in 1974 and is one of the largest oil fields in India. It has estimated reserves of 1.5 billion barrels of oil and 1.4 trillion cubic feet of natural gas.

b) **Krishna-Godavari Basin, Andhra Pradesh:** This is one of the largest natural gas reserves in India and has estimated reserves of around 11.3 trillion cubic feet of gas.

c) **Barmer Basin, Rajasthan:** This is the largest onshore oil field discovered in India in the last 30 years and has estimated reserves of around 1 billion barrels of oil.

## 2.12. Summary

Fossil fuels are non-renewable energy sources that are formed over millions of years from the remains of dead plants and animals. The three main types of fossil fuels are coal, oil, and natural gas, and they are used extensively in the production of electricity, transportation, heating, and manufacturing. Coal is a solid fuel that is formed from ancient plants that were buried and compressed over millions of years. It is primarily used for electricity generation, and India is one of the largest coal-producing countries in the world. Oil, or petroleum, is a liquid fossil fuel that is formed from the remains of ancient marine organisms. It is primarily used for transportation and heating, and the Middle East is the largest oil-producing region in the world.

Natural gas is a gaseous fossil fuel that is formed from the remains of ancient marine organisms and is primarily composed of methane. It is used for electricity generation, heating, and transportation, and Russia and the United States are the largest natural gas-producing countries in the world. Fossil fuels have been the primary source of energy for human civilization for hundreds of years, but their use has resulted in significant environmental problems, including air pollution, water pollution, and climate change. As a result, there is a growing push to transition to cleaner and more sustainable sources of energy, such as renewable energy sources like solar and wind power.

## 2.13. Terminal questions

**Q.1.** What are the fossil fuels? Discuss different types of fools used as energy sources.

**Answer:**---------------------------------------------------------------------------------------------------

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**Q.2.** What are the Gaseous fossil fuels? Discuss the Classification of gaseous fossil fuels.

**Answer:**---------------------------------------------------------------------------------------------------

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**Q.3.** What is Liquid fuel energy? Discuss the source and properties of liquid fuel energy.

**Answer:**---------------------------------------------------------------------------------------------------

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**Q.4.** What is the Diesel fuel? Discuss the source and chemical composition of diesel.

**Answer:**---------------------------------------------------------------------------------------------------

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**Q.5.** Write the net calorific values of different fuels.

**Answer:**---------------------------------------------------------------------------------------------------

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**Q.6.** Discuss about oil reservoir and reserve in world.

**Answer:**---------------------------------------------------------------------------------------------------

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## 2.14. Further suggested readings


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# Unit-3: Renewable Energy Resources

***Contents***

## 3.1. Introduction

Renewable energy resources are those sources of energy that are replenished naturally and can be used continuously without depleting them. The renewable energy resources can be classified into several categories, including solar, wind, hydroelectric, geothermal, tidal wave and biomass energy. The demand for renewable energy resources has been on the rise in recent years due to concerns about climate change, air pollution, and the depletion of non-renewable energy resources. In this article, we will provide an introduction to renewable energy resources, their types, and the benefits of using them. Solar energy is the most abundant source of energy on the planet. It is derived from the sun and can be converted into electricity using solar panels. The solar panels are made up of photovoltaic (PV) cells that convert sunlight into direct current (DC) electricity. The DC electricity is then converted into alternating current (AC) electricity using an inverter. Wind energy is another renewable energy resource that is generated from the wind. It is harnessed using wind turbines, which are large structures with blades that rotate when the wind blows. The rotation of the blades generates electricity, which is then sent to the grid. Hydroelectric energy is generated from the movement of water. It is harnessed using hydroelectric dams, which are large structures that capture the energy of moving water and convert it into electricity. Geothermal energy is generated from the heat of the earth. It is harnessed using geothermal power plants, which use the steam and hot water from deep underground to generate electricity. Tidal wave energy is used to generate electricity in coastal area. Biomass energy is generated from organic matter such as wood, crops, and waste. It is harnessed using biomass power plants, which burn the organic matter to generate steam, which is then used to generate electricity.

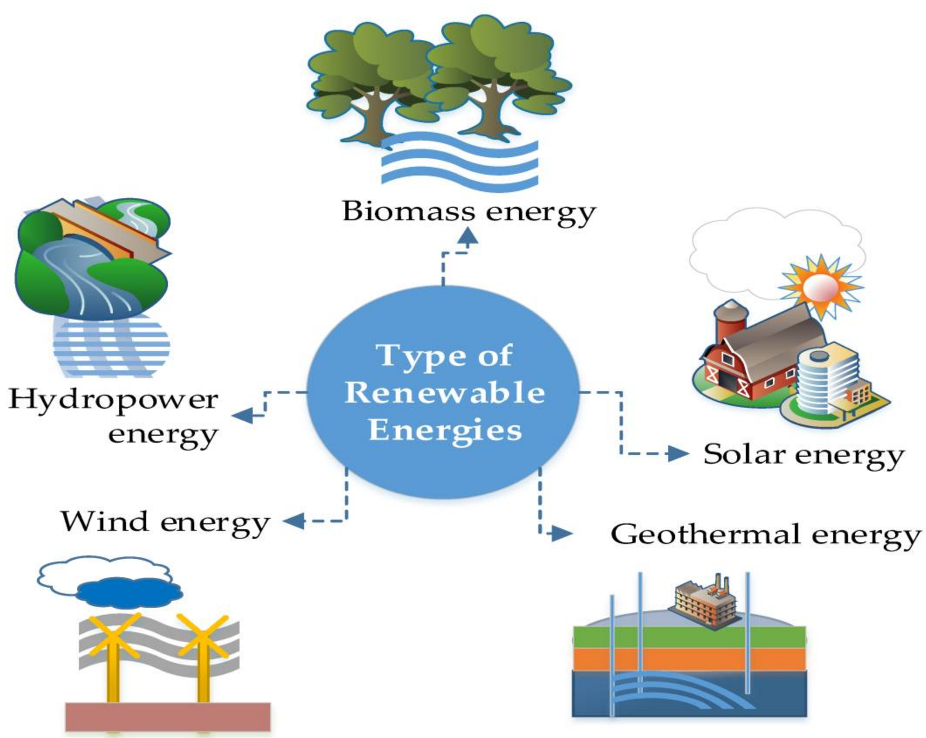
### Objectives

- To discuss renewable sources of energy
- To discuss solar and wind energy and its advantage
- To discuss hydropower energy and its advantage
- To discuss the geothermal energy and current renewable energy scenario of India

## 3.2. Renewable energy resources

The energy resources which are in exhaustible on human scales are called renewable energy resources. The renewable energy resources can be replenished in a short period of time. They are an alternative to fissile fuels and nuclear power. There are several types of renewable energy resources.

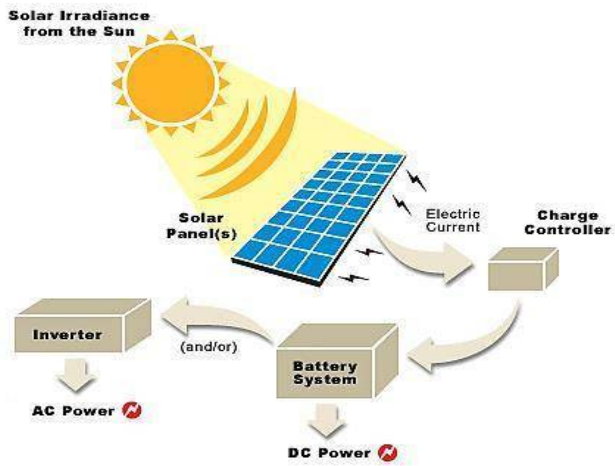
i. Solar energy
ii. Wind energy
iii. Hydropower
iv. Geothermal energy
v. Biomass energy
vi. Hydropower energy
vii. Ocean energy




Each type of renewable energy resource has unique advantages and disadvantages, and the choice of technology depends on the specific application and local conditions. Renewable energy resources are an important part of our energy mix, as they offer a clean, sustainable, and secure source of energy that can help reduce greenhouse gas emissions and mitigate the impacts of climate change. Solar energy is harnessed using photovoltaic (PV) cells, which convert sunlight into electricity, and solar thermal systems, which use mirrors or lenses to focus sunlight and create heat for electricity generation or heating. Wind turbines harness the kinetic energy of the wind and convert it into electricity. Large-scale wind farms can generate significant amounts of electricity and can be located onshore or offshore. Hydropower is generated using the energy of flowing water, such as rivers or waterfalls. The energy is harnessed using turbines to generate electricity. Geothermal energy is generated using the heat of the Earth's core. The heat is harnessed using geothermal power plants, which can generate electricity or provide heating and cooling for buildings. Biomass energy is generated using organic matter such as wood, crops, or waste products. Biomass can be burned to produce heat, or it can be converted into biogas or biofuels for electricity generation or transportation. Ocean energy is harnessed using different technologies such as tidal turbines, wave energy converters, and ocean thermal energy conversion. These technologies harness the energy of ocean currents, tides, waves, and temperature differences to generate electricity.

## 3.3. Concept of Solar energy

Solar energy is a type of renewable energy that is derived from the sun. The sun emits enormous amounts of energy in the form of electromagnetic radiation, which includes visible light, ultraviolet light, and infrared radiation. This energy can be harnessed using a variety of technologies to generate electricity or provide heat for various applications. There are several ways to harness solar energy, but the most common method is through the use of photovoltaic (PV) cells. PV cells are made up of semiconductor materials, usually silicon, which converts sunlight directly into electricity through a process known as the photoelectric effect. When photons of sunlight hit the surface of a PV cell, they knock electrons loose from the atoms in the semiconductor material. These free electrons can then flow through a circuit to generate an electrical current. PV cells are typically assembled into modules, and multiple modules are wired together to form a solar panel. Solar panels can be installed on rooftops or on the ground in large arrays to generate electricity for homes, businesses, or utilities. The electricity generated by solar panels can be used immediately or stored in batteries for use when the sun is not shining. Another way to harness solar energy is through the use of solar thermal systems. These systems use mirrors or lenses to concentrate sunlight onto a small area, creating intense heat that can be used to generate steam to drive a turbine and generate electricity. Solar thermal systems can also be used for heating water or space heating in homes and buildings.




### 3.3.1. Principle of solar energy

The principle of solar energy is based on the fact that the sun emits a vast amount of energy in the form of electromagnetic radiation, including visible light, ultraviolet radiation, and infrared radiation. This energy can be harnessed using various technologies to generate electricity or provide heat for different applications. The most common way to harness solar energy is through the use of photovoltaic (PV) cells, which are made up of semiconductor materials such as silicon. When sunlight falls on a PV cell, the energy from the photons in the sunlight knocks electrons loose from the atoms in the semiconductor material, creating a flow of electricity. Multiple PV cells are connected together to form a solar panel, which can then generate a larger amount of electricity. Another way to harness solar energy is through the use of solar thermal systems. These systems use mirrors or lenses to concentrate sunlight onto a small area, creating intense heat that can be used to generate steam to drive a turbine and generate electricity. Solar thermal systems can also be used for heating water or space heating in homes and buildings.

The principle of solar energy is based on the fact that the sun is a virtually unlimited source of energy that is available for free. Unlike fossil fuels, which are finite resources that are becoming increasingly expensive to extract, solar energy is available everywhere and does not require expensive infrastructure to transport it to where it is needed. Solar energy is also a clean source of energy, as it does not produce greenhouse gas emissions or other pollutants that contribute to climate change and air pollution. In addition to its environmental benefits, solar energy has many practical applications. It can be used to generate electricity for homes, businesses, and utilities, or to power vehicles such as electric cars. It can also be used to heat water or provide space heating in homes and buildings.

### 3.3.2. Types of solar energy technology

There are several types of solar energy technologies that can be used to harness the power of the sun. These technologies include PV solar energy, concentrated solar power, solar water heating, solar air heating, hybrid solar systems, and solar-powered vehicles. Each technology has its unique advantages and disadvantages, and the choice of technology depends on the specific application and local conditions.

**Photovoltaic (PV) Solar Energy**: PV solar energy is the most common type of solar energy technology. It involves the use of solar panels, which are made up of interconnected solar cells. When sunlight falls on a solar panel, the solar cells absorb the energy and convert it into electricity. The electricity can be used immediately or stored in batteries for later use. The main features of PV solar energy include:

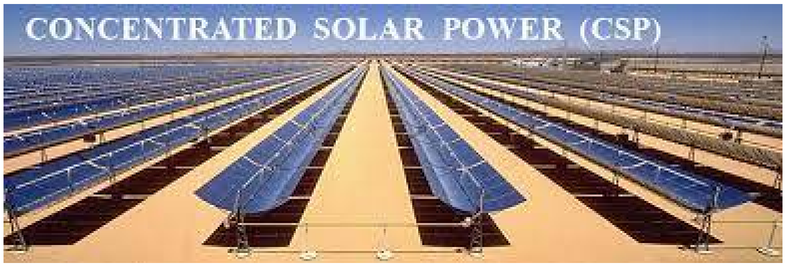
- **Solar panels:** PV solar energy systems typically use solar panels, which are made up of multiple PV cells. These panels are installed on rooftops or on the ground in areas with abundant sunlight.

- **Battery storage:** In some cases, PV solar energy systems may be connected to battery storage systems, which allow excess electricity to be stored and used later when there is less sunlight.
- **Grid connection:** PV solar energy systems can also be connected to the electricity grid, allowing excess electricity to be sold back to the utility company.

PV solar energy is a renewable energy source that has become increasingly popular in recent years due to its low environmental impact and declining costs. PV solar energy systems can be used to power homes, businesses, and even entire communities. While the initial cost of installing a PV solar energy system can be high, the long-term savings on electricity bills and potential revenue from selling excess electricity back to the grid can make it a cost-effective investment over time.

**Concentrated Solar Power (CSP):**

CSP technology uses mirrors or lenses to focus sunlight onto a small area, creating intense heat. The heat is then used to generate steam, which drives a turbine to generate electricity. CSP systems are typically used in large-scale power plants and can generate electricity even when the sun is not shining. The main features of Concentrated Solar Power include:




- **Solar collectors:** CSP systems use solar collectors, which can be parabolic troughs, dishes or towers, to focus the sun's rays onto a central receiver. The receiver may contain a fluid, such as water or molten salt, which absorbs the concentrated solar energy and heats up.
- **Thermal energy storage:** Some CSP systems may include thermal energy storage, which allows excess heat energy to be stored and used to generate electricity when the sun is not shining, such as during nighttime or cloudy days.

- **Power generation:** The heated fluid is used to generate steam, which drives a turbine to generate electricity.

CSP technology has some advantages over other types of solar power, such as PV solar energy, as it can generate electricity even when the sun is not shining and can be used to provide base load power to the grid. However, it also has some disadvantages, such as the need for large area of land to install the solar collectors, and the high cost of building and maintaining CSP power plants. Despite these challenges, CSP technology is being increasingly used around the world to generate clean, renewable energy.

**Solar Water Heating**:

Solar water heating systems use solar collectors to absorb sunlight and heat water. The heated water can be used for domestic hot water or space heating in homes and buildings. The main features of solar water heating systems include:

- **Solar collectors:** Solar water heaters use solar collectors, which are typically flat panels or tubes, to absorb the sun's energy and heat up water. The collectors are usually mounted on rooftops or on the ground in areas with ample sunlight.
- **Storage tank:** The heated water is stored in a tank, which can be insulated to prevent heat loss.
- **Backup heating system:** In some cases, solar water heating systems may include a backup heating system, such as an electric or gas water heater, to ensure a constant supply of hot water even when the sun is not shining.

Solar water heating systems can provide hot water for a variety of applications, including bathing, laundry, and dishwashing, as well as for industrial processes. They can be used in both residential and commercial settings and can help to reduce energy costs over time. However, the initial cost of installing a solar water heating system can be relatively high, and the effectiveness of the system may depend on the climate and the amount of sunlight available in the area.

**Solar Air Heating**:

Solar air heating systems use solar collectors to absorb sunlight and heat air, which is then used for space heating in homes and buildings. Solar air heating technologies use only free, renewable, and clean energy, and can help defray the rising cost of conventional energy. The solar air dryer, which is a specific type of solar air heater with a theoretical principle similar to that of space heating, is widely used for drying agricultural products, timber, fruits, and herbs. Solar air heating technology has made considerable progress. With the characteristics of high collection efficiency, no need to prevent frosting, insignificant leaks without affecting the efficiency, and low corrosion problem, the solar air collector is more appropriate to be applied to the humidification–dehumidification desalination system. However, there are still some flaws in this kind of system. First, the small heat capacity of air and the limited energy carried by air requires a large amount of circulated air, which increases electric power requirements of the fan. Second, without energy storage in solar air collectors, the system is greatly affected by weather conditions. It is two types such as

i. **Active Solar Heating:** Active solar air heating systems, a more recent development, use fans to draw in, circulate, and exhaust air. The perforated cladding system (**Fig.3.1**) is a bare plate solar collector that uses fans to draw air through thousands of tiny holes in a layer of unglazed dark metal plating, which acts as the solar absorber.

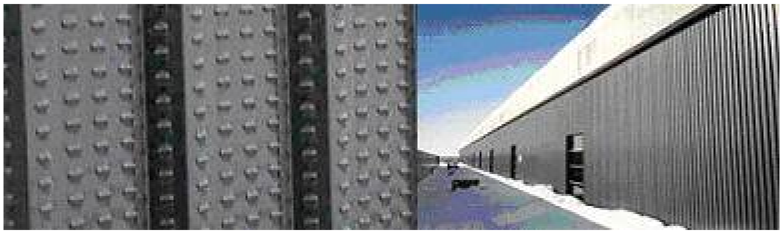


**Fig.3.1:**Perforated cladding detail, typical installation

ii. **Passive Solar Heating:** Passive solar collection can be as simple as allowing sunlight into a heated space through south facing windows. The heat energy is then stored in the building materials inside the space. Passive solar collectors (**Fig.3.2**) use the natural convective movement of heated air to transfer heat from the solar collector into the building.

**Fig. 3.2.**:Passive solar collector-on large workshop door

**Hybrid Solar Systems:**

Hybrid solar systems combine different solar energy technologies to provide both electricity and heat. For example, a hybrid solar system may include PV solar panels to generate electricity and a solar water heating system to provide hot water. The main features of a hybrid solar system are:

- **Solar panels:** Hybrid solar systems typically use solar panels to generate electricity from sunlight. The solar panels can be connected to a grid-tied inverter or a battery storage system, depending on the specific configuration of the system.
- **Other energy sources**: Hybrid solar systems may also incorporate other forms of energy generation, such as wind turbines or generators powered by biofuels or natural gas.
- **Battery storage:** Hybrid solar systems may include battery storage systems, which allow excess electricity generated by the solar panels to be stored and used later when there is less sunlight. This can increase the efficiency and reliability of the system, as well as reduce the need for energy from other sources.
- **Grid connection**: Hybrid solar systems can also be connected to the electricity grid, allowing excess electricity to be sold back to the utility company.

The benefits of a hybrid solar system include increased energy efficiency, reduced environmental impact, and increased reliability of the overall energy system. Hybrid solar systems can be used in a variety of applications, including residential, commercial, and industrial settings. However, the cost of a hybrid solar system can be higher than a traditional solar system, and the specific design of the system will depend on the energy needs of the user and the availability of other energy sources in the area.

**Solar-Powered Vehicles**:

Solar energy can also be used to power vehicles such as cars, buses, and boats. These vehicles use solar panels to generate electricity, which is stored in batteries and used to power an electric motor: it contents following

- **Solar panels:** Solar-powered vehicles use solar panels to collect energy from the sun. The panels are usually mounted on the roof of the vehicle and are made of photovoltaic cells that convert sunlight into electricity.
- **Electric motor:** Solar-powered vehicles are typically equipped with an electric motor that is powered by the electricity generated by the solar panels. The motor can be connected to a battery or other energy storage device to provide additional power when needed.
- **Energy storage:** Solar-powered vehicles may use a battery or other energy storage device to store excess energy generated by the solar panels. This energy can be used to power the vehicle when there is not enough sunlight, such as at night or on cloudy days.
- **Efficiency:** Solar-powered vehicles are highly efficient, as they convert energy from the sun directly into electricity without the need for combustion or other energy conversion processes.

The benefits of solar-powered vehicles include reduced dependence on fossil fuels, reduced greenhouse gas emissions, and reduced operating costs. However, solar-powered vehicles have some limitations, such as limited range and speed, and they may not be suitable for all types of transportation needs. Additionally, the initial cost of a solar-powered vehicle can be higher than a traditional gasoline-powered vehicle. Nonetheless, solar-powered vehicles are gaining popularity, and advancements in technology are improving their performance and efficiency.

## 3.4. Hydro energy

Hydro energy, also known as hydropower, is the energy generated from the movement of water, usually in the form of falling or flowing water. The history of hydro energy dates back to ancient times when waterwheels were used to grind grain and power machinery. In the 19th century, hydro energy was used to generate electricity, and it quickly became a popular source of energy in the early 20th century. Today, hydro energy is a significant source of electricity in many countries around the world. Hydro energy is one of the largest sources of renewable energy for electricity generation. Hydropower plants are built near rivers, dams, and other water sources to generate electricity. The energy generated is clean, reliable, and cost-effective, making it a popular choice for power generation. Hydro energy is also used for irrigation purposes, where water is pumped from a water source to irrigate crops. This is especially important in arid regions where water is scarce. Hydro energy is used for flood control purposes where dams are built to control the flow of water and prevent flooding. This is especially important in areas prone to flooding during heavy rainfall. Hydro energy is also used for navigation purposes, where canals and locks are built to allow boats to pass through rivers and lakes. Hydro energy is used for water supply purposes, where water is pumped from a water source to provide clean drinking water to communities. Hydro energy has several advantages. It is a clean, renewable, and reliable source of energy that produces no greenhouse gas emissions. It is also cost-effective and has a long lifespan, making it a popular choice for electricity generation. However, hydro energy also has some disadvantages, including the impact on aquatic ecosystems, displacement of local communities, and the high initial capital cost of building hydropower plants.

### 3.4.1. How hydro power work

The process of generating hydro power involves several components, including a water source, a dam, a turbine, and a generator. The process of generating hydro power can be broken down into the following steps:

- **Water Source**: The first step in generating hydro power is identifying a water source, such as a river or a reservoir that has a sufficient volume of water and a significant difference in elevation between two points. This elevation difference creates a potential energy source that can be harnessed to generate electricity.
- **Dam:** A dam is built across the water source to create a reservoir of water. The dam creates a difference in water levels, with the water behind the dam being at a higher elevation than the water in front of the dam.
- **Intake:** An intake structure is built at the base of the dam to allow water to flow into a pipeline or a tunnel.
- **Penstock:** The pipeline or tunnel is called a penstock, and it carries the water from the intake to the turbine.
- **Turbine:** The penstock feeds the water into the turbine, which is typically located at the base of the dam. The turbine has blades that are rotated by the force of the flowing water, which generates mechanical energy.
- **Generator:** The mechanical energy from the turbine is transferred to a generator, which converts the mechanical energy into electrical energy.
- Transmission: The electrical energy generated by the generator is transmitted to the electrical grid or to a local distribution network for use.

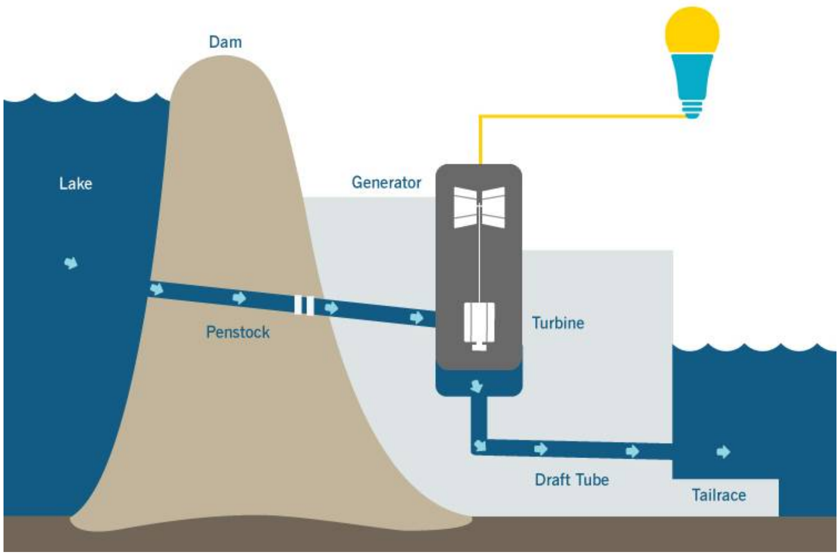
The amount of electricity generated by a hydro power plant depends on the volume of water flow and the height difference between the water source and the turbine. Larger water flows and greater height differences result in more electricity generation.

### 3.4.2. Types of hydroelectric energy plant

There are several types of hydroelectric power plants, each with its own unique features and advantages. Here are some of the most common types of hydroelectric power plants:

#### 3.4.2.1. Conventional Hydroelectric Power Plants:

These are the most common types of hydroelectric power plants that generate electricity by using the kinetic energy of falling water to drive a turbine, which in turn drives a generator. They typically use a dam to create a reservoir of water, which is then used to drive a turbine to generate electricity. These power plants are typically located near dams, which create a large reservoir of water that can be released as needed to generate electricity. Conventional hydroelectric power plants can range in size from small, run-of-the-river plants to large, multi-dam facilities. The basic components of a conventional hydroelectric power plant include:




- **Dam:** A structure built across a river to create a reservoir of water.
- **Intake gates:** Openings in the dam through which water flows into the power plant.
- **Penstock**: A large pipe that carries water from the dam to the turbine.
- **Turbine:** A machine with blades that is turned by the force of water flowing through it.
- **Generator:** A machine that converts the rotational energy of the turbine into electrical energy.
- **Transformer:** A device that steps up the voltage of the electrical energy generated by the generator so that it can be transmitted over long distances.
- **Transmission lines:** Cables that carry the electricity from the power plant to homes and businesses.

Conventional hydroelectric power plants are a reliable and renewable source of energy, and they produce no greenhouse gases or other pollutants. However, their construction can have environmental impacts, such as flooding large areas of land and altering the natural flow of rivers.

### 3.4.2.2. Pumped Storage Hydroelectric Power Plants:

These power plants are used to store excess electricity generated during off-peak hours by pumping water from a lower reservoir to a higher reservoir. During peak demand hours, the water is released back to the lower reservoir through a turbine, generating electricity. This type of plant is particularly useful for balancing the intermittent output of other renewable energy sources, such as wind and solar. The main components of a pumped storage hydroelectric power plant include:

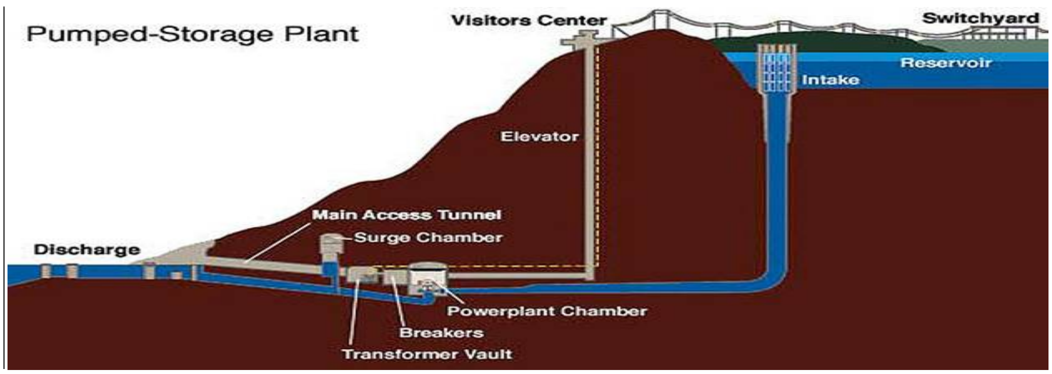



**Fig.3.3:** Schematic of a pumped-storage hydro facility
Source: Tennessee Valley Authority

- **Upper reservoir:** A large man-made or natural body of water at a higher elevation.
- **Lower reservoir:** A large man-made or natural body of water at a lower elevation.
- **Pumping station:** A facility that pumps water from the lower reservoir to the upper reservoir during off-peak hours when electricity demand is low and electricity is cheap.
- **Turbine:** A machine with blades that is turned by the force of water flowing through it, generating electricity when the water flows from the upper reservoir to the lower reservoir.
- **Generator:** A machine that converts the rotational energy of the turbine into electrical energy.
- **Transmission lines:** Cables that carry the electricity from the power plant to homes and businesses.

During off-peak hours, when electricity demand is low, the power plant uses excess energy from other power plants to pump water from the lower reservoir to the upper reservoir. Then, during peak hours, when electricity demand is high, the water is released back to the lower reservoir through a turbine, generating electricity that can be used to meet the increased demand. This process can be repeated as many times as needed, making pumped storage hydroelectric power plants a flexible and reliable source of energy that can help stabilize the grid and support the integration of variable renewable energy sources such as wind and solar.

#### 3.4.2.3. Run-of-the-River Hydroelectric Power Plants:

These power plants use the natural flow of a river or stream to generate electricity without the need for a dam or reservoir. The water is diverted from the river into a channel, which drives a turbine to generate electricity. Run-of-the-river power plants are typically smaller than conventional hydroelectric power plants and have a lower environmental impact. Its main components of a run-of-the-river hydroelectric power plant include:

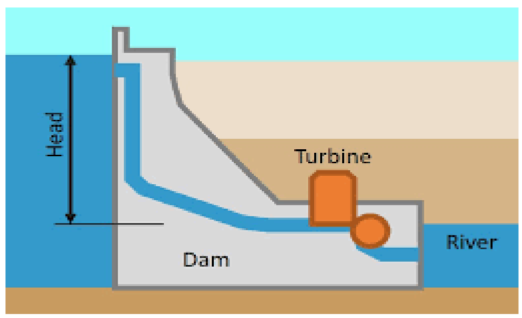



**Fig. 3.4:** Schematic representation of Run-of-the-River Hydroelectric Power Plants

- **Intake structure:** A structure that diverts water from the river into the power plant.
- **Penstock:** A large pipe that carries water from the intake structure to the turbine.
- **Turbine:** A machine with blades that is turned by the force of water flowing through it.
- **Generator:** A machine that converts the rotational energy of the turbine into electrical energy.
- **Transformer:** A device that steps up the voltage of the electrical energy generated by the generator so that it can be transmitted over long distances.
- **Transmission lines**: Cables that carry the electricity from the power plant to homes and businesses.

Unlike conventional hydroelectric power plants, which require large dams and reservoirs to store water, run-of-the-river hydroelectric power plants use the natural flow of the river to generate electricity. This means that they have a smaller environmental footprint and do not require the same level of engineering and construction as conventional hydroelectric power plants. However, their output can vary depending on the flow of the river, which can be affected by seasonal changes, weather patterns, and other factors.

**3.4.2.4. Tidal Hydroelectric Power Plants**:

These power plants use the rise and fall of tides to generate electricity. The power plants typically use a dam or barrage to capture water during high tide, which is then released through a turbine to generate electricity during low tide. Tidal hydroelectric power plants have the advantage of being predictable and consistent, but they are limited to areas with significant tidal fluctuations. The main components of a tidal hydroelectric power plant include:

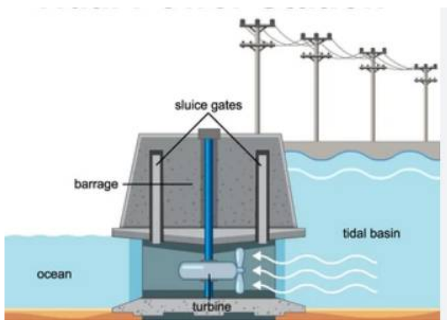



**Fig.3.5:** Tidal power station

- **Tidal barrage or fence:** A barrier or series of barriers that are built across a bay or estuary to create a large reservoir of water.
- **Turbines:** Machines with blades that are turned by the force of water flowing through them.
- **Generator:** A machine that converts the rotational energy of the turbines into electrical energy.
- **Transformer**: A device that steps up the voltage of the electrical energy generated by the generator so that it can be transmitted over long distances.
- Transmission lines: Cables that carry the electricity from the power plant to homes and businesses.

As the tides rise and fall, water flows into and out of the reservoir through the turbines, generating electricity. Tidal power plants can generate electricity reliably and predictably, as tides are driven by the gravitational pull of the moon and the sun, and their timing and magnitude can be accurately predicted years in advance. However, tidal power plants can have environmental impacts, such as altering the natural flow of water and affecting marine ecosystems.

### 3.4.2.5. In-Stream Hydrokinetic Power Plants:

These power plants use the natural flow of a river or stream to generate electricity without the need for a dam or reservoir. The turbines are placed directly in the water, either on the riverbed or floating on the surface, and are driven by the flow of the water. In-stream hydrokinetic power plants have a lower environmental impact than conventional hydroelectric power plants, but their efficiency can be affected by changes in water flow. The main components of an instream hydroelectric power plant include:

- **Turbine:** A machine with blades that is turned by the force of water flowing through it.
- **Generator:** A machine that converts the rotational energy of the turbine into electrical energy.
- **Control system:** A system that regulates the flow of water through the turbine to maximize electricity generation.
- **Transmission lines:** Cables that carry the electricity from the power plant to homes and businesses.

Instream hydroelectric power plants can have a smaller environmental footprint than conventional hydroelectric power plants, as they do not require large dams or reservoirs, and can be designed to minimize their impact on fish and other aquatic organisms. However, their output can vary depending on the flow of the river or stream, which can be affected by seasonal changes, weather patterns, and other factors. Instream hydroelectric power plants are best suited for locations with a relatively consistent flow of water and a high potential for electricity generation.

### 3.4.3. Limitation of hydroelectric plants

While hydropower plants have many advantages as a source of renewable energy, they also have some limitations that need to be considered. Here are some of the main limitations of hydropower plants:

1. It require a significant volume of water flow,
2. The construction of large dams, reservoirs, and transmission lines for hydropower plants can be expensive, which can limit the availability of financing for these projects.
3. The construction and operation of hydropower plants can have significant environmental and social impacts, particularly on aquatic ecosystems and local communities.
4. Climate change could affect the reliability of hydropower plants and limit their ability to provide a consistent source of electricity.
5. it is expensive and time-consuming due to require ongoing maintenance and safety monitoring to ensure that they are operating safely and effectively.

### 3.4.4. Hydropower plant in India

Hydropower has the potential to play a significant role in India's energy mix, as the country has a large number of rivers and water resources that can be harnessed to generate electricity. However, the construction of new hydropower projects in India is often accompanied by social and environmental concerns, such as the displacement of local communities and the impact on natural ecosystems. As a result, there is a need to carefully balance the benefits of hydropower with its potential impacts. India has a long history of using hydropower to generate electricity, with the first hydropower plant being built in Darjeeling in 1898. Today, India has a total installed capacity of around 50,000 MW of hydropower, making it one of the largest producers of hydropower in the world. The major hydropower plants in India are such as

- ✓ **Bhakra Nangal Dam:** Located in the northern state of Himachal Pradesh, the Bhakra Nangal Dam is one of the largest hydropower projects in India, with a total capacity of 1,325 MW. This dam is a concrete gravity dam that is 226 meters high and 518 meters long. It has a capacity of 9.34 billion cubic meters of water. The Bhakra Nangal Dam has been a significant contributor to the development of the northern Indian states of Punjab, Haryana, and Rajasthan. It has helped to control flooding, provide irrigation water to farmers, and generate electricity for millions of people.

- ✓ **Sardar Sarovar Dam:** Located on the Narmada River in Gujarat, the Sardar Sarovar Dam has a total capacity of 1,450 MW. The dam is a concrete gravity dam that is 163 meters high and 1.2 kilometers long. It has a capacity of 9.5 billion cubic meters of water. he dam has a spillway to control the flow of water and prevent flooding.
- ✓ **Tehri Dam:** Located on the Bhagirathi River in Uttarakhand, the Tehri Dam is one of the tallest dams in the world and has a total capacity of 2,400 MW. This Dam is a multi-purpose rock and earth-fill embankment dam on the Bhagirathi River, located in the Indian state of Uttarakhand. It is one of the highest dams in India and the tallest dam in Asia, with a height of 260 meters. The dam is made of rock and earth-fill embankment with a clay core, and is designed to withstand earthquakes of up to 8.4 magnitudes on the Richter scale.
- ✓ **Nathpa Jhakri Dam:** Located on the Satluj River in Himachal Pradesh, the Nathpa Jhakri Dam has a total capacity of 1,500 MW.
- ✓ **Nathpa Jhakri Dam**: Located on the Satluj River in Himachal Pradesh, the Nathpa Jhakri Dam has a total capacity of 1,500 MW.
    - o In addition to these large hydropower projects, India also has a number of smaller hydropower plants that are located across the country. These plants typically have capacities of less than 25 MW and are used to generate electricity for local communities and industries.

**Hirakund Dam:** Located on Mahanadi River in Sambhalpur district of Odisha. it is largest earthen dam in the world. Hirakund Reservoir is 55 km long which is multipurpose river valley project. This reservoir is presently called Ramsar site. The installed capacity of this dam is 347.5 mw.

## 3.5. Wind energy

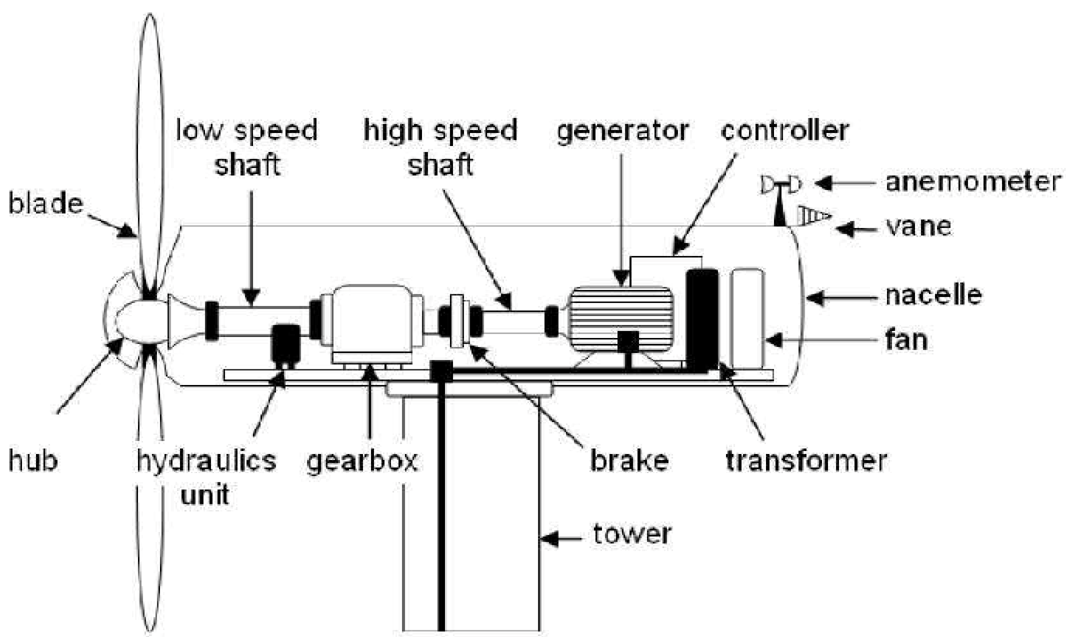
Wind energy is a renewable energy source that has gained popularity in recent years as a clean and sustainable alternative to traditional fossil fuels. It is generated by harnessing the power of wind through the use of wind turbines, which convert kinetic energy into electricity. Wind energy is defined as the process of generating electrical power from the wind. It involves the use of wind turbines to capture the energy of the wind and convert it into electricity that can be used to power homes, businesses, and other applications. The use of wind energy dates back thousands of years to the use of windmills in ancient civilizations such as Persia and China. Windmills were used for a variety of purposes, including grinding grain, pumping water, and generating electricity. In the 20th century, wind energy emerged as a viable alternative to fossil fuels, with the first modern wind turbine being developed in Denmark in the 1950s. Since then, wind energy has grown rapidly, with wind power capacity increasing by an average of 22% per year over the past decade. Wind energy is generated by harnessing the kinetic energy of the wind through the use of wind turbines. Wind turbines consist of rotor blades that are connected to a hub, which in turn is connected to a gearbox and a generator. When the wind blows, the rotor blades rotate, turning the hub and generating electricity. The electricity generated by the wind turbine is then sent to a transformer and distributed to the grid. Wind energy has a wide range of applications, from small-scale residential and commercial applications to large-scale utility projects. It is a renewable energy source that can be used to generate electricity in areas with strong and consistent winds, such as coastal areas and mountain passes. Wind energy is also a key component of many countries' renewable energy portfolios, with wind power accounting for a significant percentage of electricity generation in countries such as Denmark, Germany, and Spain. Wind power generation capacity in India has significantly increases in recent years. As on march 31, 2023 the total wind power capacity was 42.633 gig watts (GW) the fourth largest installed wind power capacity in the world. Wind power capacity is mainly speared across the south, western and northwestern states on India.

### 3.5.1. How wind energy generated

Wind energy is generated through the use of wind turbines, which are tall structures with large blades that rotate when exposed to the force of the wind. The motion of the blades generates mechanical energy, which can be converted into electrical energy through the use of a generator. The basic components of a wind turbine include the rotor, blades, hub, nacelle, tower, and electrical systems. The rotor is the spinning part of the turbine that includes the blades and hub. The blades are typically made of lightweight, aerodynamic materials and are designed to capture the kinetic energy of the wind. The nacelle is the housing for the generator, gearbox, and other key components, and is located at the top of the tower. The tower is the tall structure that supports the turbine, and can range in height from 50 to 100 meters or more. When the wind blows, it causes the blades of the turbine to rotate. The kinetic energy of the spinning blades is transferred to the rotor, which in turn drives a gearbox that increases the rotational speed of the generator. The generator then converts the mechanical energy into electrical energy, which is transmitted through a series of cables and transformers to a substation, where it is fed into the grid. When the wind blows, it causes the blades of the turbine to rotate. The kinetic energy of the spinning blades is transferred to the rotor, which in turn drives a gearbox that increases the rotational speed of the generator. The generator then converts the mechanical energy into electrical energy, which is transmitted through a series of cables and transformers to a substation, where it is fed into the grid. When the wind blows, it causes the blades of the turbine to rotate. The kinetic energy of the spinning blades is transferred to the rotor, which in turn drives a gearbox that increases the rotational speed of the generator. The generator then converts the mechanical energy into electrical energy, which is transmitted through a series of cables and transformers to a substation, where it is fed into the grid.

### 3.5.2. Wind energy conservation systems

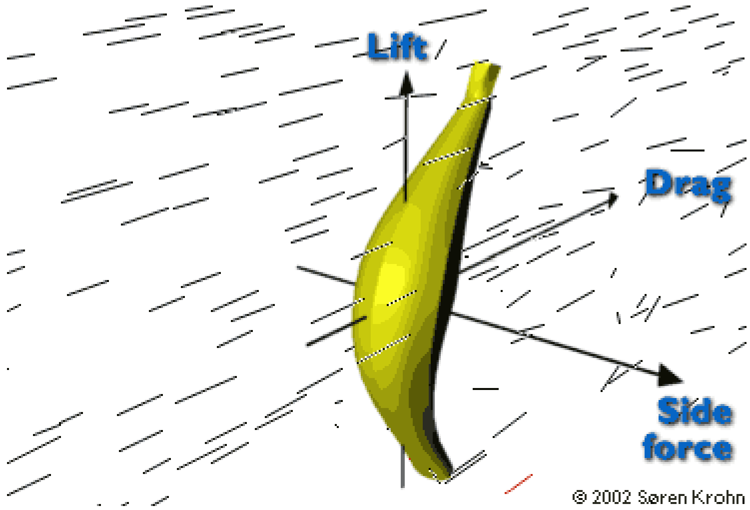
Wind energy conservation systems are technologies and practices designed to improve the efficiency and effectiveness of wind energy systems. These systems are aimed at reducing the environmental impact of wind energy, improving energy production, and reducing the cost of wind energy.



One important aspect of wind energy conservation systems is wind resource assessment. This involves measuring and analyzing wind patterns at potential wind energy sites to determine the wind resource available. Accurate wind resource assessments are critical for designing efficient and effective wind energy systems. Another important aspect of wind energy conservation systems is wind turbine design. Advances in wind turbine technology have led to the development of larger, more efficient wind turbines that can generate more electricity with fewer turbines. Innovations in blade design, materials, and manufacturing processes have led to increased energy capture and reduced maintenance costs.Wind energy conservation systems also include technologies and practices aimed at improving the reliability and efficiency of wind turbines. These include condition monitoring systems, which can detect and diagnose problems in wind turbines before they lead to system failures. Remote monitoring systems and predictive maintenance systems can also help improve the reliability and efficiency of wind energy systems. Finally, wind energy conservation systems also include environmental and social impact assessments. These assessments are aimed at identifying and mitigating potential negative impacts of wind energy systems on the environment and local communities. This includes assessing the potential impact on wildlife, cultural resources, and local economies.

### 3.5.3. Lift and Drag force in the wind energy

Lift and drag forces are two fundamental aerodynamic forces that play a crucial role in the operation of wind turbines and the generation of wind energy. Lift force is the force that acts perpendicular to the direction of motion of an airfoil, such as the blades of a wind turbine. This force is generated by the difference in air pressure on the upper and lower surfaces of the airfoil as air flows over it. The force parallel to the steam is called drag (air resistance). A moment around this axis is called a rolling moment. Drag is given a positive sign, when it pulls in the same direction as the stream. Drag is a loss that must be overcome with another force, if an object is to move against a stream. As the wind flows over the curved surface of the airfoil, it creates an area of low pressure on the upper surface and an area of high pressure on the lower surface. The resulting pressure difference generates a lift force that lifts the airfoil upward, perpendicular to the direction of motion. Drag force, on the other hand, is the force that acts parallel to the direction of motion of an airfoil. It is generated by the resistance of the air to the motion of the airfoil.




As the air flows over the surface of the airfoil, it creates friction and turbulence, which generate a drag force that opposes the motion of the airfoil. In wind turbines, lift force is used to generate rotational motion of the blades, which is then converted into electricity through a generator. The blades of a wind turbine are designed to generate lift force by using a curved, airfoil shape that maximizes the pressure difference between the upper and lower surfaces of the blade. Drag force, on the other hand, can be a limiting factor in the efficiency of wind turbines, as it can slow down the rotation of the blades and reduce the amount of energy generated. This is why wind turbine blades are designed to minimize drag force, by using smooth, streamlined shapes and reducing surface roughness.

### 3.5.4. **Advantage of wind energy**

Wind energy has numerous advantages, some of which include:

- ✓ It the renewable and sustainable source of energy that does not produce greenhouse gases or other pollutants.
- ✓ It is the cost-effective with conventional sources of electricity.
- ✓ It is easily available and abundant source of energy that is available all over the world.
- ✓ It requires low maintenance and it has cost-effective option for generating electricity.
- ✓ It provides energy security as a alternative sources for energy consumption
- ✓ Its can provide a range of benefits to local communities, including job creation, tax revenue, and community investment.

- ✓ It is flexible source of electricity that can be used in combination with other renewable energy sources, such as solar and hydroelectric power, to provide a reliable and sustainable energy mix.

### 3.5.5. Disadvantage of wind energy

The wind energy has many advantages as a renewable energy source,

- ✓ It needs proper wind speeds lake of wind speed its is not useful for energy generation
- ✓ During wind energy for electricity generation, as backup sources of energy may be needed when wind speeds are low.
- ✓ Wind turbines require large area of land, as well as access roads and transmission lines.
- ✓ Wind turbines can be large and imposing structures, and some people may find them unattractive or disruptive to the landscape.
- ✓ Wind turbines can pose a risk to birds and bats, as they may collide with the spinning blades.

### 3.5.6. Limitation of wind energy

One of the biggest limitations of wind energy is its intermittency. Wind speeds can vary significantly over short periods of time, which can make it difficult to rely on wind energy as a consistent source of power. This variability can lead to issues with grid stability and energy storage.

Wind energy is dependent on the availability of wind. This means that wind turbines must be located in areas with consistent and strong wind speeds, which may not always be near population centers or existing infrastructure. This can make it difficult to integrate wind energy into the grid and may require the construction of new transmission lines. The construction and operation of wind turbines can have a negative impact on the environment. Wind turbines can cause noise pollution, disrupt wildlife habitats, and pose a risk to birds and bats. Additionally, the construction of new wind turbines may require the destruction of natural habitats and can have visual impacts on landscapes. Wind turbines require a significant amount of land, both for the turbines themselves and for the transmission infrastructure needed to connect them to the grid. This can be a challenge in areas with limited available land, especially in densely populated regions.

### 3.5.7. Application of wind energy

Wind energy has a wide range of applications, from small-scale residential wind turbines to large commercial wind farms. Here are some of the most common applications of wind energy: Wind energy has a wide range of applications, from small-scale residential wind turbines to large commercial wind farms. Here are some of the most common applications of wind energy: Wind-powered water pumps are used to pump water for irrigation, livestock, and domestic use. These pumps can be simple, low-cost devices that are easy to maintain and operate, making them ideal for rural areas with limited access to electricity. Small wind turbines can be used to provide power to remote areas that are not connected to the grid. These systems can be used to power homes, schools, and health clinics in off-grid areas, improving access to electricity and supporting economic development. Wind energy can be combined with other renewable energy sources, such as solar power and hydropower, to create hybrid energy systems. These systems can provide a more reliable and stable supply of electricity, especially in areas with variable wind speeds. Wind power can also be used to power transportation, through the use of sailboats and wind-powered vehicles. While these applications are not as common as electricity generation and water pumping, they are still important examples of the versatility of wind energy.

### 3.5.8. Current energy scenario of wind power

The current energy scenario of wind power is promising, with wind energy becoming an increasingly important source of electricity generation in many countries around the world. According to the International Energy Agency (IEA), wind power is the second-largest source of renewable energy in the world, after hydropower. As of 2021, the global installed capacity of wind power is over 743 GW, with China, the United States, and Germany leading in terms of total capacity. In 2020, wind power accounted for 7% of global electricity generation, with Denmark, Portugal, and Ireland leading in terms of wind power's share of total electricity generation. The growth of wind power has been driven by a range of factors, including declining costs, supportive government policies, and advances in technology. Wind power has become increasingly cost-competitive with traditional fossil fuels, with the levelized cost of electricity from onshore wind power falling by over 40% since 2010. Offshore wind power has also become more cost-competitive, with the levelized cost of electricity falling by over 30% since 2015. Government policies and incentives have played a significant role in supporting the growth of wind power, particularly in Europe and China. Many countries have implemented feed-in tariffs, tax incentives, and other policies to support the development of wind power projects. In addition, advances in technology have led to the development of larger, more efficient wind turbines, which can generate more electricity with fewer turbines. he future of wind power is expected to be bright, with many countries setting ambitious targets for the deployment of wind power. The IEA projects that wind power capacity will grow by an average of 10% per year between 2020 and 2025, reaching over 1,000 GW by 2025. This growth is expected to be driven by a range of factors, including declining costs, supportive government policies, and increasing demand for clean energy sources. India has seen a significant increase in wind energy deployment in recent years, making it one of the leading countries in the world for wind power generation. As of 2021, India has an installed capacity of over 39 GW of wind power, which accounts for approximately 10% of the country's total installed power capacity. The Indian government has set ambitious targets for the deployment of wind power, aiming to increase the country's wind power capacity to 60 GW by 2022. To achieve this target, the government has implemented a range of policies and incentives to support the development of wind power projects, including feed-in tariffs, tax incentives, and competitive bidding processes. The Indian government has set ambitious targets for the deployment of wind power, aiming to increase the country's wind power capacity to 60 GW by 2022. To achieve this target, the government has implemented a range of policies and incentives to support the development of wind power projects, including feed-in tariffs, tax incentives, and competitive bidding processes.

## 3.6. Ocean energy tidal and wave’s energy

Ocean energy is a type of renewable energy that is derived from the movement of water in the world's oceans. It can be classified into two main categories: tidal energy and wave energy. Tidal energy is generated from the rise and fall of the tides, while wave energy is generated from the motion of waves on the surface of the ocean. The ocean energy dates back to the early 20th century, when the first attempts were made to harness the power of ocean currents. Since then, a number of different technologies have been developed to harness the power of the oceans, including tidal barrages, tidal stream turbines, wave energy converters, and ocean thermal energy conversion systems. Tidal energy is typically generated using tidal barrages, which are large structures that are built across estuaries or other areas where there is a significant tidal range. As the tides rise and fall, the water flows through turbines in the barrage, generating electricity that is fed into the grid. Wave energy, on the other hand, is generated by the motion of waves on the surface of the ocean. This energy can be harnessed using a variety of different technologies, including oscillating water columns, point absorbers, and attenuators. These technologies work by converting the motion of the waves into mechanical energy, which is then used to generate electricity. The scope of ocean energy is significant, as it has the potential to provide a significant amount of renewable energy to the world's power grids. According to estimates, the global potential for tidal energy alone is around 800 TWh per year, which is equivalent to around 3% of the world's electricity demand. The potential for wave energy is also significant, with some estimates suggesting that wave energy could provide up to 10% of the world's electricity needs. Despite its potential, ocean energy is still in the early stages of development, and faces a number of challenges, including high capital costs, technological and operational challenges, and environmental concerns. However, with ongoing research and development, it is expected that ocean energy will become an increasingly important source of renewable energy in the coming decades.

### 3.6.1. How ocean energy works

Ocean energy is harnessed using a variety of technologies that work by converting the movement of water in the ocean into electricity. There are several different types of ocean energy technologies, including tidal barrages, tidal stream turbines, wave energy converters, and ocean thermal energy conversion systems.

Tidal barrages are large structures that are built across estuaries or other areas with a significant tidal range. As the tides rise and fall, the water flows through turbines in the barrage, generating electricity that is fed into the grid. Tidal stream turbines, on the other hand, are similar to wind turbines, but are designed to be submerged in water. As the tidal currents move the blades of the turbine, they generate electricity that is fed into the grid.

Wave energy converters work by harnessing the motion of waves on the surface of the ocean. There are several different types of wave energy converters, including oscillating water columns, point absorbers, and attenuators. Oscillating water columns work by using the motion of the waves to compress air in a chamber, which is then used to drive a turbine and generate electricity. Point absorbers work by using the motion of the waves to move a buoy up and down, which is then used to generate electricity. Attenuators work by using the motion of the waves to move a series of floats, which are then used to generate electricity.

Ocean thermal energy conversion systems work by harnessing the temperature difference between the surface of the ocean and deeper water. These systems typically use a fluid with a low boiling point, such as ammonia, to evaporate at the surface of the ocean. The resulting steam is then used to drive a turbine and generate electricity. The steam is then condensed using cold water from deeper in the ocean and the process is repeated.

### 3.6.2. Ocean thermal energy conversion

Ocean thermal energy conversion (OTEC) is a technology that harnesses the temperature difference between the warm surface water and the cold deep water in the ocean to generate electricity. OTEC has the potential to be a significant source of renewable energy, as the ocean is a vast and largely untapped resource that can provide a consistent and reliable source of energy. In this article, we will explore the history, principle, advantages, limitations, and current status of OTEC technology.

The concept of ocean thermal energy conversion dates back to the late 19th century, when French physicist Jacques Arsene d'Arsonval first proposed the idea of using the temperature difference between the surface water and the deep water in the ocean to generate electricity. However, it was not until the 1930s that the first experimental OTEC plant was built in Cuba, which generated a small amount of electricity using a low-pressure turbine.

In the decades that followed, OTEC technology was further developed and tested in various locations around the world, including the United States, Japan, and India. However, despite these efforts, OTEC has yet to be commercialized on a large scale due to a number of technical, economic, and environmental challenges.

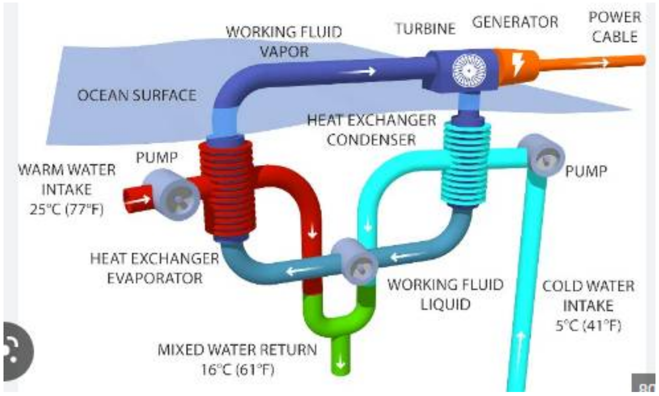
### 3.6.3. Principle of Ocean Thermal Energy Conversion

The principle behind ocean thermal energy conversion is based on the fact that the ocean's surface water is typically warmer than the deep water below. This temperature difference, known as the thermal gradient, can be harnessed to generate electricity using a closed-cycle or open-cycle system.

In a closed-cycle OTEC system, warm surface water is used to vaporize a working fluid, such as ammonia, which drives a turbine to generate electricity. The vapor is then cooled and condensed using cold water from the deep ocean, which is pumped to the surface using a pipe or other mechanism. The condensed fluid is then returned to the evaporator to repeat the cycle. The OTEC technology uses the temperature difference between the cold water in the deep sea (5°C) and the warm surface seawater (25°C) to generate clean, renewable electricity. The technology requires a minimum of 20°C (36°F) difference between the surface and deep ocean temperatures. Large amounts of deep cold seawater and warm surface seawater are pumped to run a power cycle to produce electricity. A heat exchanger evaporator generates steam by vapourising an ammonia fluid with warm surface seawater to drive a turbine generator for producing electricity. Once the steam transfers its energy, a heat exchanger condenser cools the ammonia vapour, turns it back into a liquid and conveys it to a heat exchanger evaporator to repeat the cycle. In an open-cycle OTEC system, warm surface water is used to evaporate seawater, which creates steam that drives a turbine to generate electricity. The steam is then condensed using cold water from the deep ocean, and the resulting fresh water is collected and used for various purposes, such as irrigation or desalination. The cold water is then returned to the ocean.

### 3.6.4. Advantages of Ocean Thermal Energy Conversion

One of the main advantages of OTEC is that it can provide a consistent and reliable source of energy. Unlike solar and wind power, which are subject to variations in weather patterns, the temperature difference between the warm surface water and the cold deep water in the ocean remains relatively constant over time. This means that OTEC can provide a stable source of baseload power that can help to reduce reliance on fossil fuels and other non-renewable sources of energy.



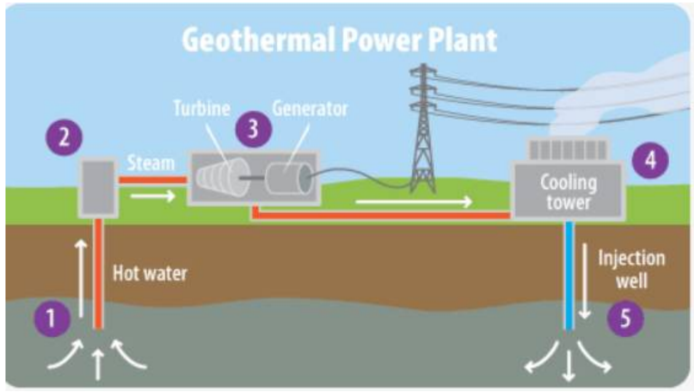

Another advantage of OTEC is that it can provide a range of co-benefits, such as the production of fresh water through the desalination of seawater. This can be particularly important in regions where water scarcity is a major challenge, as it can help to alleviate water stress and support sustainable development.

### 3.6.5. Limitations of Ocean Thermal Energy Conversion

Despite its potential advantages, OTEC technology also faces a number of challenges that have limited its commercial viability. One of the main challenges is the high capital cost of building and operating OTEC plants, which can be prohibitively expensive compared to other sources of renewable energy. This is due in part to the need to build large and complex infrastructure, such as pipes and heat exchangers, to transfer the warm surface water and cold deep water to the OTEC plant.

## 3.7. Geothermal energy

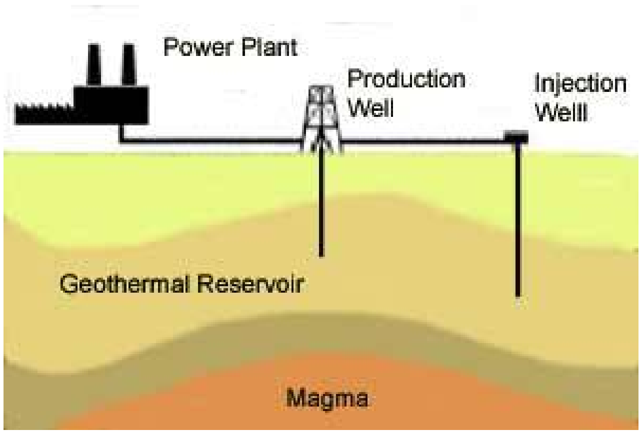
Geothermal energy is a renewable source of energy that harnesses the heat produced by the Earth's core to generate electricity. This form of energy has been used for thousands of years, and it continues to be an important source of energy today. The history of geothermal energy can be traced back to ancient times when people used hot springs for bathing and heating. The first geothermal power plant was built in Italy in 1904, and since then, the technology has continued to evolve. Geothermal energy is sourced from the heat generated by the Earth's core. The Earth's core is estimated to have a temperature of around 6,000°C. This heat is transferred to the Earth's crust through a process called conduction. The crust acts as a natural insulator, trapping the heat within the Earth's core.




The principle of geothermal energy is based on the fact that the Earth's crust is a massive heat reservoir. The heat energy from the Earth's core is constantly flowing to the surface of the Earth. This energy can be harnessed using various geothermal technologies. Geothermal energy can be extracted in different ways, depending on the type of geothermal resource. There are three main types of geothermal resources: hydrothermal, petrothermal, and enhanced geothermal systems (EGS). Hydrothermal resources are the most common type of geothermal resource. They are found in areas where there is a combination of high heat flow and high permeability. These areas are usually located near tectonic plate boundaries, where there is a lot of volcanic activity. Hydrothermal resources are typically found in the form of hot springs and geysers. Petrothermal resources are found in areas where the Earth's crust is hot but impermeable. These resources require drilling into the Earth's crust to access the hot rocks. The heat from the rocks is then used to generate electricity. Overall, geothermal energy is a promising source of renewable energy that has the potential to provide a significant portion of the world's energy needs. As the technology continues to improve, geothermal energy is likely to become an increasingly important source of clean, reliable, and sustainable energy.

### 3.7.1. Harnesses of geothermal energy

Geothermal energy is harnessed using various technologies depending on the type of geothermal resource. The most common method used to harness geothermal energy is called a geothermal power plant. Geothermal power plants use the heat from the Earth's crust to generate electricity. They typically consist of four main components: a production well, a heat exchanger, a turbine, and a generator.




- **Production well:** A production well is drilled into a geothermal reservoir to access the hot water or steam. The hot water or steam is then pumped to the surface.
- **Heat exchanger:** The hot water or steam is passed through a heat exchanger, where it is used to heat a working fluid, such as ammonia or butane. The working fluid boils, producing high-pressure steam that is used to drive a turbine.
- **Turbine:** The high-pressure steam from the heat exchanger is used to drive a turbine. The turbine is connected to a generator that converts the mechanical energy from the turbine into electricity.
- **Generator:** The generator converts the mechanical energy from the turbine into electricity. The electricity is then sent to the power grid.

There are different types of geothermal power plants, including binary cycle, flash steam, and dry steam power plants.

**i. Binary cycle power plants:**

In binary cycle power plants, the hot water or steam from the production well is passed through a heat exchanger, where it heats a secondary fluid with a lower boiling point, such as isobutene. The secondary fluid then boils and drives a turbine.

**ii. Flash steam power plants:**

In flash steam power plants, the hot water from the production well is flashed, or rapidly depressurized, in a flash tank. The rapid depressurization causes the water to boil and produce steam. The steam is then used to drive a turbine.

### iii. Dry steam power plants:

In dry steam power plants, the steam from the production well is used directly to drive a turbine. Dry steam power plants are only possible in areas where the geothermal reservoir produces steam with no water content.

### 3.7.2. Types of geothermal energy

There are primarily three types of geothermal energy:

- Hydrothermal Energy
- Enhanced Geothermal Systems (EGS)
- Ground-source heat pumps (GSHPs)

**a. Hydrothermal Energy**

Hydrothermal energy is the most commonly used geothermal energy. It uses the natural circulation of hot water and steam to generate electricity. Hydrothermal systems use two types of geothermal resources:

i. **Vapor-dominated systems:** These systems are found in areas where temperatures are high enough to produce steam, and there is no or little water. These systems use steam directly to drive turbines and generate electricity.

ii. **Liquid-dominated systems:** These systems are found in areas where the temperature is relatively low and produce hot water. In these systems, the hot water is pumped to the surface, where it is used to generate steam to drive turbines and produce electricity.

b. **Enhanced Geothermal Systems (EGS)**

Enhanced Geothermal Systems (EGS) are engineered reservoirs created to extract heat from areas that do not have natural hydrothermal resources. EGS systems work by injecting water into hot dry rock formations, creating fractures in the rock, and then circulating water through the fractures to create a heat exchange.

c. **Ground-source heat pumps (GSHPs):** Ground-source heat pumps (GSHPs) use the constant temperature of the Earth's crust to heat and cool buildings. The pumps circulate a fluid through a loop of pipes buried in the ground, transferring heat to or from the ground depending on the season.

d. In addition to these three primary types, there are also other geothermal energy technologies being developed, such as co-produced geothermal and hybrid systems. Co-produced geothermal systems use waste fluids from oil and gas production to generate electricity, while hybrid systems combine geothermal with other renewable energy sources such as solar or wind to increase energy efficiency and reduce costs.

### 3.7.3. Advantages of geothermal energy:

- ✓ Geothermal energy is base on load power.
- ✓ It is economically feasible in high grade areas now
- ✓ Geothermal energy is environmental benign technology because it produces very little greenhouse gas emissions or pollution.
- ✓ It requires the cost effects and low developmental cost. This makes it a cost-effective source of energy in the long run.
- ✓ Geothermal power plants have high efficiency rates and can operate 24/7.
- ✓ Geothermal power plants have a high capacity factor; they run continuously day and night with an uptime typically exceeding 95 percent.

### 3.7.4. Disadvantages of geothermal energy

- ✓ Geothermal energy resources are location-specific and are only available in certain areas.
- ✓ The construction of geothermal power plants can have an impact on the environment. The drilling and extraction of geothermal fluids can cause earthquakes and land subsidence, which can impact nearby ecosystems.
- ✓ The upfront costs of building a geothermal power plant can be high.

## 3.8. Indian scenario of renewable energy consumption

Renewable energy consumption in India has seen a significant increase in recent years, driven by government policies and initiatives aimed at promoting clean energy. The country is rapidly transitioning from fossil fuels to renewable energy, with a target to achieve 175 GW of renewable energy capacity by 2022. This target has now been increased to 450 GW by 2030. India is blessed with abundant renewable energy resources, including solar, wind, hydro, biomass, and geothermal. The country has a vast potential for renewable energy, with over 300 days of sunshine and large wind corridors along the coastlines and in the hinterland. India is also home to several large rivers that can be used for hydroelectricity generation.

**Solar Energy**: India has made remarkable progress in solar energy, and it is one of the fastest-growing solar markets in the world. The government has set a target of installing 100 GW of solar capacity by 2022, of which 40 GW is expected to come from rooftop solar systems. India is now the third-largest solar market in the world, with a cumulative installed capacity of over 40 GW as of December 2021.

**Wind Energy**: India has a large potential for wind energy, with over 8,000 km of coastline and several high-wind corridors in the hinterland as Rajasthan. The country is the fourth-largest wind power market in the world, with a cumulative installed capacity of over 40 GW as of December 2021. The wind energy sector in India is dominated by large-scale utility projects, with several large wind parks being developed across the country.

**Hydro Energy:** India has a large potential for hydro energy, with several large rivers and their tributaries flowing through the country. The government has set a target of achieving 40 GW of installed capacity from hydroelectric power by 2030. As of December 2021, India's cumulative installed capacity from hydroelectric power was over 50 GW.

**Biomass Energy:** India has a large potential for biomass energy, with several sources of biomass available, including agriculture and forestry waste, municipal solid waste, and biogas from anaerobic digestion. The government has set a target of achieving 10 GW of installed capacity from biomass energy by 2030. As of December 2021, India's cumulative installed capacity from biomass energy was over 9 GW. The biomass energy sector in India is dominated by small-scale projects, with several decentralized systems being developed across the country.

**Geothermal Energy:** India has a limited potential for geothermal energy, with only a few regions having suitable geothermal resources. The government has set a target of achieving 1 GW of installed capacity from geothermal energy by 2030. As of December 2021, India had no installed capacity from geothermal energy. The government has introduced several policies and incentives to promote the adoption of geothermal energy.

## 3.9. Summary

Renewable energy resources are those sources of energy that are replenished naturally and can be used continuously without depleting them such are solar, wind, hydroelectric, geothermal, and biomass energy. The demand for renewable energy resources has been on the rise in recent years due to concerns about climate change, air pollution, and the depletion of non-renewable energy resources. In this article, we will provide an introduction to renewable energy resources, their types, and the benefits of using them. Solar Energy is the energy obtained from the sun's rays. It is harnessed through the use of solar panels, which convert sunlight into electricity. Examples include solar water heaters, solar-powered lights, and solar-powered cars. Wind Energy is the energy obtained from the wind's motion. It is harnessed through the use of wind turbines, which convert the kinetic energy of the wind into electricity. Biomass Energy is the energy obtained from organic matter such as plants, wood, and agricultural waste. Ocean Energy is the energy obtained from the ocean's waves, tides, and currents. It is harnessed through the use of various technologies such as wave energy converters and tidal turbines. The renewable energy resources are increasingly being used to generate electricity and heat, and they offer a sustainable alternative to fossil fuels. They have the potential to reduce greenhouse gas emissions and mitigate the impact of climate change while promoting energy security and economic development.

## 3.10. Terminal questions

**Q.1.** What do you understand by renewable energy?

**Answer**-----------------------------------------------------------------------------------------------------------

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**Q.2.** What is the solar energy? Why should used solar energy?

**Answer:**----------------------------------------------------------------------------------------------------------

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**Q.3.** Discuss the concept of solar energy and its uses.

**Answer:**-----------------------------------------------------------------------------------------------------
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**Q.4.** Define the wind energy. How to generate wind energy?

**Answer:**-----------------------------------------------------------------------------------------------------
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**Q.5.** What is the hydropower energy? How hydropower is produce energy?

**Answer:**-----------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------------

**Q.6.** What is geothermal energy? Discuss its advantage and disadvantage?

**Answer:**-----------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------------

**Q.7.** Discuss renewal energy scenario of India.

**Answer:**-----------------------------------------------------------------------------------------------------
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## 3.11. Further suggested readings


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**SBSEVS-01N**

***Energy Resources and Green Technology***

# Block- II

# Biomass Energy and Energy Polices

## UNIT -4

## Biomass as a Energy Resources

## UNIT-5

## Other Source of Energy

## UNIT-6

## Energy Policies

# Unit- 4: Biomass as energy source

**Structure**



## 4.1. Introduction

People have used biomass energy from living things since the earliest “cave men” first made wood fires for cooking or keeping warm. Biomass is organic, meaning it is made of material that comes from living organisms, such as plants and animals. The most common biomass materials used for energy are plants, wood, and waste. These are called biomass feedstock's. Biomass energy can also be a non-renewable energy source. Biomass contains energy first derived from the sun: Plants absorb the sun's energy through photosynthesis, and convert carbon dioxide and water into nutrients (carbohydrates). The energy from these organisms can be transformed into usable energy through direct and indirect means. Biomass can be burnt to create heat (direct), converted into electricity (direct), or processed into biofuels (indirect).

Biomass is a promising option for providing locally produced, renewable energy in Pennsylvania. While it is not unusual for homes in the state to be heated with firewood, other forms of biomass fuel are not as common and commercial-scale use of biomass fuel is very limited. A person who plans to use biomass for fuel or design equipment for biomass heat needs to understand the performance characteristics of biomass in order to avoid possible problems and utilize the biomass effectively. Biomass can be a source of liquid fuel (e.g., biodiesel) or gaseous fuel (e.g., wood gas), but the most common use is as a solid fuel (e.g., wood, biomass pellets).

**Objectives**

This is the second block on energy resources and green technology. It consists of following two units. Under forth unit (Biomass as energy source) we have following objectives. These are as under:

- To know definition of biomass resources.
- To know about dedicated bioenergy crops
- To know about different bioenergy routes from biomass.
- What are the challenges in bioenergy utilization?

## 4.2. Biomass as energy source

The energy from these organisms can be transformed into usable energy through direct and indirect means. Biomass can be burned to create heat (direct), converted into electricity (direct), or processed into befoul (indirect). The climate impact of bioenergy varies considerably depending on where biomass feedstock's come from and how they are grown. For example, burning wood for energy releases carbon dioxide; those emissions can be significantly offset if the trees that were harvested are replaced by new trees in a well-managed forest, as the new trees will absorb carbon dioxide from the air as they grow. However, the establishment and cultivation of bioenergy crops can displace natural ecosystems, degrade soils, and consume water resources and synthetic fertilisers.

The main biomass types harvested directly for energy is wood, some food crops and all perennial energy crops. One third of the global forest area of 4 billion hectares is used for wood production or other commercial purposes, and forests provide 85% of all biomass used for energy globally. In the EU, forests provide 60% of all biomass used for energy, with wood residues and waste being the largest source.

Woody biomass used for energy often consists of trees and bushes harvested for traditional cooking and heating purposes, particularly in developing countries, with 25 EJ per year used globally for these purposes. This practice is highly polluting. The World Health Organization (WHO) estimates that cooking-related pollution causes 3.8 million annual deaths. The United Nations Sustainable Development Goal 7 aims for the traditional use of biomass for cooking to be phased out by 2030. Short-rotation coppices and short-rotation forests are also harvested directly for energy, providing 4 EJ of energy, and are considered sustainable. The potential for these crops and perennial energy crops to provide at least 25 EJ annually by 2050 is estimated (EJ-Exajoule, IEJ = $10^{18}$J].

Food crops harvested for energy include sugar-producing crops (such as sugarcane), starch-producing crops (such as corn), and oil-producing crops (such as rapeseed). Sugarcane is a perennial crop, while corn and rapeseed are annual crops. Sugar- and starch-producing crops are used to make bio-ethanol, and oil-producing crops are used to make biodiesel. The United States is the largest producer of bio-ethanol, while the European Union is the largest producer of biodiesel. The global production of bioethanol and biodiesel provides 2.2 and 1.5 EJ of energy per year, respectively. Bio-fuel made from food crops harvested for energy is also known as "first-generation" or "traditional" bio-fuel and has relatively low emission savings. The IPCC (Intergovernmental Pannel of Climate Change) estimates that between 0.32 and 1.4 billion hectares of marginal land are suitable for bioenergy worldwide.

## 4.3. Biomass Resources

The term **Biomass Resources,** sometimes referred to as *biorenewable resources*, are all forms of organic materials, including plant matter both living and in waste form, as well as animal matter and their waste products. As such biomass resources are generally classified as being either waste materials or dedicated energy crops. A waste material can be any municipal solid waste and industrial waste material that has been discarded because it no longer has any apparent value to the user or which represents a nuisance or even a potential pollutant to the local environment. If the organic waste products from one process was used as primary source of feedstock in another process.

For example, materials such as waste cardboard, wood and paper recycled into newspapers, books and magazines, etc. If these waste materials were economically converted into electricity, heat, liquid bio-fuels, or chemicals, then they could be considered as a biomass resource rather than an unwanted waste stream. Waste materials that would qualify as a biorenewable resource include agricultural residues, yard and garden waste, municipal solid waste, food processing waste, animal manure, etc. Existing landfill areas are now filled beyond capacity.

The search for new landfill sites for the dumping of solid waste is becoming increasingly difficult due to public protest. Finding new landfill sites away from urbanized areas means that the longer distance travelled from the city center increases the wastes transportation cost tremendously. But the energy generated from waste cannot be ignored as a valuable bioenergy source. If effectively harnessed, the energy produced from wastes can be used to lessen the demand for energy generation using nonrenewable fossil fuel sources. Furthermore, the generation of energy from solid waste materials brings extra significance by reducing the volume of the the unwanted waste, saving on landfill space and providing a biomass resource which would otherwise be of no value.

## 4.4. Dedicated Energy Crops

Dedicated energy crops are grown specifically for their utilization in energy conversion processes in ways that do not displace food production. They provide a source for the production of renewable energy, chemicals, and materials due to their composition of sugars, lipids, proteins, and fibers. These crops are often referred to as cellulosic biomass and are further classified into herbaceous and short-rotation wood crops (fuel wood). Short-rotation wood crops are subdivided into softwood and hardwood, each of which has individual benefits, depending on the conversion process, desired products, or applications. Hardwoods contain less ash than softwoods, but they also contain less carbon, have a lower energy density, and have less availability as residues. Herbaceous energy crops are divided into perennials (3–10 year growing cycles) and annuals, with perennials being the preferred resource.

In general, energy crops with a larger fraction of fibrous material (lignocellulose) contain the highest calorific value, making it advantageous to maximize the yield of this plant fraction for the production of energy and fuels. Fuel wood (dedicated energy crop) produces usable heat for the residential, commercial, and power in the electric utility sector. This accounted for 30% of the current consumption of woody biomass and 20% of the total US biomass energy consumption. Approximately 65% of biomass consumed in 2010 was from forest crops. The main herbaceous dedicated energy crops in the US are used for transportation fuels such as ethanol from corn grain and biodiesel from soybeans. Corn ethanol production uses 35% of the total US corn grain crop produced in 2009. Therefore, dedicated energy crops have low availability in terms of potential unused resources.

Most potential dedicated energy crops of natural vegetation are perennial species. Propagation will involve transplanting of rhizome pieces during autumn and winter. Initially this may be done by hand but considerable mechanisation is possible using techniques developed in the Swedish Energy Reed Project. Once a healthy stand is established repeated harvesting will be possible without incurring annual planting costs. The time and frequency of harvesting will be dictated by factors such as the possibility of regret within a growing season, the resilience of the vegetation to successive annual harvests and the need to replace, by fertilizer application, the plant nutrients removed by harvesting. The strategy selected will depend on the economic choice between maximizing energy yield and minimizing the energy input involved in management. Bracken and Butterbur illustrate two possible strategies.

Dedicated energy crops are crops that are specifically grown for the purpose of producing bioenergy. These crops have high energy content and can be grown on land that is unsuitable for food crops. Some of the dedicated energy crops include:

**Switchgrass (Panicum Virgatum):** Switchgrass is a perennial grass that is native to North America. It has a high biomass yield and can grow in a wide range of soil types and climatic conditions. Switchgrass is used for biofuel production, as well as for soil conservation and as a forage crop for livestock.

**Gaint-Miscanthus:** (Hybrid of Miscanthus sinensis and M. sacchariflorus) Miscanthus is a perennial grass that is native to Asia. It has a high biomass yield and can grow in a wide range of soil types and climatic conditions. Miscanthus is used for biofuel production, as well as for soil conservation and as a forage crop for livestock.

**Willow (Salizx):** Willow is a fast-growing woody crop that can be harvested for bioenergy after just a few years of growth. It is native to temperate regions and can grow in a wide range of soil types and climatic conditions. Willow is used for biofuel production, as well as for soil conservation and as a source of wood for furniture and other products.

**Poplar (Populus) :** Poplar is a fast-growing woody crop that can be harvested for bioenergy after just a few years of growth. It is native to temperate regions and can grow in a wide range of soil types and climatic conditions. Poplar is used for biofuel production, as well as for soil conservation and as a source of wood for furniture and other products.

**Sugarcane (Saccharum officinarum):** Sugarcane is a tropical grass that is native to Southeast Asia. It has a high biomass yield and is used for biofuel production, as well as for the production of sugar and other products.

**Jatropha (Jatropha curcas)** : Jatropha is a tropical shrub that is native to Central and South America. It has a high oil content and is used for the production of biodiesel.

**Cammelina:** Camelina is an oilseed crop that is native to Europe and Central Asia. It has a high oil content and can be grown in rotation with other crops. Camelina is used for the production of biodiesel.

**Algae:** Algae are aquatic organisms that can be grown in ponds or tanks. They have a high oil content and can be used for the production of biodiesel.

These crops are being researched and developed to increase their yield, efficiency, and sustainability as a source of bioenergy.

## 4.5. Characteristics of bioenergy crops

Plant species, with fast growth, tolerance to biotic and abiotic stresses, and low requirements for biological, chemical or physical pretreatments, are being evaluated as potential bioenergy crops. Here are some characteristics of energy crops:

### 5.5.1. Agronomic and architectural traits:

Agronomically bioenergy crop should require low inputs for establishment, need low fossil fuel inputs, should be adaptable to marginal lands, and provide high biomass and energy yield that is expected to help reduce global warming and combat Global Climate Change (GCC).

### 5.5.2. Physiological and eco-physiological traits:

A bioenergy crop plant can be viewed as a solar energy collector and thermo-chemical energy storage system. Numerous physiological and eco-physiological traits needed to maximize radiation interception, radiation, WUE (Water use efficiency) and NUE (Nitrogen use efficiency), and to confer environmental sustainability, should be targeted to enhance plant biomass and bioenergy production

### 5.5.3. Biochemical composition and caloric content:

The caloric value of a material is an expression of the energy content, or heat value, released when burned in air. Plants differ in their biochemical composition (i.e., carbohydrates, proteins, lipids, organic acids, etc.) and in the amount of glucose to produce a unit of these organic compounds. Therefore, plant composition determines the availability of energy from specific biomass type. The climate impact of bioenergy varies considerably depending on where biomass feedstock comes from and how they are grown. For example, burning wood for energy releases carbon dioxide; those emissions can be significantly offset if the trees that were harvested are replaced by new trees in a well-managed forest, as the new trees will absorb carbon dioxide from the air as they grow. However, the establishment and cultivation of bioenergy crops can displace natural ecosystems, degrade soils, and consume water resources and synthetic fertilizers.

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**Wood:** The calorific content of wood varies depending on the species and moisture content, but it typically ranges from 16-20 MJ/kg.

**Grasses:** The calorific content of grasses also varies depending on the species and moisture content, but it typically ranges from 15-18 MJ/kg.

**Agricultural residues (such as corn stover and wheat straw):** The calorific content of agricultural residues varies depending on the type of residue and the method of harvesting, but it typically ranges from 12-15 MJ/kg.

**Algae:** The calorific content of algae is relatively low compared to other types of biomass, ranging from 7-12 MJ/kg.

**Municipal solid waste:** The calorific content of municipal solid waste varies depending on the composition of the waste, but it typically ranges from 8-12 MJ/kg.

It is important to note that the biochemical composition and calorific content of biomass can be affected by various factors, such as the stage of growth, the method of cultivation, and the climate conditions. Therefore, it is important to carefully select and cultivate biomass sources to maximize their energy potential.

## 4.6. Bioenergy routes from biomass

Over the last century, there has been increasing debate concerning the use of biomass for different purposes such as foods, feeds, energy fuels, heating, cooling and most importantly biorefinery feedstock. The biorefinery products were aimed to replace fossil fuels and chemicals as they are renewable form of energy. Biomass is a biodegradable product from agricultural wastes and residues, forestry and aquaculture. Biomass could be sourced from a variety of raw materials such as wood and wood processing by-products, manure, fractions of organic waste products and agricultural crops. As a form of renewable energy, they have the advantages of easy storage, transportation, flexible load utilization and versatile applications. The aim of this study is to provide an overview for thermo chemical and biochemical biomass conversion technologies that were employed currently. Attention was also paid to manufacture of biofuel because of their potentials as key market for large-scale green sustainable biomass product.

Biomass is matter from recently living (but now dead) organisms which is used for bioenergy production. There are variations in how such biomass for energy is defined, e.g. only from plants, or from plants and algae, or from plants and animals. The vast majority of biomass used for bioenergy does come from plants. Bioenergy is a type of renewable energy with potential to assist with climate change mitigation.

Some people use the terms biomass and biofuel interchangeably, but it is now more common to consider biofuel to be a liquid or gaseous fuel used for transportation, as defined by government authorities in the US and EU. From that perspective, biofuel is a subset of biomass.

The European Union's Joint Research Centre defines solid biofuel as raw or processed organic matter of biological origin used for energy, such as firewood, wood chips, and wood pellets.

Biomass (for energy) is matter from recently living (but now dead) organisms which is used for bioenergy production. Examples include wood, wood residues, energy crops, agricultural residues, and organic waste from industry and households. Wood and wood residues is the largest biomass energy source today. Wood can be used as a fuel directly or processed into pellet fuel or other forms of fuels. Other plants can also be used as fuel, for instance corn, switch grass and bamboo (Bambusa spp.). The main waste feed stocks are wood waste, agricultural waste, municipal solid waste, and manufacturing waste. Upgrading raw biomass to higher grade fuels can be achieved by different methods, broadly classified as thermal, chemical, or biochemical.

The climate impact of bioenergy varies considerably depending on where biomass feedstock's come from and how they are grown. For example, burning wood for energy releases carbon dioxide; those emissions can be significantly offset if the trees that were harvested are replaced by new trees in a well-managed forest, as the new trees will absorb carbon dioxide from the air as they grow. However, the establishment and cultivation of bioenergy crops can displace natural ecosystems, degrade soils, and consume water resources and synthetic fertilizers.

In 2020 biomass produced 58 EJ (exajoules) of energy, compared to 172 EJ from crude oil, 157 EJ from coal, 138 EJ from natural gas, 29 EJ from nuclear, 16 EJ from hydro and 15 EJ from wind, solar and geothermal combined. Approximately 86% of modern bioenergy is used for heating applications, with 9% used for transport and 5% for electricity. Most of the global bioenergy is produced from forest resources. The IEA's Net Zero by 2050 scenario calls for traditional bioenergy to be phased out by 2030, with modern bioenergy's share increasing from 6.6% in 2020 to 13.1% in 2030 and 18.7% in 2050. The IPCC (Intergovernmental Panel on Climate Change) believes that bioenergy has a significant climate change mitigation potential if implemented correctly. Most of the IPCC's pathways including substantial contributions from bioenergy in 2050 (average at 200 EJ)

Biomass accumulates chemical energy in form of carbohydrates through combination of solar power and carbon dioxide during the process of photosynthesis. This has made it to be a potential energy source since the carbon dioxide captured during photosynthesis could be released when it burns. It is cheap and available in all forms such as forest and agricultural residues, wood, by-products of biological materials, organic components of municipal and sludge wastes, etc. There are several ways to convert biomass into useful products which largely depends on biomass characteristics and the end product. The technologies applied in the conversion of biomass are mainly categorized under thermo chemical or biological methods. There are several bioenergy routes from biomass, which can be broadly classified into thermal, biochemical, and thermo chemical processes. Each of these routes has its advantages and disadvantages, and the choice of route depends on factors such as the availability of feedstock, the desired end products, and the local conditions.

Biomass can be converted into several useful products for energy generation and chemicals. There are some factors that influence the choice of a conversion technology to be applied on the biomass. These factors include quality and quantity of the biomass feedstock, availability, choice of end-products, process economics and environmental issues as in given figure.

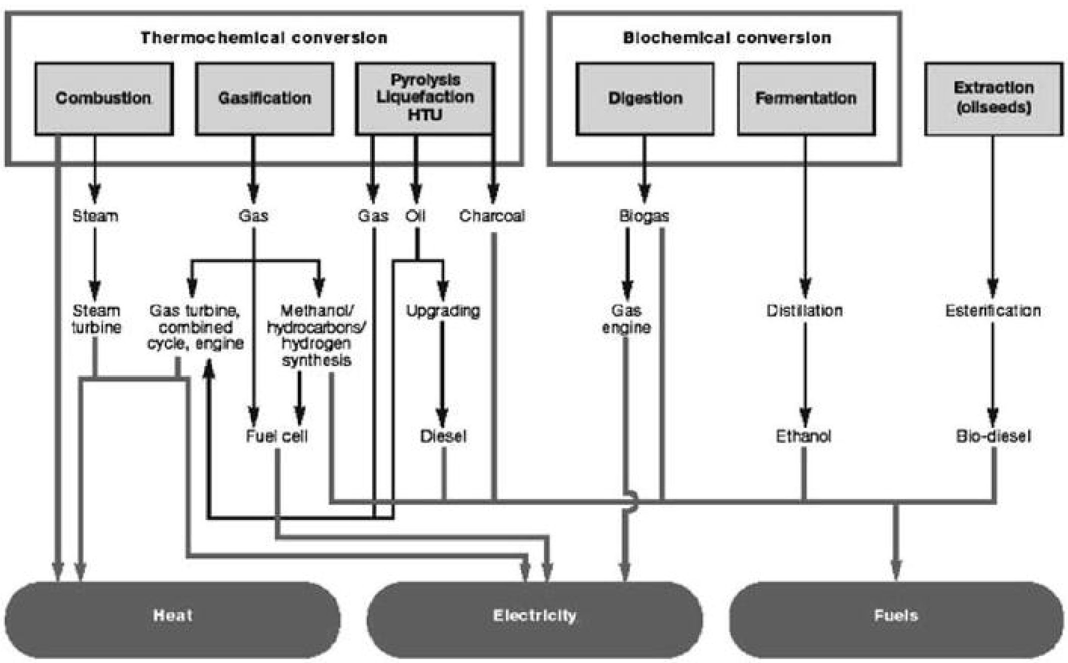


**Fig.4.1:** Main biomass conversion routes

### 4.6.1. Thermal processes:

Biomass can be converted into energy through thermal processes, which involve the combustion of biomass to produce heat. The heat can be used to generate steam, which is then used to generate electricity or produce heat for industrial processes. Thermal processes include direct combustion, co-firing, and gasification.

a) **Direct combustion:** This is the simplest and most common method of biomass conversion. The biomass is burned in a boiler to produce heat, which is then used to generate electricity or produce heat for industrial processes. Direct combustion can be carried out using a range of biomass feedstocks, including wood chips, sawdust, and agricultural residues.
b) **Co-firing:** Co-firing involves the combustion of biomass along with coal in existing coal-fired power plants. Co-firing can reduce greenhouse gas emissions and has a lower cost of implementation than building new biomass power plants. The main challenge is the availability and quality of biomass feedstock.
c) **Gasification:** Gasification involves the conversion of biomass into a gas called syngas, which can be used to generate electricity or produce heat for industrial processes. Syngas can also be converted into transportation fuels or chemicals. Gasification can achieve high efficiency and reduce greenhouse gas emissions, but it requires a high capital investment and careful management of the gas cleaning process.

### 4.6.2. Biochemical processes:

Biomass can also be converted into energy through biochemical processes, which involve the use of microorganisms to break down biomass and produce bioproducts such as biofuels, bioplastics, and biochemicals. Biochemical processes include fermentation, anaerobic digestion, and enzymatic hydrolysis.

#### 1. Fermentation:

Biomass can be fermented to produce bioethanol, a transportation fuel that can be blended with gasoline. Fermentation can be carried out using different microorganisms, including yeast and bacteria. The technology is well-established, but the production cost can be high, and it competes with food production. In fermentation process microorganisms such as yeast and bacteria convert sugars in biomass into biofuels such as bioethanol and biobutanol. Fermentation can also produce other bioproducts such as organic acids and enzymes. The main challenge of fermentation is the high cost of feedstock and the competition with food production.

a) **Anaerobic digestion:** Anaerobic digestion involves the breakdown of biomass in the absence of oxygen using microorganisms to produce biogas, which is composed of methane and carbon dioxide. Biogas can be used to generate electricity or heat, or it can be upgraded to biomethane, which can be used as a transportation fuel. Anaerobic digestion can achieve high efficiency and reduce greenhouse gas emissions, but it requires careful management to ensure that the input materials are properly prepared.

b) **Enzymatic hydrolysis**: Enzymatic hydrolysis involves the use of enzymes to break down cellulose and hemicelluloses in biomass into sugars, which can be fermented to produce biofuel. Enzymatic hydrolysis can achieve high efficiency, but the cost of enzymes and the quality of feedstock are important challenges.

Currently, the use of lignocelluloses biomass as raw material for the generation of bioenergy has received a considerable attention for the development of sustainable ways for production of energy. Most of the researches conducted for biomass conversion technologies heads towards discovery of advanced ways to produce energy fuels so as to tackle its shortage that the world is facing. Also, the studies are aimed towards reduction of greenhouse gases and other harmful effects posed by fossil fuels to the environment. From above, it can be concluded that biomass is a green source of energy in recent times. The study also indicated that thermo-chemical and biochemical technologies for the conversion of biomass into different energy products was started several decades ago, but it slowed down due to the discovery of fossil fuels. The biomass conversion technologies gained momentum recently due the fact that it is clean, sustainable and renewable source of energy.

### 4.6.3. Thermo chemical processes:

The major options within thermo chemical biomass conversion processes include combustion, gasification, pyrolysis, and liquefaction as in given figure. The most practiced thermo chemical conversion of biomass industrially is combustion process, which is used for heat and electricity generation. Most of biomass thermo chemical conversions were carried out with or without the use of catalysts, though the use of catalyst has distinct effects on the end-products.

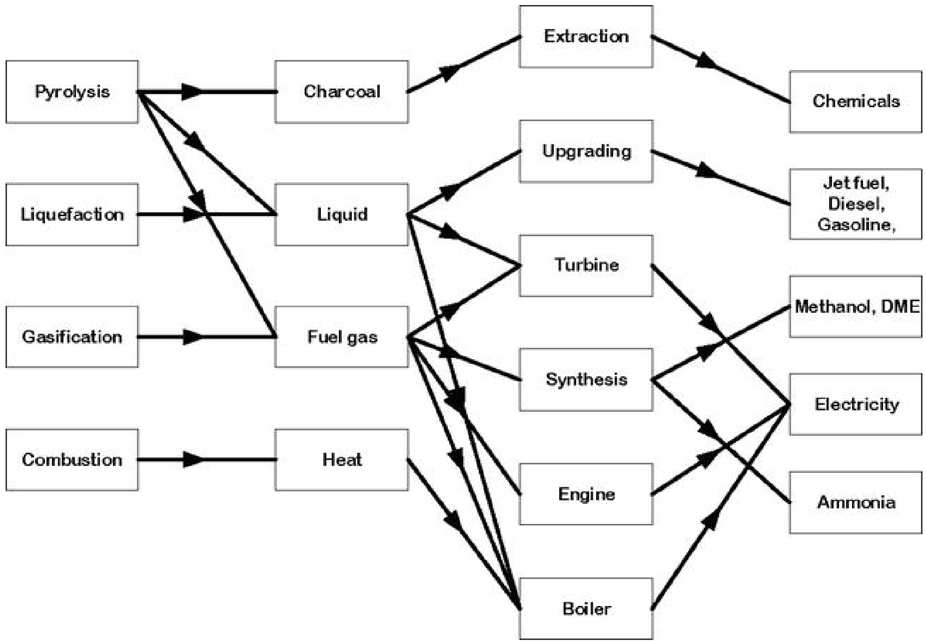


**Fig.4.2:** Thermo chemical conversion processes and end products

### 4.6.3.1.Combustion:

Biomass combustion involves burning biomass in the presence of oxygen to produce heat and steam. The heat can be used to generate electricity, heat buildings, or power industrial processes. Combustion is a mature technology and can be used with a variety of biomass feedstocks, including wood, agricultural residues, and municipal solid waste.

**Pyrolysis:** Pyrolysis involves heating biomass in the absence of oxygen to produce biochar, a solid residue that can be used as a soil amendment, and a liquid called pyrolysis oil, which can be used as a transportation fuel. Pyrolysis can produce high-quality biofuel. The term pyrolysis is defined as the thermal depolymerization of organic matter in the presence of nitrogen or absence of oxygen. Pyrolysis is an exothermic reaction with heat requirements that ranges between 207 and 434 kJ/kg of which many wood based and agricultural biomasses were heated in an inert atmosphere to produce vapors and a carbon rich residue. The vapors composed of fragments from cellulose, hemicelluloses and lignin polymers. These vapors can be condensed into free flowing organic liquid known as the bio-oil. On the other hand, the remaining carbon residues is left as bio-char as in given figure.

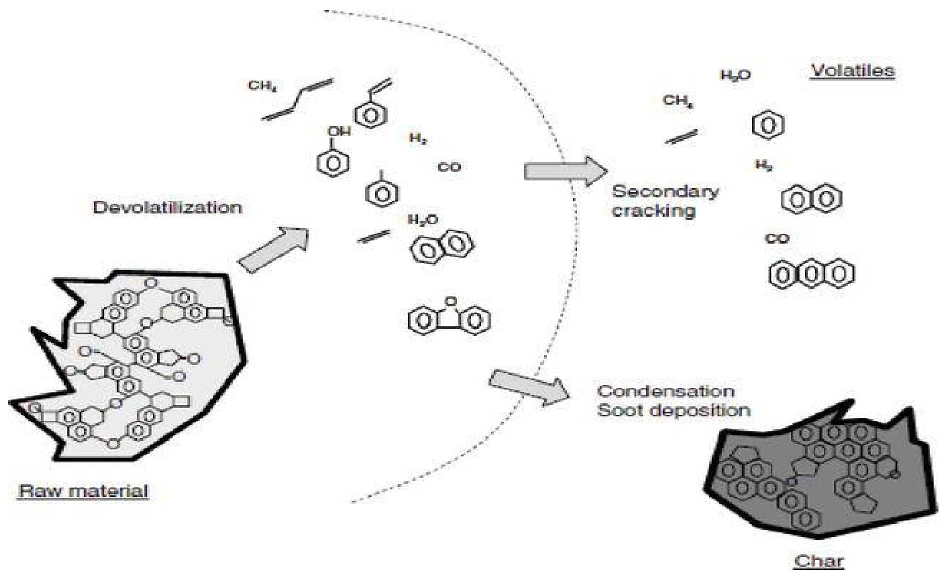


**Fig.4.3:** Carbonization reaction scheme of a carbonaceous material

The polymeric substances distribution in bio-oil largely depends on the lignocelluloses contents of the biomass feed. Many researchers investigated the individual pyrolysis characteristics of cellulose, hemicelluloses and as well lignin. Hemicelluloses was observed to decomposes at 220-315°C, cellulose decomposes between the range of 314-400 °C, while lignin decomposition takes place from 160 to 900°C and it generates a solid residue with highest percentage of about 40%. From energy view point, cellulose pyrolysis was observed to be an endothermic reaction, while the reactions of hemicellulose and lignin are an exothermic. The gaseous products obtained from pyrolysis of these three components were similar and mainly comprises of Carbon dioxide ($CO_2$), Carbon Monoxide (CO), Methane ($CH_4$) and other organic gases. Micro Gas Chromatography (Micro-GC) was employed to analyze the releasing behavior of the $H_2$ and total gases released when the three gases were pyrolyzed in a packed bed. Hemicelluloses was observed to have higher yield for $CO_2$, cellulose gives higher yield for CO with high presence of aromatic ring and methoxyl, while the lignin cracking and deformation yields higher $H_2$ and $CH_4$.

#### 4.6.3.2.Gasification

The process of biomass gasification was discovered independently in France and England by the year 1798. The technology did not come into its limelight until 60 years later. The gasification process continued flourishing until 30 years later when natural gas from oil fields was discovered. Until 1970, the use of natural gas for cooking and lighting was substituted with liquid fuels due to discovery of oil. Generally, biomass gasification is an endothermic thermo chemical conversion of solid biomass fuel using gasifying agents such as air, steam or $CO_2$ to form a mixture of combustible gases which may include $H_2$, $CH_4$, CO and $CO_2$. The process is carried out at temperatures between 800 and 1300°C. Nowadays, flexibility of the gasification technology coupled with the different uses of the produced syngas, allows for the integration of biomass gasification with many industrial processes and as well with power generation systems.

Biomass feedstock characteristics such as particle size, moisture content, shape, heating value, carbon content and ash content significantly affect the gasifies performance. However, knowledge on feedstock parameters such as volatility, elemental analysis, heat content and biomass potential for fouling or slogging is essential for evaluation of gasification process. Therefore, feedstock with low volatile contents is preferred for partial oxidation gasification, while those with high volatile content are more suitable for indirect gasification process.

**4.6.3.3.Hydrothermal gasification**

Hydrothermal gasification is a biomass treatment that involves the use of water at high temperatures and pressures. Products formed during this process are as a result of different reactions that take place in the biomass which mainly depends on factors like temperature, pressure, and time of treatment. To understand the process, behavior of water at high temperature and pressure must be known. The given figure indicated the phase diagram of water, where at 273.15 K and atmospheric pressure (0.101325 MPa), ice melts to liquid water, while at 373.15 K liquid water boils and vapourized to steam. However, boiling point of water is affected by pressure and this means at high pressure the boiling point decreases, while at low pressure it increases. Likewise, pressure has effect on volume of water when it changes to steam. The volume of water increases greatly when it changes to steam. This change in volume is as high as 1600 times under atmospheric pressure.

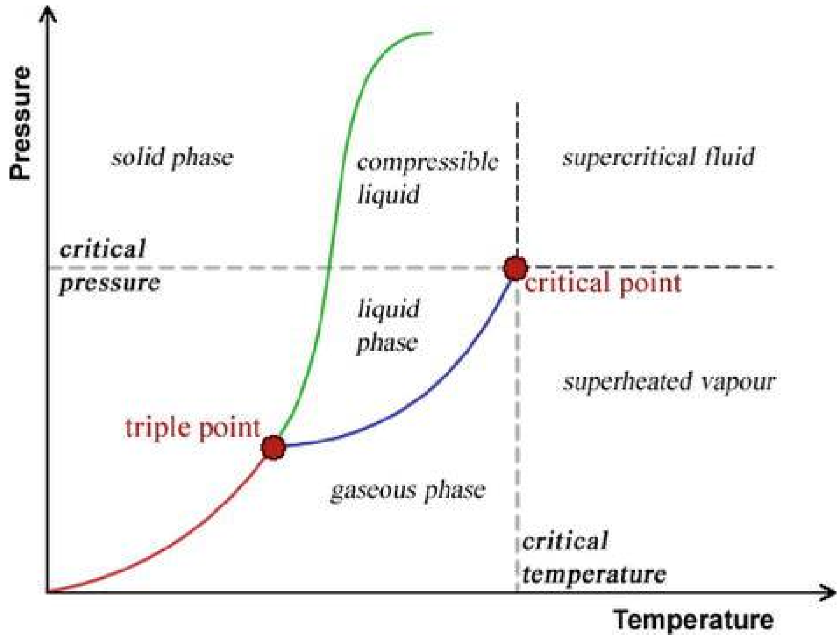


**Fig.4.4:** The Phase diagram of water

Thermochemical processes have the advantage of being able to convert a wide variety of biomass feedstocks into energy, and they can be used to produce electricity, heat, and biofuels. However, they also have some disadvantages, such as high capital costs, high operating costs, and the production of emissions and residues that require proper handling and disposal. Therefore, it is important to carefully evaluate the technical, economic, and environmental aspects of each process to select the most appropriate technology for a specific application.

#### 4.6.3.4. Hydrothermal Liquefaction:

Biomass is heated in the presence of water at high pressure and temperature to produce a liquid called bio-oil, which can be used as a transportation fuel. Hydrothermal liquefaction is an emerging technology that has the potential to produce high-quality biofuels, but the process is still under development and the capital cost can be high.

## 4.8. Utilization of bioenergy

Bioenergy is a field that relates to various processes and applications, because it very often has a very large. This field can concern the production of energy through direct biomass combustion, the use of gas fuels, liquid biofuels, and the use of microbial populations to produce biohydrogen or for waste treatment. Here is an explanation of each of these applications.

Non-edible lignocelluloses biomass materials are attracting increasing attention as renewable, economical, and abundant resources to reduce dependency on petroleum resources and minimize energy and material feedstock costs. These resources do not cause additional increase in the carbon dioxide level in the earth's atmosphere compared to fossil-based energy fuels such as coal, gasoline or natural gas. The carbon dioxide captured in biomass growth mostly balances with the release of carbon dioxide from bioenergy/biofuel. Therefore, use of biomass energy has the potential to reduce greenhouse gas emissions.

Biomass materials are the largest carbon sources for production of various fuels, chemicals and platform compounds and byproducts. Because of their heterogeneous, complex and rigid structures it is hard to breakdown these materials to smaller components and/or convert to a wide range of value-added products. Biomass has a relatively low energy density; therefore, it requires more biomass feedstock's to supply the same amount of energy as a traditional hydrocarbon fuel. High oxygen contents of biomass materials can also negatively affect their conversion to various products such as fuels. For instance, in order to produce hydrocarbons fuels that can be comparable with petroleum-based ones oxygen should be removed from biomass structure. Efficiency of conversion processes can also varied depending on the biomass types (hardwood, softwood, grass, etc.).

## 4.9. Direct biomass combustion

Biomass can be directly burnt in order to produce heat. This is the most basic application of bioenergy, and is the most widespread bioenergy technology. The use of biomass as a heating source, however, can sometimes be more complex than the simple burning of wooden logs. In the past years, wood and herbaceous pellets as well as briquettes have become popular means to create more efficient fuels that can be, in certain regions, less harmful to human health than the direct combustion of biomass.

### 4.9.1. Gas fuels

Through pyrolysis or gasification processes, it is possible to produce fuels from solid biomass. This results into a cycle with a higher thermal efficiency. The first step is a pyrolysis phase (heating of organic matter), which forms a solid char, a liquid fraction and volatile gases. All three fractions can be used independently or further processed. In the creation of syngas, the volatiles and part of the char react with oxygen to create carbon monoxide. The char further reacts with carbon monoxide to create the gaseous fuel called syngas, a mix of dehydrogenate and carbon dioxide. This gas can then be used as a fuel for burning and for electricity generation.

### 4.9.2. Liquid biofuels

Liquid biofuels are usually classified in 2 categories: biodiesel and ethanol. Biodiesel is usually made with vegetable oils or other feedstocks with a high lipid and oil content. The transesterification process generates a less viscous liquid with a relatively high heating value that can be used in diesel engines. It provides lower fine particle counts in the exhaust and is generally considered an extremely "clean" feedstock for a diesel engine. Ethanol is usually produced through the fermentation of certain organic materials under the action of microbial populations or yeasts. It is a good alternative to highly-refined liquid fossil fuels and can replace them in biofuel designed or modified combustion engines. The utilization of biofuels is currently investigated for its applications in motors and other engines, as well as its effects on the expected life of combustion engines that work with blends of liquid biofuels and conventional fossil fuels.

Since 2013, total primary energy consumption in India has been the third highest in the world (see world energy consumption) after China (see energy in China) and United States (see energy in United States). India is the second-top coal consumer in the year 2017 after China. India ranks third in oil consumption with 22.1 cores (221 million) tons in 2017 after United States and China. India is net energy importer to meet nearly 47% of its total primary energy in 2019.

### 4.9.3.Coal

Coal and lignite production was 73.1 cores (731 million) tons in the financial year 2019-2020. India was the fourth top coal producer in 2017 with 294.2 Mote (7.8% global share). Nearly 80% of total electricity generated (utility and captive) in India is from coal and it is the main source of the nation's greenhouse gas emissions. According to Greenpeace the largest coal belt in India is at Jharia. Before coal mining Jharia had forests inhabited by tribes. In 1971 the coal mines were nationalized. Bharat Coking Coal Limited (BCCL) took over Jharia coal mines.

India accounts for the world’s greatest concentration of coal seam fires. Mine area suffers from pollution of air, water and land. As of 2019, coal production was integrated into the Central Government; for example, the Government owned about 75% of Coal India Limited, which supplied about 84% of India's thermal coal. India imports coking coal as good quality coking coal deposits suitable for iron and steel production are not available. In the financial year 2021 -22, India imported nearly 57.16 million tons (90%) against the consumption of 63.74 MT. Sponge iron route using noncoking coal is also followed to produce iron and steel which does not depend on coke or natural gas.

### 4.9.4. Oil and natural gas

India was the third top crude oil consumer globally (4.8% of the world) with 221 Mt in 2017. India was the second-top net crude oil (including crude oil products) importer of 205.3 Mt in 2019. India has 49.72 lakh (4.972 million) barrels per day (5.1% of the world) crude oil refining capacity which is ranked 4th globally in 2017. Nearly 1 core (10.937 million) tons Liquefied Petroleum Gas (LPG) was consumed during April to September 2019 (six months) in the domestic sector mainly for cooking. The number of domestic connections are 274 million (one connection for five people) with a circulation of more than 40 crore (400 million) LPG cylinders whose net aggregate length would form a 2,00,000 km long pipe line which is more than the length of total railway track laid in India. India is second largest consumer of LPG globally. Most of the LPG requirement is imported. Piped city gas supply in India is not yet developed on major scale.

### 4.9.5. Biomass and charcoal

Biomass is a renewable energy source and its use for energy generation is mostly carbon-neutral fuel. Carbon dioxide is first taken up by plants during photosynthesis, and later released when biomass is burned. Presently, only 20% of households in India use biomass and charcoal for cooking purpose as LPG use for cooking purpose is rising rapidly. In addition biomass is also used marginally in commercial cooking, electricity generation, process industries, etc. The total biomass use in India is nearly 177 Mtoe in the year 2013. Substantial surplus crop residue is also burnt in agriculture fields to clear the land for the next crop. Nearly 75 crore (750 million) tons of non edible (by cattle) biomass is available annually in India which can be put to use for higher value addition without $CO_2$ emissions.

Huge quantity of imported coal is being used in pulverized coal-fired power stations. Raw biomass is not suitable for use in the pulverized coal mills as they are difficult to grind into fine powder due to caking problem. However 100% biomass can be fired after torrefaction in the pulverized coal mills for replacing imported coal. Terrified biomass plants can be integrated with existing pulverized coal-fired power stations using the available hot flue gas as heat source. Co-firing dry biomass up to 20% heat input with coal is also possible directly in pulverized coal-fired power stations without facing caking problem. North West and southern regions can replace imported coal use with biomass where surplus agriculture/crop residue biomass is burnt in the fields causing pollution problems. As traditional use of biomass is being replaced by LPG at a faster pace, biomass burning in agriculture fields would become major source for causing higher level air pollution.

Biogas which is mainly methane/natural gas can also be used for generating protein-rich cattle, poultry and fish feed in villages economically by cultivating Methylococcus capsulate bacteria culture with tiny land and water foot print. The carbon dioxide gas produced as by product from these plants can be put to use in cheaper production of algae oil from algae particularly in tropical countries like India which can displace the prime position of crude oil in near future. Union government is implementing many schemes to utilize productively the agro waste or biomass in rural areas to uplift rural economy and job potential.

#### 4.9.6. Biofuel

India imports 85% of petroleum products with an import cost of $55 billion in 2020-21, India has set a target of blending 20% ethanol in petrol by 2025 resulting in import substitution saving of US$4 billion or 30,000 crore and India provides financial assistance for manufacturing ethanol from rice, wheat, barley, corn, sorghum, sugarcane, sugar beet, etc. In 2016, ethanol market penetration had reached 3.3% blend rate.

### 4.10. Electricity

India was the third largest electricity producer in the world with 1,383 TWh generations in FY 2019–2020 and 99.99% of the population having access to power supply. By 2013, India became the world's third largest producer of electricity with 4.8% global share, surpassing Japan and Russia. India ranks 6th globally in hydropower generation during the year 2019. India has

136 GW (38%) installed capacity of renewable energy. It is one of the world leaders in renewable energy investments and installations. India has set a target of 175 gig watts (GW) of renewable energy capacity by 2022. This would include 100 GW capacities from solar energy sources, 60 GW from wind power, 10 GW from blooper, and 5 GW from small hydropower.

## 4.11. Summary

Biomass refers to organic materials, such as wood, crops, and waste that can be used to produce energy. Biomass is considered a renewable energy source because plants can be regrown and waste can be replenished. Biomass can be converted into various forms of energy, such as heat, electricity, and transportation fuels. There are different methods for converting biomass into energy, including combustion, gasification, and anaerobic digestion. Combustion involves burning biomass to produce heat, which can be used to generate steam and produce electricity. Gasification involves heating biomass in the absence of oxygen to produce a gas that can be burned for energy. Anaerobic digestion involves breaking down biomass in the absence of oxygen to produce biogas, which can be used to generate electricity or as a transportation fuel. Biomass has several advantages as an energy source, including its abundance, renewability, and low carbon footprint. However, it also has some drawbacks, such as its potential impact on land use, water use, and biodiversity, as well as the emissions of air pollutants during the conversion process. Overall, biomass can be a promising energy source, especially for communities that have access to ample biomass resources and are looking for a sustainable way to produce energy. However, careful planning and management are necessary to ensure that biomass is used in a responsible and sustainable manner.

## 4.12. Terminal questions

**Q.1.** Describe biomass with examples.

**Answer:-----------------------------------------------------------------------------------------------------**

**-----------------------------------------------------------------------------------------------**

**Q.2.** Explain the characteristics of bioenergy crops.

**Answer:**-----------------------------------------------------------------------------------------------------------

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**Q.3.** What are the biomass resources?

**Answer:**-----------------------------------------------------------------------------------------------------------

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**Q.4.** Write short notes on the followings.

**a)** Dedicated bioenergy crops

**b)** Bioenergy crops

**Answer:**-----------------------------------------------------------------------------------------------------------

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**Q.5.** Explain conversion of biomass into fuels.

**Answer:**-----------------------------------------------------------------------------------------------------------

-----------------------------------------------------------------------------------------------------

**Q.6.** Explain the conversion of biomass into fuels.

**Answer:**-----------------------------------------------------------------------------------------------------------

-----------------------------------------------------------------------------------------------------

**Q.7.** Describe different challenges in bioenergy utilization.

**Answer:**-----------------------------------------------------------------------------------------------------------

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## 4.13. Further readings


1. Environmental Ecology, Bio-Diversity, Climate Change & Disaster Management by Ravi P. Agrahari
2. Environmental Studies: Third Edition by R. Rajagopalan
3. Environment: for Civil Services Prelims & Main and Other competitive examinations by D.R. Khullar and J A C S Rao
4. Environment: for Civil Services, and Other competitive examinations by D.R. Khullar and J A C S Rao

# Unit- 5: Other Source of Energy

**5.1.** Introduction

Objectives

**5.2.** Conventional energy

**5.3.** Non-conventional energy

**5.4.** Non-Conventional Energy Resources in India

5.4.1. Solar Energy

5.4.2. Wind power

5.4.3. Biogas

5.4.4. Tidal Energy

5.4.5. Hydropower

5.4.6. Geothermal energy

**5.5. Energy by nuclear Fusion**

**5.6.** Ethanol production

**5.7.** Pyrolysis

**5.8.** Gasification

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**5.10.** Urban wastes/Municipal solid waste (MSW)

**5.11.** Urban waste to resource recovery

**5.12.** Recycling of energy

**5.13.** Industrial Waste Energy Recycling

**5.14.** Summary

**5.15.** Terminal questions

**5.16.** Further readings

## 5.1. Introduction

Most of the energy we use today comes from fossil fuels (stored solar energy). But fossils fuels have a disadvantage in that they are non-renewable on a human time scale, and because other potentially harmful effects on the environment. In any event, the exploitation of all energy sources (with the possible exception of direct solar energy used for heating); ultimately rely on materials on planet earth.

The potential of renewable energy sources is enormous; they have the potential to meet many times the world's energy demand. Renewable energy sources such as biomass, wind, solar, hydropower, and geothermal can provide sustainable energy services, based on the use of routinely available, indigenous resources. A transition to renewable-intensive energy future is looking increasingly likely. The costs of solar and wind power systems have dropped substantially in the past 30 years, and continue to decline, whereas the price of oil and gas continue to fluctuate. Renewable energy prices and the social and environmental costs of using fossil fuels are heading in opposite directions. Furthermore, the economic and policy mechanisms needed to support the widespread dissemination and sustainable markets for renewable energy systems have also rapidly evolved. It is becoming clear that future growth in the energy sector is primarily in the new regime of renewable (and to some extent natural gas-based) systems, and not in conventional oil and coal sources. Financial markets are awakening to the future growth potential of renewable and other new energy technologies, and this is a likely harbinger of the economic reality of truly competitive renewable energy systems.

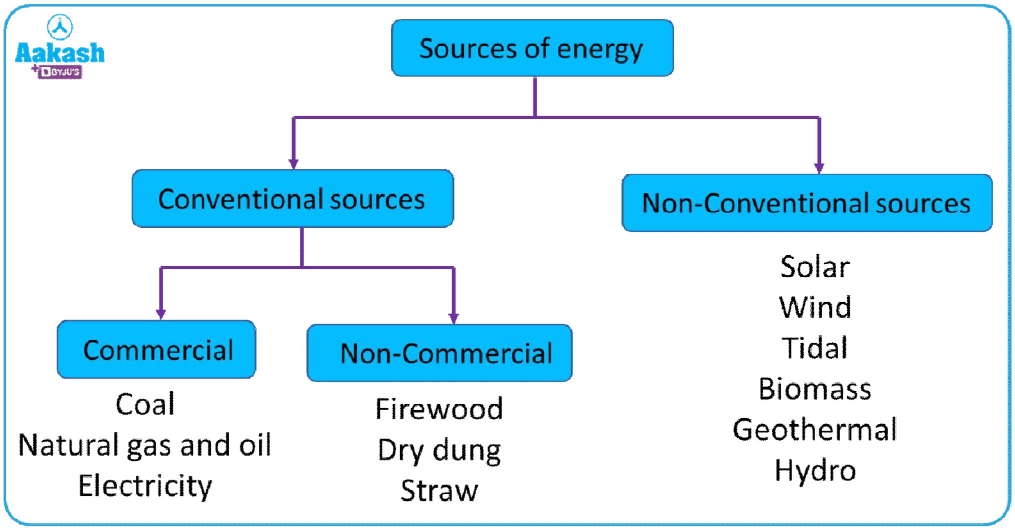



**Fig.5.1**: Different sources of energy

Renewable energy systems are usually founded on a small-scale, decentralized paradigm that is inherently conducive to, rather than at odds with, many electricity distribution, cogeneration (combined heat and power), environmental, and capital cost issues. As an alternative to custom, onsite construction of centralized power plants, renewable systems based on photovoltaic (PV) arrays, windmills, biomass, or small hydropower setups can be viewed as mass-produced "energy appliances" capable of being manufactured at low cost and tailored to meet specific energy loads and service conditions. These systems can have dramatically reduced as well as widely dispersed environmental impacts, rather than larger, more centralized impacts that in some cases are serious contributors to ambient air pollution, acid rain, and global climate change.

Renewable energy sources currently supply somewhere between 15% and 20% of the world's total energy demand. The supply is dominated by traditional biomass, mostly fuel wood used for cooking and heating, especially in developing countries in Africa, Asia, and Latin America. A major contribution is also obtained from the use of large hydropower systems with nearly 20% of the global electricity supply being provided by this source. New renewable energy sources (solar energy, wind energy, modern bioenergy, geothermal energy, and small hydropower) are currently contributing about 2%. A number of scenario studies have investigated the potential contribution of renewable to global energy supplies, indicating that in the second half of the 21st century their contribution might range from the present figure of nearly 20% to more than 50%, with the right policies in place.

**Objectives**

This is the second block on energy resources and green technology. It consists of following two units. Under fifth unit (Other source of energy) we have following objectives. These are as under:

- To know about conventional and nonconventional energy
- To discuss the ethanol and methanol production
- To know about pyrolysis and gasification.
- To know about recycling for energy and resource recovery

Primary energy sources take many forms, including nuclear energy, fossil energy, like oil, coal and natural gas and renewable sources like wind, solar, geothermal and hydropower. These primary sources are converted to electricity, a secondary energy source, which flows through power lines and other transmission infrastructure to your home and business.

The international system of units of measurement of energy is joule. The unit of energy is named after James Prescott Joule. Joule is a derived unit equal to the energy expended in applying a force of one Newton through a distance of one meter. However, energy is also expressed in many other units not part of the SI, such as ergs, calories, British Thermal Units, kilowatt-hours, and kilocalories, which require a conversion factor when expressed in SI units.

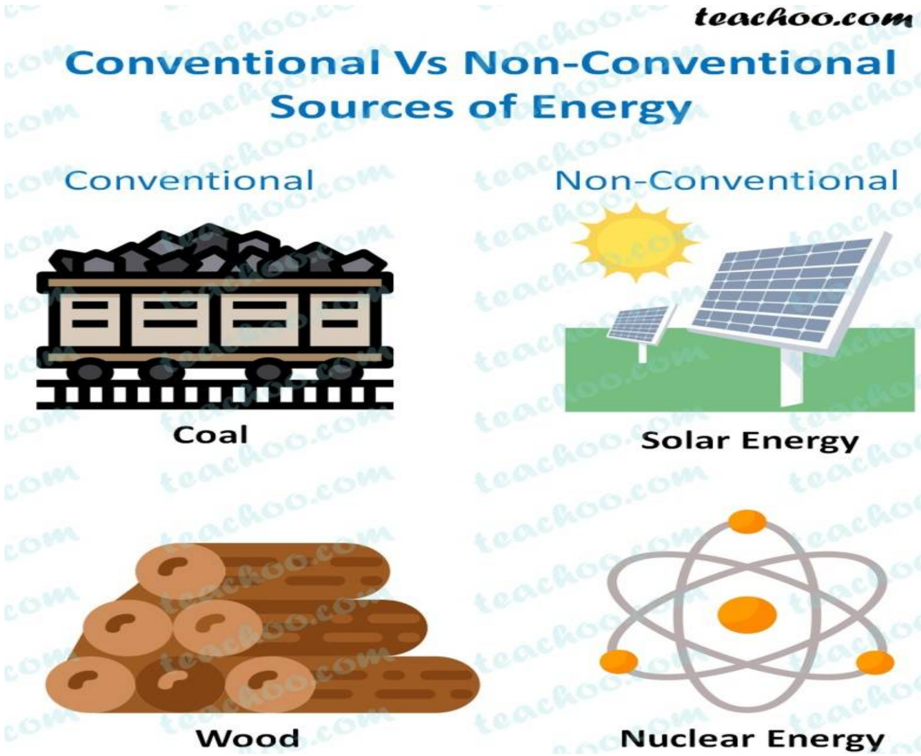



**Fig.5.2:** Conventional and non-conventional energy

## 5.2. Conventional energy

Conventional energy sources such as natural gas, oil, coal, or nuclear are finite but still hold the majority of the energy market. However, renewable energy sources like wind, fuel cells, solar, biogas/biomass, tidal, geothermal, etc. are clean and abundantly available in nature and hence are competing with conventional energy sources. Among the renewable energy sources wind energy has a huge potential of becoming a major source of renewable energy for this modern world. Wind power is a clean, emissions-free power generation technology.

As per the Global Wind Energy Council (GWEC) 2013 statistics, cumulative global capacity has reached to a total of 318 GW, which shows an increase of nearly 200 GW in the past 5 years. GWEC predicts that wind power could reach nearly 2000 GW by 2030, supply between 16.7% and 18.8% of global electricity and help save over 3 billion tons of $CO_2$ emissions annually. From this scenario, it is clear that wind power is going to dominate the renewable as well as the conventional energy market in the not too distant future. Wind energy is the only power generation technology that can deliver the necessary cuts in $CO_2$ emissions from the power sector in the critical period up to 2020, when greenhouse gas emissions must peak and begin to decline if we are to have any hope of avoiding the worst impacts of climate change. However, grid integration, voltage, and power fluctuation issues should adequately be addressed due to the huge penetration of wind power to the grid.

Conventional energy sources based on oil, coal, and natural gas have proved to be highly effective drivers of economic progress, but at the same time damaging to the environment and to human health. Furthermore, fossil fuel-driven economies tend to be cyclical in nature, due to the effects of oligopoly in production and distribution. The traditional fossil fuel-based energy sources are facing increasing pressure on a host of environmental fronts, with perhaps the most serious challenge confronting the future use of coal being the Kyoto Protocol greenhouse gas (GHG) reduction targets. It is now clear that any effort to maintain atmospheric levels of $CO_2$ below even 550 ppm cannot be based fundamentally on an oil- and coal-powered global economy, barring radical carbon sequestration efforts.

## 5.3. Non-conventional energy

Non-conventional energy sources, also known as Renewable energy sources, are sources that are continuously replenished by natural processes. Solar energy, wind energy, bio-energy (sustainably grown bio-fuels), hydropower, and other renewable energy sources are examples. A renewable energy system converts energy from the sun, wind, falling water, sea waves, geothermal heat, or biomass into usable heat or electricity. The majority of non-conventional energy comes from the sun and wind, either directly or indirectly, and can never be depleted, thus the term "renewable."

## 5.4. Non-Conventional Energy Resources in India

- India is endowed with non-traditional energy sources such as sunlight, water, wind, and biomass.
- Furthermore, the growing demand for energy has led to the country's reliance on fossil fuels such as oil, coal, and gas. In this regard, the potential shortage of gases and oil has raised concerns as a result of rising energy prices.

- The growing demand for energy has made the country reliant on fossil fuels such as coal, oil, and gas.
- Potential oil and gas shortages due to price increases and over-exploitation of energy, raising concerns about the future security of energy supply.
- Furthermore, the increased use of fossil fuels causes serious environmental issues.
- As a result, there is an urgent need to use renewable energy sources such as solar energy, wind energy, tide energy, biomass, and waste energy.
- These are referred to as non-conventional energy sources.
- It has the most extensive programs for the development of renewable energy resources.
- Non-Conventional Energy Resources are:
    - Solar Energy
    - Wind power
    - Biogas
    - Tidal Energy
    - Geothermal Energy

### 5.4.1. Solar Energy

- India is a tropical country. It has enormous potential for harnessing solar energy. Photovoltaic technology directly converts sunlight into electricity.
- Solar energy is quickly gaining popularity in rural and remote areas. Madhapur, near Bhuj in Gujrat is home to India's largest solar plant, where solar energy is used to sterilise milk cans.

**Fig.5.3:** Solar plant for energy production

- The use of solar energy is expected to reduce rural households' reliance on firewood and dung cakes, contributing to environmental conservation and an adequate supply of manure in agriculture.
- The capacity of the National Thermal Power Corporation Limited (NTPC) project would be nearly double that of Rajasthan's Bhadla solar park, which is currently the country's largest single-location solar power plant.
- NTPC hopes to have built 60 GW (gigawatts) of renewable energy capacity by 2032.
- Several solar-powered devices are available on the market and are widely used in rural India.
- Among them are:
    - Solar Cooker
    - Water heater
    - Dryer
    - Lantern
    - Pumps
    - Lighting

### 5.4.2. Wind power

- India is now regarded as a global **"wind superpower."**
- Winds are formed when air moves from warmer to colder areas, and these airflows are captured in windmills and wind turbines to generate electricity.
- Wind energy is not a new discovery; it has been used for millennia in the form of traditional windmills to grind maize, pump water, and sail ships.
- Wind power can now be used to generate energy on a larger scale thanks to advances in technology.

**Fig-5.4**:Wind energy production

- Tamil Nadu has the largest wind farm cluster, stretching from Nagercoil to Madurai.
- Apart from these, important wind farms can be found in Andhra Pradesh, Karnataka, Gujarat, Kerala, Maharashtra, and Lakshadweep.
- Nagarcoil and Jaisalmer are well-known in the country for their effective use of wind energy.
- The Jaisalmer wind park is Indian's second largest and globally the fourth-largest operational onshore wind farm.
- According to the Indian Meteorological Department, the average annual wind velocity in peninsular India is 6.5-8 m/s along the coastlines of Gujarat, the Western Ghats, and some parts of central India.

### 5.4.3. Biogas

- In rural areas, shrubs, farm waste, animal and human waste is used to generate biogas for domestic consumption.
- Organic matter decomposition produces gas, which has a higher thermal efficiency than kerosene, dung cake, and charcoal.
- Municipal, cooperative, and individual biogas plants exist. In rural India, plants that use cattle dung are known as 'Gobar gas plants.'
- These provide the farmer with two benefits: energy and improved manure quality. By far the most efficient use of cattle dung is biogas.

- It improves manure quality while reducing tree and manure loss from the combustion of fuel wood and cow dung cakes.
- The Indian government intended to build approximately 5,000 **Compressed Biogas (CBG)** plants across the country by 2023, with the following feedstock.
- Biogas is an excellent and effective way to promote rural development in developing countries such as India. The following are some of the applications for biogas: -Cooking, heating, lighting, and electricity generation
- Biogas slurries can produce organic manure, which can be used in place of chemical fertilisers in agriculture.
- Sanitation issues can be addressed because toilets are directly linked to biogas plants.

### 5.4.4. Tidal Energy

- Tides in the ocean can be used to generate electricity. Floodgate dams are constructed across inlets.
- Water flows into the inlet during high tide and becomes trapped when the gate is closed.
- When the tide falls outside the flood gate, the water retained by the floodgate flows back to the sea via a pipe that passes through a turbine that generates electricity.
- The Gulf of Kachchh in India provides ideal conditions for utilising tidal energy.
- The National Hydropower Corporation is constructing a 900 MW tidal energy power plant here.
- According to a 2014 study conducted by the Indian government, India has a tidal power potential of 12.5 gigatonnes spread across the coastlines of Gujarat, Tamil Nadu, and West Bengal.

### 5.4.5. Hydropower

- Hydropower is water-based energy that uses kinetic energy to generate electricity.
- Free-flowing water (from reservoirs and dams) spins a turbine, which generates electricity in a manner similar to wind energy.
- India has the most hydropower reserves, which can meet a demand of approximately 85 GW.
- According to an International Hydropower Association report, India will have a total installed capacity of 50 Gigawatts by 2020, surpassing Japan to become the world's fifth-largest hydropower producer.

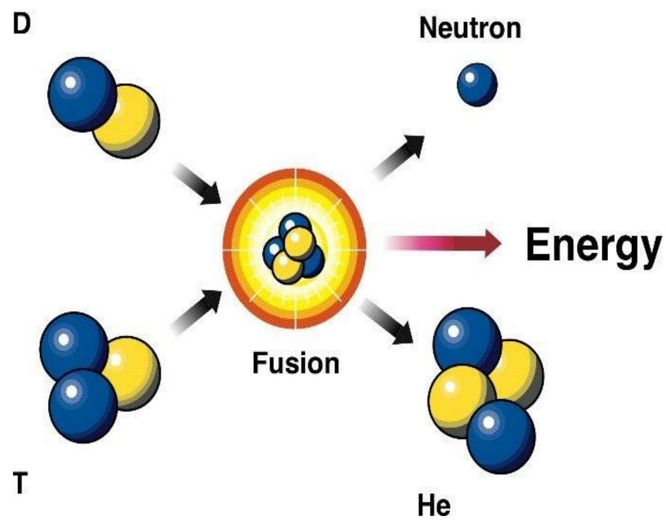
### 5.4.6. Geothermal energy

- Geothermal energy is the heat and electricity generated by using heat from the Earth's interior.
- Geothermal energy exists because the Earth's temperature increases with depth. High temperatures are found at shallow depths where the geothermal gradient is steep.
- In such areas, groundwater absorbs heat from the rocks and becomes hot. It's so hot that when it reaches the earth's surface, it condenses into steam. This steam powers turbines and generates electricity.
- In India, there is hundreds of hot water springs that could be used to generate electricity.
- In India, two pilot projects to harness geothermal energy have been established.
- The first is in the **Parvati Valley** near Manikaran in Himachal Pradesh, and the second is in the **Puga Valley** in Ladakh.

## 5.5. Energy by nuclear Fusion

**Nuclear Fusion reactions** power the Sun and other stars. In a fusion reaction, two light nuclei merge to form a single heavier nucleus. The process releases energy because the total mass of the resulting single nucleus is less than the mass of the two original nuclei. The leftover mass becomes energy. Einstein's equation ($E=mc^2$), which says in part that mass and energy can be converted into each other, explains why this process occurs. If scientists develop a way to harness energy from fusion in machines on Earth, it could be an important method of energy production.

Fusion can involve many different elements in the periodic table. However, researchers working on fusion energy applications are especially interested in the deuterium-tritium (DT) fusion reaction. DT fusion produces a neutron and a helium nucleus. In the process, it also releases much more energy than most fusion reactions. In a potential future fusion power plant such as a **tokamak** or **stellarator**, neutrons from DT reactions would generate power for our use. Researchers focus on DT reactions both because they produce large amounts of energy and they occur at lower temperatures than other elements.




The Department of Energy Office of Science, Fusion Energy Sciences (FES) program seeks to develop a practical fusion energy source. To do so, FES partners with other Office of Science programs. They work with the Advanced Scientific Computing Research program to use scientific computing to advance fusion science as well as the Nuclear Physics program on nuclear reaction databases, generation of nuclear isotopes, and research in nucleosynthesis. FES also partners with the DOE's National Nuclear Security Administration to pursue fundamental research on fusion reactions in support of DOE's nuclear stockpile stewardship mission

## 5.6. Ethanol production

Ethanol production from cellulosic biomass involves five unit operations: pretreatment, cellulose production, enzymatic hydrolysis, microbial fermentation, and product recovery. - Consolidated bioprocessing (CBP) combines the three biologically mediated steps (cellulase production, enzymatic hydrolysis, and microbial fermentation) into a single operation. CBP has outstanding potential for providing a breakthrough solution for the biological conversion of cellulosic biomass into ethanol. The implementation of CBP requires microbes that can produce a functional cellulase system while generating ethanol at high yields and concentrations. CBP-enabling microorganisms can be developed via two strategies: a native cellulolytic strategy, which involves identifying a naturally occurring cellulolytic microorganism (or a consortium of microorganisms) and then improving its ability to ferment sugars into ethanol at high yields and at high titers, and a recombinant cellulolytic strategy, which involves engineering noncellulolytic organisms so that they can utilize cellulose to produce ethanol at high yields and titers by heterologously expressing cellulases.

Ethanol production is very ancient linked with making potable alcohol. The liquor containing corn, grapes juice, molasses, etc. are fermented by adding yeast to it in batch fermentators for a number of hours (minimum 40 hours) when fermentation gets completed it is distilled to remove water and undesirable compounds for achieving 99 per cent + purity.

***Through sugarcane:***

Through sugarcane sugar route. The major source of ethanol production in the country is via sugarcane-sugar-molasses (Saccharum officinarum) route. This provides better economy by sale of sugar; molasses becomes the byproduct of the sugar. Average sugar cane productivity in India is about 70 MT per hectare and ethanol produced from one MT of sugarcane is 70 litres.

***Through sugar beet:***

In European countries sugar beet is preferred. Sugar beet (Beta vulgaris) has certain advantages over sugarcane. It provides higher yield (12.5 to 17.5 tons per hectare of sugar against 7.5 to 12 tons of sugar per hectare from sugarcane in addition to low requirement of water, lower maturity time and lower power requirement for crushing. Sugar beet cultivation and its processing to ethanol needs to be promoted in the country

***Starch-based alcohol production:***

Alcohols are produced from a large number of different starch crops as barley (Hordeum vulgare), wheat Triticum aestivum), corn (Zea mays), potato (Solanum tuberosum), sorghum, (Sorghum bicolor) etc. The conversion of starch into alcohol follows the same process of fermentation and distillation as that of sugarcane. Corn can provide about 275 litres of ethanol from one MT. With productivity of 2 MT per hectare, 550 litres of ethanol can be produced from one hectare of corn plantation. In addition to lower yield per hectare of ethanol, corn presents the problem of disposal of residue, but it can be used as animal feed. It can, however, be utilised for value added products which can provide starch-based alcohol production economical. Corn oil is edible and its use in India for production of ethanol is not economically feasible.

***Ethanol made from cellulosic biomass:***

In the coming years it is believed that cellulosic biomass will be the largest source of bioethanol. The broad category of biomass for the production of ethanol includes agricultural crops and residues and wood. Biomass resources are abundant and have multiple application potential. Among the various competing processes, bioethanol from lignocellulosic biomass appears to have economic potential. The crops residues such as rice straw, bagasse, etc. are not currently used to derive desired economic and environmental benefits and thus they could be important resource base for bioethanol production. As for example one MT of rice straw or bagasse can give over 400 litres of ethanol.

Cellulosic materials are polymers of sugar and are difficult to decompose by enzymes and need breaking of bonds beforehand. Two different routes are being tried. One is by action of chemical (acid or new generation of enzymes) and the second is the thermal route of gasification. The first route is being generally followed as in paper pulp industry. However, for ethanol production economics are not favourable. The gasification route provides better economics but looks to be very complicated. It is as yet in an experimental stage.

**Methanol production**

Methanol (also called methyl alcohol and wood spirit, amongst other names) is an organic chemical and the simplest aliphatic alcohol, with the formula $CH_3OH$ (a methyl group linked to a hydroxyl group, often abbreviated as MeOH). It is a light, volatile, colorless and flammable liquid with a distinctive alcoholic odour similar to that of ethanol (potable alcohol). Methanol acquired the name wood alcohol because it was once produced chiefly by the destructive distillation of wood. Today, methanol is mainly produced industrially by hydrogenation of carbon monoxide. Methanol consists of a methyl group linked to a polar hydroxyl group. With more than 20 million tons produced annually, it is used as a precursor to other commodity chemicals, including formaldehyde, acetic acid, methyl tert-butyl ether, methyl benzoate, anisole, peroxyacids, as well as a host of more specialised chemicals.

Methanol synthesis is a widely studied process and the product, methanol, is commonly utilized as a fuel, a solvent, an energy storage medium, and a feedstock in the industry. Especially in energy-related conversion, methanol is assumed to play an important role in the future. To meet the demands of the future, that makes requirements for process development to achieve sustainable and energy-efficient ways to produce methanol a necessity.

Methanol production is a standard outlet for natural gas. Nevertheless, the methanol price level in the past hindered a possible extension of the usage of methanol. Methanol costs are mainly dictated by feedstock costs and capital-related charges. On one hand the individual methanol synthesis process scheme will influence the efficiency of the usage of the gas, on the other hand the capital-related charges are affected by the economics of plant scale, both being effective parameters for lowering the price of the methanol product.

In the energy sector, fuel cell vehicles with on-board hydrogen generation from methanol are ready to market within the next years. In the chemical sector the route over methanol to olefins is one of the most promising new applications. Another option with high potential is the conversion of methanol to hydrogen.

**Applications**

Methanol is used as a denaturant for ethanol, the product being known as "denatured alcohol" or "methylated spirit". This was commonly used during the U.S. prohibition to discourage consumption of bootlegged liquor, and ended up causing several deaths. These types of practices are now illegal in the U.S., being considered homicide. Methanol is used as a solvent and as an antifreeze in pipelines and windshield washer fluid. Methanol was used as an automobile coolant antifreeze in the early 1900s. As of May 2018, methanol was banned in the EU for use in windscreen washing or defrosting due to its risk of human consumption as a result of 2012 Czech Republic methanol poisonings.

In some waste water treatment plants, a small amount of methanol is added to wastewater to provide a carbon food source for the denitrifying bacteria, which convert nitrates to nitrogen gas and reduce the nitrification of sensitive aquifers. Methanol is used as a destaining agent in polyacrylamide gel electrophoresis.

## 5.7. Pyrolysis

Pyrolysis is one of the technologies available to convert biomass to an intermediate liquid product that can be refined to drop-in hydrocarbon biofuels, oxygenated fuel additives and petrochemical replacements. Pyrolysis is the heating of an organic material, such as biomass, in the absence of oxygen. Biomass pyrolysis is usually conducted at or above 500 °C, providing enough heat to deconstruct the strong bio-polymers mentioned above. Because no oxygen is present combustion does not occur, rather the biomass thermally decomposes into combustible gases and bio-char. Most of these combustible gases can be condensed into a combustible liquid, called pyrolysis oil (bio-oil), though there are some permanent gases ($CO_2$, CO, $H_2$, light hydrocarbons), some of which can be combusted to provide the heat for the process.

Thus, pyrolysis of biomass produces three products: one liquid, bio-oil, one solid, bio-char and one gaseous, syngas. The proportion of these products depends on several factors including the composition of the feedstock and process parameters. However, all things being equal, the yield of bio-oil is optimized when the pyrolysis temperature is around 500 °C and the heating rate is high (1000 °C/s) fast pyrolysis conditions. Under these conditions, bio-oil yields of 60-70 wt% of can be achieved from a typical biomass feedstock, with 15-25 wt% yields of bio-char. The remaining 10-15 wt% is syngas. Processes that use slower heating rates are called slow pyrolysis and bio-char is usually the major product of such processes. The pyrolysis process can be self-sustained, as combustion of the syngas and a portion of bio-oil or bio-char can provide all the necessary energy to drive the reaction.

**Pyrolysis,** the chemical decomposition of organic (carbon-based) materials through the application of heat. Pyrolysis, which is also the first step in gasification and combustion, occurs in the absence or near absence of oxygen, and it is thus distinct from combustion (burning), which can take place only if sufficient oxygen is present. The rate of pyrolysis increases with temperature. In industrial applications the temperatures used are often 430 °C (about 800 °F) or higher, whereas in smaller-scale operations the temperature may be much lower. Two well-known products created by pyrolysis are a form of charcoal called biochar, created by heating wood, and coke (which is used as an industrial fuel and a heat shield), created by heating coal. Pyrolysis also produces condensable liquids (or tar) and noncondensable gases.

**Applications**

Pyrolysis has numerous applications of interest to green technology. It is useful in extracting materials from goods such as vehicle tires, removing organic contaminants from soils and oily sludges, and creating biofuel from crops and waste products. Pyrolysis can help break down vehicle tires into useful components, thus reducing the environmental burden of discarding the tires. Tires are a significant landfill component in many areas, and they release PAHs (Poly Aromatic Hydrocarbon) and heavy metals into the air when they are burned.

However, when tires are pyrolyzed, they break down into gas and oil (usable for fuel) and carbon black (usable as filler in rubber products, including new tires, and as activated charcoal in filters and fuel cells). In addition, pyrolysis can remove organic contaminants, such as synthetic hormones, from sewage sludge (semisolid materials that remain after wastewater is treated and the water content reduced) and make heavy metals remaining in the sludge inert, which allows the sludge to be used safely as fertilizer.

## 5.8. Gasification

Gasification is a technological process that can convert any carbonaceous (carbon-based) raw material such as coal into fuel gas, also known as synthesis gas (syngas for short). Gasification occurs in a gasifier, generally a high temperature/pressure vessel where oxygen (or air) and steam are directly contacted with the coal or other feed material causing a series of chemical reactions to occur that convert the feed to syngas and ash/slag (mineral residues).

Syngas is so called because of its history as an intermediate in the production of synthetic natural gas. Composed primarily of the colorless, odorless, highly flammable gases carbon monoxide (CO) and hydrogen ($H_2$), syngas has a variety of uses. The syngas can be further converted (or shifted) to nothing but hydrogen and carbon dioxide ($CO_2$) by adding steam and reacting over a catalyst in a water-gas-shift reactor. When hydrogen is burned, it creates nothing but heat and water, resulting in the ability to create electricity with no carbon dioxide in the exhaust gases. Furthermore, hydrogen made from coal or other solid fuels can be used to refine oil, or to make products such as ammonia and fertilizer. More importantly, hydrogen enriched syngas can be used to make gasoline and diesel fuel. Polygeneration plants that produce multiple products are uniquely possible with gasification technologies. Carbon dioxide can be efficiently captured from syngas, preventing its greenhouse gas emission to the atmosphere and enabling its utilization (such as for Enhanced Oil Recovery) or safe storage.

Gasification offers an alternative to more established ways of converting feedstocks like coal, biomass, and some waste streams into electricity and other useful products. The advantages of gasification in specific applications and conditions, particularly in clean generation of electricity from coal, may make it an increasingly important part of the world's energy and industrial markets. The stable price and abundant supply of coal throughout the world makes it the main feedstock option for gasification technologies going forward. The technology's placement markets with respect to many techno-economic and political factors, including costs, reliability, availability and maintainability (RAM), environmental considerations, efficiency, feedstock and product flexibility, national energy security, public and government perception and policy, and infrastructure will determine whether or not gasification realizes its full market potential.

## 5.9. Biogas

Biogas is a mixture of gases, primarily consisting of methane, carbon dioxide and hydrogen sulphide, produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste, wastewater, and food waste. It is a renewable energy source. Biogas is produced by anaerobic digestion with anaerobic organisms or methanogen inside an anaerobic digester, biodigester or a bioreactor.

### Composition of Biogas

Biogas is primarily methane ($CH_4$) and carbon dioxide ($CO_2$) and may have small amounts of hydrogen sulfide ($H_2S$), moisture and siloxanes. Biogas is primarily methane ($CH_4$) and carbon dioxide ($CO_2$) and may have small amounts of hydrogen sulfide ($H_2S$), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used in fuel cells and for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat. The Typical composition of biogas is given the given table.

**Table-1:** Typical composition of biogas

| Compound | Formula | % by volume |
|---|---|---|
| Methane | $CH_4$ | 50–80 |
| Carbon dioxide | $CO_2$ | 15–50 |
| Nitrogen | $N_2$ | 0–10 |
| Hydrogen | $H_2$ | 0–1 |

| | | |
|---|---|---|
| Hydrogen sulfide | $H_2S$ | 0–0.5 |
| Oxygen | $O_2$ | 0–2.5 |

Biogas can be compressed after removal of carbon dioxide and hydrogen sulphide, the same way as natural gas is compressed to CNG, and used to power motor vehicles. In the United Kingdom, for example, biogas is estimated to have the potential to replace around 17% of vehicle fuel. It qualifies for renewable energy subsidies in some parts of the world. Biogas can be cleaned and upgraded to natural gas standards, when it becomes bio-methane.

Biogas is considered to be a renewable resource because its production-and-use cycle is continuous, and it generates no net carbon dioxide. As the organic material grows, it is converted and used. It then regrows in a continually repeating cycle. From a carbon perspective, as much carbon dioxide is absorbed from the atmosphere in the growth of the primary bio-resource as is released, when the material is ultimately converted to energy.

**Applications**

Biogas can be used for electricity production on sewage works, in a combined heat and power (CHP) gas engine, where the waste heat from the engine is conveniently used for heating the digester; cooking; space heating; water heating; and process heating. If compressed, it can replace compressed natural gas for use in vehicles, where it can fuel an internal combustion engine or fuel cells and is a much more effective displacer of carbon dioxide than the normal use in on-site CHP plants.

## 5.10. Urban wastes/Municipal solid waste (MSW)

Municipal solid waste (MSW), commonly known as trash or garbage in the United States and rubbish in Britain, is a waste type consisting of everyday items that are discarded by the public. "Garbage" can also refer specifically to food waste, as in a garbage disposal; the two are sometimes collected separately. In the European Union, the semantic definition is 'mixed municipal waste,' given waste code 20 03 01 in the European Waste Catalog. Although the waste may originate from a number of sources that has nothing to do with a municipality, the traditional role of municipalities in collecting and managing these kinds of waste have produced the particular etymology 'municipal.'

### Composition of municipal waste

The composition of municipal solid waste varies greatly from municipality to municipality, and it changes significantly with time. In municipalities which have a well-developed waste recycling system, the waste stream mainly consists of intractable wastes such as plastic film and non-recyclable packaging materials. At the start of the 20th century, the majority of domestic waste (53%) in the UK consisted of coal ash from open fires. In developed areas without significant recycling activity it predominantly includes food wastes, market wastes, yard wastes, plastic containers and product packaging materials, and other miscellaneous solid wastes from residential, commercial, institutional, and industrial sources.

Most definitions of municipal solid waste do not include industrial wastes, agricultural wastes, medical waste, radioactive waste or sewage sludge. Waste collection is performed by the municipality within a given area. The term *residual waste* relates to waste left from household sources containing materials that have not been separated out or sent for processing. Waste can be classified in several ways, but the following list represents a typical classification:

- Biodegradable waste: food and kitchen waste, green waste, paper (most can be recycled, although some difficult to compost plant material may be excluded)
- Recyclable materials: paper, cardboard, glass, bottles, jars, tincans, aluminum cans, aluminum foil, metals, certain plastics, textiles, clothing, tires, batteries, etc.
- Inert waste: construction and demolition waste, dirt, rocks, debris
- Waste from electrical and electronic equipment (WEEE) electrical appliances, light bulbs, washing machines, TVs, computers, screens, mobile phones, alarm clocks, watches, etc.
- Composite wastes: waste clothing, Tetra Pack food and drink cartons, waste plastics such as toys and plastic garden furniture
- Hazardous waste including most paints, chemicals, tires, batteries, light bulbs, electrical appliances, fluorescent lamps, aerosol spray cans, and fertilizers
- Toxic waste including pesticides, herbicides, and fungicides
- Biomedical waste, expired pharmaceutical drugs, etc.

## 5.11. Urban waste to resource recovery

Municipal authorities in developing countries are facing immense challenges in managing both solid and liquid waste in a sustainable way. Recycling is not yet high on their agenda although they appreciate the potential of composting for waste volume reduction. This offers an entry point to introduce organic waste recycling as a component of sustainable integrated sanitation which has the potential of a win-win situation by reducing waste flows, ensuring environmental health, supporting food production and creating livelihoods. However, due to several constraints recycling attempts have often a short life time.

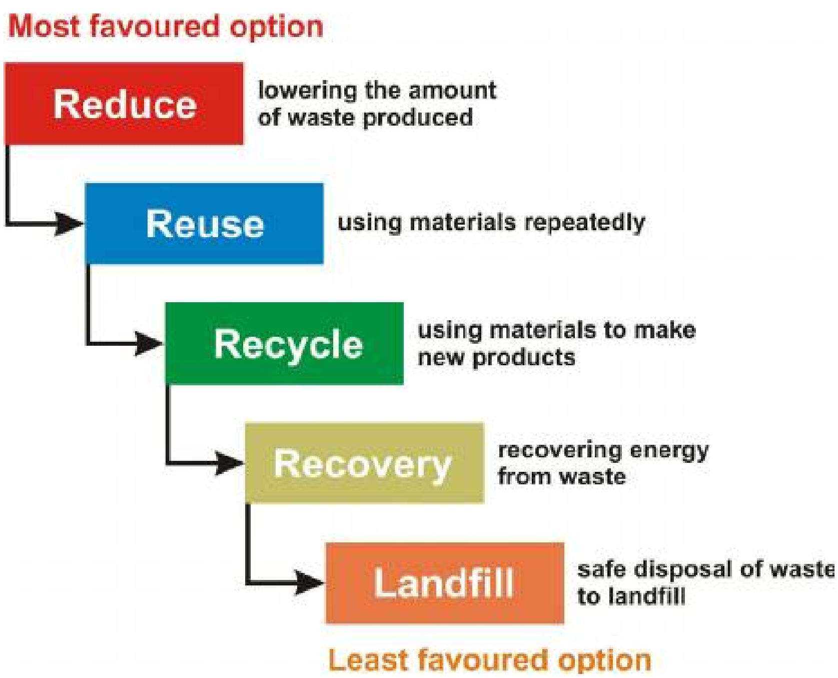



**Fig.5.5:** Different waste-hierarchy

It concludes with a framework for the analysis and the planning of recycling interventions in the context of sustainable sanitation, looking in particular at community-based options for solid waste and human excreta. Organic fertilizer production has a great potential to deal with the poor organic waste management challenge. In Ghana, the large amount of organic waste generated provides an opportunity to produce organic fertilizer. There are numerous benefits associated with organic fertilizer production such as decrease in odor nuisance from dump sites and availability of dump sites for alternative agricultural uses, and the organic fertilizer produced is used for crop production. Conversion of organic and municipal waste to compost also provides human and environmental health protection and opportunities for employment.

Waste management has actually been regulated by the government in Law No.18/2008, namely waste management is not only the responsibility of the government. A closely related area of concern in developing countries is waste management. Community and business doers as waste producers must do so in order to create clean and healthy environment.

## 5.12. Recycling of energy

Energy recycling is the recovery of energy that would normally be wasted in industrial processes by flaring, exhausting to the atmosphere or operating low efficiency equipment, and converting it into electricity or thermal energy (steam or heated water). Combined Heat and Power (CHP) is a form of energy recycling, where processes and equipment are designed to produce power and also supply heat rather than waste it. Energy recycling and CHP can be implemented at industrial sites, manufacturing facilities and large institutions such as hospitals and universities.

In a typical electric power generation plant, input fuel is used to create electricity while excess thermal energy (in the form of steam) is wasted in the process. Many facilities, both commercial and industrial, require a substantial amount of thermal energy for heating, cooling and other low temperature processes. By locating an electric generation plant on-site at a facility that has a significant demand for thermal energy, steam or heated water that is typically wasted can be used by the host. Each CHP plant lowers their host's energy costs and reduces emissions as compared to buying power off of the grid or burning fuels to produce steam with boilers.

Energy recycling is the energy recovery process of utilizing energy that would normally be wasted, usually by converting it into electricity or thermal energy. Undertaken at manufacturing facilities, power plants, and large institutions such as hospitals and universities, it significantly increases efficiency, thereby reducing energy costs and greenhouse gas pollution simultaneously. The process is noted for its potential to mitigate global warming profitably. This work is usually done in the form of combined heat and power (also called cogeneration) or waste heat recovery.

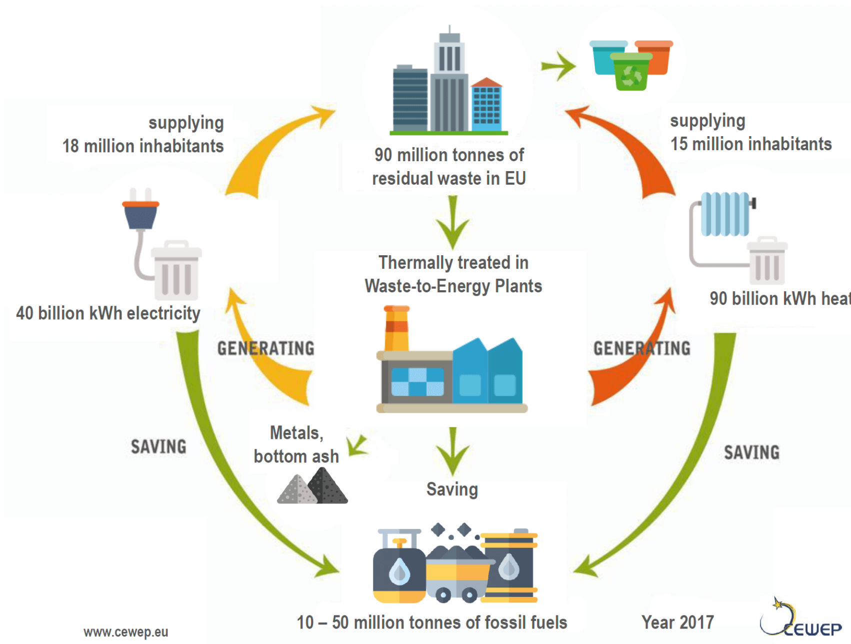



**Fig.5.6:** Recycling of energy

## 5.13. Industrial Waste Energy Recycling

Many industrial processes produce byproduct energy streams such as (i) hot exhaust gases, (ii) flare gases and (iii) high pressure gases. Hot exhaust gases are generated by facilities such as coke ovens, blast furnaces, petroleum refineries and hot rolled steel ovens, which all have high temperature exhaust gasses that can be converted into electricity and thermal energy. Waste gasses are typically created in industrial processes, such as those that occur in blast furnaces, which reduce iron ore to molten iron and produce byproduct gas that must be flared or disposed of. Finally, energy in the form of pressure drop energy is created when gases, including steam and natural gas, flow from high pressure pipes to low pressure points of use. Electric power and thermal energy can be produced by capturing and recycling these forms of waste energy produced by industrial processes.

## 5.14. Summary

Energy conservation and sustainable development are two of the world's most pressing issues today. Thus, the only way to provide an adequate supply of energy to this world and its massive population is to improve and innovate new ways to practice sustainable use of these energy sources. Our country is currently heavily reliant on traditional energy sources, which cannot provide a long-term solution to the current energy supply crisis. As a result, the only way to conserve these non-renewable energy sources is to convert our energy supply sources into unconventional energy sources.

## 5.15. Terminal questions

**Q.1.** Describe biomass with examples.

**Answer:**-----------------------------------------------------------------------------------------------------

-----------------------------------------------------------------------------------------------------

**Q.2.** Explain the characteristics of bioenergy crops.

**Answer:**-----------------------------------------------------------------------------------------------------

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**Q.3.** What are the biomass resources?

**Answer:**-----------------------------------------------------------------------------------------------------

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**Q.4.** Write short notes on the followings.

- **i.** Dedicated bioenergy crops
- **ii.** Bioenergy crops

**Answer:**-----------------------------------------------------------------------------------------------------

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**Q.5.** Explain conversion of biomass into fuels.

**Answer:**-----------------------------------------------------------------------------------------------------

-----------------------------------------------------------------------------------------------------

**Q.6.** Explain the conversion of biomass into fuels.

**Answer:**-----------------------------------------------------------------------------------------------------

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## 5.16. Further readings

1. Environmental Ecology, Bio-Diversity, Climate Change & Disaster Management by Ravi P. Agrahari
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# Unit-6: Energy Policies

***Contents***



## 6.1. Introduction

The energy policy of India is to increase the locally produced energy in India and reduce energy poverty with more focus on developing alternative sources of energy, particularly like nuclear, solar and wind energy. Net energy import dependency was 40.9% in year 2021-22. The primary energy consumption in India grew by 10.4% in Year 2021, it is the third biggest with 6% global share after China and USA. The total primary energy consumption from coal (45.88%), crude oil (29.55%), natural gas (6.17%), nuclear energy (1.09%), hydroelectricity (3.91%) and renewable power (3.40%) is 809.2 metric tonne of oil equipment (Mtoe) (excluding traditional biomass use) in the calendar year 2018. In 2018, India's net imports are nearly 205.3 million tons of crude oil and its products, 26.3 Mtoe of LNG and 141.7 Mtoe coal totaling to

373.3 Mtoe of primary energy which is equal to 46.13% of total primary energy consumption of country.

**Objectives**

- Indian emission norms in transportation sector
- National programmes to promote biomass energy production in India
- Solar photovoltaic programmes in India
- Energy resources available in India
- Urban and rural energy consumption
- National green tribunal (NGT) act

## 6.2 .Indian emission norms in transportation sector

The first State emission norms came into force in 1991 for Petrol vehicles and in1992 for Diesel vehicles. From April 1995, fitting of catalytic converters in new Petrol driven passenger cars was mandated in the four Metros and also introduction of unleaded petrol. From April 2000, unleaded petrol is available in the country. In developed countries lead was phased out from petrol over a period of more than 10 years, while in India this was achieved just in 6 years. The comparative statement of emission norms as under, indicates that the time gap between the introduction of norms in Europe and our country is narrowing:

| | Euro I | Euro I | Euro II | Euro III |
|---|---|---|---|---|
| ***European Norms*** | ***1983*** | ***1992*** | ***1996-97*** | ***2000-2001*** |
| ***Indian Norms*** | ***1996*** | ***1.4.2000*** | ***** | ****** |

Bharat Stage-II norms, which are a close to Euro-II norms have been introduced in National Capital Region (NCR) for passenger vehicles upto Gross weight of vehicles (GVW) 3.5T from 1.4.2000 and for heavier vehicles from 24.10.2001 in National Capital Territory (NCT) of Delhi.

In Mumbai, these have been extended from 1.1.2001 to 31.10.2001 respectively. For both Chennai and Kolkata, the corresponding dates are 1.7.2001 and 31.10.2001 respectively. These norms have been extended to Agra, Ahmedabad, Bangalore, Hyderabad, Kanpur, Pune and Surat from 1.4.2003 and Lucknow and Sholapur from 1.6.2004 for all category of vehicles. The transport vehicles plying on inter-State permits or on National Permits or on All India Tourist Permits or plying from these cities to the other regions of the respective States have been exempted.

**Bharat Stage-II** norms involve supply of Petrol and Diesel with 0.05% sulphur content. Inrest of the country, petrol has Sulphur content of 0.1% with effect from 1.4.2000 as against 0.05% in these cities and NCR of Delhi.

Similarly, Sulphur content in diesel have been reduced in the country, from a level of 1.0% maximum in 1996 to 0.25% on 1.4.2000. In respect of NCT of Delhi and the above mentioned cities the sulphur content in Diesel is similarly 0.05%.

**Bharat Stage-III** emission norms have been effect from 1-4-2005 in respect of Four Wheeled vehicles manufactured on and from 1st April, 2005 in the National Capital Region and the cities of Mumbai, Kolkata, Chennai, Bangalore, Hyderabad including Secundrabad, Ahmedabad, Pune, Surat, Kanpur and Agra except for four wheeled transport vehicles plying on Inter-State Permits or National Permits or All India Tourist Permits within the jurisdiction of these cities.

In addition to petrol and diesel, CNG and LPG are permitted to be used as auto fuels. Alternative fuels like di-methyl ether, bio-diesel, hydrogen, electric and fuel cell vehicles etc., are at various stages of experimentation. The emission norms for tractors were first notified in the year 1999. The next generation norms have been laid down. While Bharat Stage II norms have come into force from 01.06.2003, the Bharat Stage III norms has come into force from 01.10.2005. Next generation emission norms for two-wheelers and three-wheelers manufactured on and after 1.4.2005 have been notified.

**Steps for curbing risk of vehicular pollution**

This Ministry has taken several steps in this direction. Workshop-cum-training programmes are organized two every year at Aromatic Research Association of India (ARAI), Pune and Indian Institute of Petroleum (IIP), Dehradun. In these workshops, officers of the State Transport Department are given training regarding checking of vehicular pollution more scientifically and effectively. Fitness norms for commercial vehicles have been tightened with effect from 28th March 2001.

**Pollution under Control (PUC) Norms**

Stricter PUC norms for in use motor vehicles have been notified vide Gazette Notification No. G.S.R. 111(E) dated 10.2.2004. These norms have come into force from 1st October, 2004.

**SAQ1: Self Assessment Questions**

**Q1.** Where the Workshop-cum-training programmes are organized for curbing risk of vehicular pollution

**Ans**. ARAI, Pune and IIP, Dehradun.

**Q2.** PUC norms for in use motor vehicles have been notified vide Gazette Notification No. G.S.R. 111(E) dated 10.2.2004 are effective form?

**Ans.** 1st October, 2004.

**Q3**. Bharat Stage III norms has come into force from?

**Ans.** 01.10.2005

**Q4**. The first State emission norms came into force ?

**Ans**. 1991 for Petrol vehicles and 1992 for Diesel vehicles.

## 6.3. National programmes to promote biomass energy production in India

Biomass has always been an important energy source for the country considering the benefits it offers. It is renewable, widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. Biomass is also capable of providing firm energy. About 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs. Ministry of New and Renewable Energy has realised the potential and role of biomass energy in the Indian context and hence has initiated a number of programmes for promotion of efficient technologies for its use in various sectors of the economy to ensure derivation of maximum benefits. For efficient utilization of biomass, bagasse based cogeneration in sugar mills and biomass power generation have been taken up under biomass power and cogeneration programme.

Biomass power & cogeneration programme is implemented with the main objective of promoting technologies for optimum use of country's biomass resources for grid power generation. Biomass materials used for power generation include bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, de-oiled cakes, coffee waste, jute wastes, groundnut shells, saw dust etc.

**POTENTIAL**

As per a recent study sponsored by MNRE, the current availability of biomass in India is estimated at about 750 million metric tons per year. The Study indicated estimated surplus biomass availability at about 230 million metric tonnes per annum covering agricultural residues corresponding to a potential of about 28 GW. This apart, about 14 GW additional power could be generated through bagasse based cogeneration in the country's 550 Sugar mills, if these sugar mills were to adopt technically and economically optimal levels of cogeneration for extracting power from the bagasse produced by them.

**Combustion**

The thermo chemical processes for conversion of biomass to useful products involve combustion, gasification or pyrolysis. The most commonly used route is combustion. The advantage is that the technology used is similar to that of a thermal plant based on coal, except for the boiler. The cycle used is the conventional rankine cycle with biomass being burnt in high-pressure boiler to generate steam and operating a turbine with the generated steam. The exhaust of the steam turbine can either be fully condensed to produce power, or used partly or fully for another useful heating activity. The latter mode is called cogeneration. In India, cogeneration route finds application mainly in industries.

**Biogas**

Brief Introduction: Biogas is produced when bio-degradable organic materials or wastes such as cattle-dung, biomass from farms, gardens, kitchens, industry, poultry droppings, night soil and municipals wastes are subjected to a scientific process called Anaerobic Digestion (A.D.) in a Biogas Plants. Biogas Plant designs depend upon several factors and the feed stock to be processed is of paramount importance. Biogas is the mixture of gases (primarily methane ($CH_4$) and Carbon dioxide ($CO_2$) and traces of Hydrogen Sulfide ($H_2S$) and Moisture) produced by the decomposition of bio-degradable organic matter in the absence of oxygen from raw materials such as agricultural waste, cattle dung, poultry droppings, municipal waste, plant material, sewage, green waste or kitchen waste. Biogas has a calorific value of about 5000 kcal per $m^3$. The digested slurry produced from Biogas Plants as a by-product is a better source of nutrient enriched organic manure for use in Agriculture. It not only helps in improving the crop yield but also maintain the soil health.

There is ample potential of setting-up biogas plants considering the livestock population of 512.06 million, which includes about 300 million total population of bovines (comprising of cattle, buffalo, mithun and yak). The livestock sector contributes about significantly to India's GDP and will continue to increase. The dissemination of biogas technology is a boon for Indian farmers with its direct and collateral benefits.

*The Ministry of New and Renewable Energy promoted installation of biogas plants by implementing Central Sector Schemes under Off-Grid/distributed and decentralized Renewable Power.*

i. New National Biogas and Organic Manure Programme (NNBOMP), for Biogas Plant size ranging from 1 cu.m. to 25 cu.m. per day.
ii. Biogas Power Generation (Off-grid) and Thermal energy application Programme (BPGTP), for setting up biogas plants in the size range of 30 $m^3$ to 2500 $m^3$ per day, for corresponding power generation capacity range of 3 kW to 250 kW from biogas or raw biogas for thermal energy /cooling applications.

Biogas contains about 55-65 % of methane, 35- 44 % of carbon dioxide ($CO_2$) and traces of other gases, such as Hydrogen Sulphide ($H_2S$), Nitrogen ($N_2$) and Ammonia ($NH_3$). Biogas, in its raw form that is without any purification can be used as clean cooking fuel like LPG, lighting, motive power and generation of electricity. It can be used in diesel engines to substitute diesel up to 80% and up to 100% replacement of diesel by using 100% Biogas Engines. Further, Biogas can be purified and upgraded up to 98% purity of methane content to make it suitable to be used as a green and clean fuel for transportation or filling in cylinders at high pressure of 250 bar or so and called as **Compressed Bio-Gas (CBG).**

Initially, Biogas Plants were developed for digesting cattle dung. However, over a period of time, technology has been developed for the bio-methanation of various types of biomass materials and organic wastes. Biogas plant designs are now available from 0.5 $M^3$ to 1000 $M^3$ unit size or achieving higher Biogas Plant sizes, depending upon availability of the raw material such as for family/ household, small farmers, dairy farmers and for community, institutional and industrial/ commercial applications. The unit size of industrial and municipal wastes based biogas plants may go up to 15000 M3 to 20000 M3 biogas productions per day.

**Design and approved models:**

Ministry of New & Renewable Energy (MNRE) has approved various designs of biogas plants and the same have become proven ones for field worthiness. Indian standards for Biogas Plants, accessories and appliances have been also brought out by the MNRE and Bureau of Indian Standard (BIS). There are 4 types of basic model and 10 types of designs of biogas plants approved under the New National Biogas and Organic Manure Program (NNBOMP). The details of which are available in the scheme Guidelines. All approved designs are eligible for financial subsidies and other facilities uniformly across the country.

MNRE continuous to give high priority for the development and utilization of biogas as energy in its various forms. Under the National Biogas and Manure Management Programme (NBMMP), about 50.0 Lakh (5 Million) Family size plants have been installed up to 2017-18. The NBMMP scheme has been redesigned, modified and renamed as New National Biogas and Organic Manure Programme (NNBOMP) and continued from 2018-19 with the aim to enhance the biogas production from small Biogas plants of 1 to 25 $M^3$ capacity. The scheme aims to set up about 2.5 Lakh units of Biogas plants of various sizes in the above mentioned capacity range with an overall biogas generation of about 8 lakh Cu. M. per day. For various approved components. Now 100% biogas engines in smaller capacity ranges are available, and the surplus biogas can be utilized for meeting lighting, small power and electricity requirement from a Biogas Plant.

***Biogas based Power Generation (Off-grid) and Thermal Application Programme (BPGTP)***

Biogas plants are reliable source of decentralized Renewable Energy for heating, cooking as well as generating electricity/ power generation and thermal energy application alternatives in our country. In order to promote this Decentralized Renewable Energy Source (DRES) of power generation, specifically in the small capacity range (3 kW to 250 kW) and thermal energy for heating/cooling from the biogas produced from Biogas plants of 30 $M^3$ to 2500 $M^3$ size, operated based on the availability of required quantity of biodegradable organic waste(s).

The organic bio-degradable wastes from various sources such as cattle dung/ animal wastes, food & kitchen waste, poultry dropping waste, agro-industry waste etc. are the feed stock for Biogas plants. These plants are especially beneficial for meeting Off-grid Power requirements for individual dairy and poultry plants, dairy co-operatives for operation of dairy equipment and other electrical, thermal and cooling energy requirements for plant operation. The installations of such biogas systems replaces diesel in DG sets and also reduce the electricity bills of the individual farmers/ beneficiary, entrepreneurs, dairy farmer, dairy co-operatives thereby helping to increase the income of farmers/ end users. The nutreient enriched organic bio-manure is another stream of income generation from biogas projects and at the same time saving in the expenditure of chemical fertilizers by reduction of use of chemical fertilizers and other profitable ventures like organic farming.

Biogas plants installed under the scheme meet the electrical or thermal requirements of the beneficiaries and dairy farmers and other organizations. It is used for milk chilling applications and other general applications such as pumping, lighting, irrigation as well as cooking. The farmers can also sell out surplus biogas/ electricity to his neighbours in off-grid mode.

**Impact of biogas power plants:**

Based on the data reported and evaluation done through third party study, the overall impact of the programme implementation was observed to be encouraging. As revealed from the table given below, for a case study of 45 Biogas plants and extrapolated for 163 projects,

| **Parameter Values*** | |
|---|---|
| Total No. of Plants | 163 |
| Annual Energy Cost Savings (In Rs. Lakhs) | 787 |
| Annual CO2 Savings (In Tons) | 9587 |
| Annual Bio-manure Production (In Tons) | 32582 |
| Direct Employment (Man-days) | 63438 |

*Implementation of BPGTP:*

The BPGTP Scheme is being implemented by the Agriculture and Rural Development Departments of the States and Dairy Cooperatives. However, the programme is also implemented through the State Renewable Energy Agencies (SNAs), Biogas Development and Training Centres (BDTCs), Khadi and Village Industries Commission (KVIC) and National Dairy Development Board (NDDB) in States where Agriculture and State Rural Development Departments are not in a position to implement. The Programme Implementing Agencies (PIAs) may take help of Panchayati Raj Institutions/ Local Bodies (LBs) as an overarching Institutions allowing need based interventions under the community development programme in rural areas as well as areas to cover North Eastern Areas, Forest Fringe Villages, in large population concentration of SC/ ST communities including in tribal areas.

**SAQ2: Self Assessment Questions**

**Q1.** How much total primary energy use in the country is still derived from biomass?

Ans. About 32%

**Q2.** Biogas is the mixture of gases?

Ans. Primarily methane ($CH_4$) and Carbon dioxide ($CO_2$) and traces of Hydrogen Sulfide ($H_2S$) and Moisture

**Q3.** When was National Biogas and Manure Management Programme name changed?

Ans. New National Biogas and Organic Manure Programme (NNBOMP) from 2018-19.

**Q4.** Biogas Power Generation (Off-grid) and Thermal energy application Programme (BPGTP), for setting up biogas plants?

**Ans.** Size range of 30 $m^3$ to 2500 $m^3$ per day, for corresponding power generation capacity range of 3 kW to 250 kW from biogas or raw biogas for thermal energy /cooling applications.

## 6.4. Solar photovoltaic programmes in India

The Sun has been worshiped as a life-giver to our planet since ancient times. The industrial ages gave us the understanding of sunlight as an energy source. India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar photovoltaic power can effectively be harnessed providing huge scalability in India. Solar also provides the ability to energy generate power on a distributed basis and enables rapid capacity addition with short lead times. Off-grid decentralized and low-temperature applications will be advantageous from a rural application perspective and meeting other energy needs for power, heating and cooling in both rural and urban areas. From an energy security perspective, solar is the most secure of all energy sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar energy (if captured effectively) can meet the entire country's power requirements.

There has been a visible impact of solar energy in the Indian energy scenario during the last few years. Solar energy based decentralized and distributed applications have benefited millions of people in Indian villages by meeting their cooking, lighting and other energy needs in an environment friendly manner. The social and economic benefits include reduction in drudgery among rural women and girls engaged in the collection of fuel wood from long distances and cooking in smoky kitchens, minimization of the risks of contracting lung and eye ailments, employment generation at village level, and ultimately, the improvement in the standard of living and creation of opportunity for economic activities at village level. Further, solar energy sector in India has emerged as a significant player in the grid connected power generation capacity over the years. It supports the government agenda of sustainable growth, while, emerging as an integral part of the solution to meet the nation's energy needs and an essential player for energy security.

National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions. National Solar Mission (NSM) was launched on 11th January, 2010. NSM is a major initiative of the Government of India with active participation from States to promote ecological sustainable growth while addressing India's energy security challenges. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022. This is line with India's Intended Nationally Determined Contributions

(INDCs) target to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources and to reduce the emission intensity of its GDP by 33 to 35 percent from 2005 level by 2030.

In order to achieve the above target, Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, Viability Gap Funding (VGF) Schemes, Central Public Sector Understandings (CPSU) Scheme, Defense Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc.

Various policy measures undertaken included declaration of trajectory for Renewable Purchase Obligation (RPO) including Solar, Waiver of Inter State Transmission System (ISTS) charges and losses for inter-state sale of solar and wind power for projects to be commissioned up to March 2022, Must run status, Guidelines for procurement of solar power though tariff based competitive bidding process, Standards for deployment of Solar Photovoltaic systems and devices, Provision of roof top solar system and Guidelines for development of smart cities, Amendments in building bye-laws for mandatory provision of roof top solar for new construction or higher Floor Area Ratio, Infrastructure status for solar projects, Raising tax free solar bonds, Providing long tenor loans from multi-lateral agencies, etc.

Recently, India stands 4th in solar PV deployment across the globe as on end of 2021. Solar power installed capacity has reached around 61.97 GW as on 30th November, 2022. Presently, solar tariff in India is very competitive and has achieved grid parity.

**SAQ3: Self Assessment Questions**

**Q1.** National Institute of Solar Energy has assessed the Country's solar potential?

**Ans.** About 748 GW assuming 3% of the waste land area to be covered by Solar PV modules.

**Q2.** When Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions.

**Ans.** National Solar Mission (NSM) was launched on 11th January, 2010.

**Q3.** Target of the Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible.

**Ans.** The Mission targets installing 100 GW grid-connected solar power plants by the year 2022.

## 6.5. Energy resources available in India

The following points highlight the two important sources of energy in India. They are: A. Conventional Sources and B. Non-Conventional Sources.

### 6.5.1. Conventional Sources of Energy

Conventional sources of energy are as follows:

**1. Coal:**

Coal is the major source of energy. It provides employment to over 7 lakh workers. Its reserves are substantial. Coal has a favour over other fuels as it can be converted into other forms of energy. Presently, it is the principal source of electricity in India. According to an estimate, coal and lignite account for about 60 percent of the country's commercial energy consumption.

In future, they are also expected to play more important role in the power generation. Besides this, coal is also an essential input in the steel and carbo-chemical industries. Coal's reserves are mainly clustered around a belt extending over the western part of West-Bengal, South Bihar, Orissa, North-Eastern and Central Madhya Pradesh, Eastern figure of Maharashtra and the northern extremity of Andhra Pradesh.

In Assam, there are also some scattered deposits. According to the estimates made by Geological Survey of India, the reserves of coal upto January 1990 are to the tune of 18604 crore tones seams of 0.5 meter and above thickness down to a depth of 1200 meter. Among these, 27 percent of reserves are of coking variety and the remaining 73 percent are of non-coking variety.

The current estimate of lignite reserves in India is about 629 crore tones, 80 percent occurring in Tamil Nadu. Smaller deposits exist in Gujarat, Rajasthan and Jammu & Kashmir. Neyveli area of Tamil Nadu contains about 330 crore tones -of which 200 crore tones fall in the proven category.

Neyveli lignite has much less ash content than the average Indian Coal and is consistent in quality. The growth of coal production after nationalisation of industries in 1972 was to the tune of 1.7 crore tones which in 1988-89 rose to the extent of 19.5 crore tones. This has placed

India into fifth position on the global map. The total requirement of coal is likely to increase to 400 million tones. The strategies for higher production have been as under:

i. To increase production from existing mines through marginal improvement.
ii. To open new mines, both underground and open cast, adopting latest technology.
iii. Reconstruction of existing mines having up-gradation of production through mechanization.

The consumption of coal at the end of Sixth Plan was 139.23 million tones as against the target of 155.70 million tones. During the Seventh Plan, overall demand for coal would shoot up to 220 million tones. The coal production was 327.79 million tones in 2001-02 against the production of 211 million tones in 1990-91.

**2. Petroleum:**

The second half of the present century may be called the oil age. That is why, it is called the "Oil King" or the "Liquid Gold". It is a very important source of energy and the basis of many chemical industries. In Indian context, the resources in mineral oil and natural gas are small and these are confined on Nahar-Katia-Moran area in Upper Assam, Bombay High Off and the Bassein structure, Ankleshwar region of Gujarat. The actual output of crude oil before the recent discoveries of oil fields used to be negligible, only 0.5 million tones, till 1961 but with the striking of new oil wells since then, the output has significantly increased to 12.5 million tones in 1980-81 and 34.1 million in 1989-90. It further increased to 36.8 million tones in 2000-01. India's total proved reserves of crude oil are estimated to be 131.3 million tones. Further, the production of crude oils shot upto 24.3 crore tones in 2000-01 against 16.83 lakh tones in 1990-91. The domestic production of crude oil fell short of requirements. Similarly, in 1990-91, about 1.8 crore tones of crude oil and 62.6 lakh tones of petroleum products were imported to meet the country's requirements. Net imports of crude oil and petroleum products during 1990-91 estimated to be 1.96 crore tones and 53.5 lakh tones, respectively.

**Oil Exploration:**

The world energy crisis which took place in October, 1973 following dizzy heights in oil prices by OPEC countries has given a severe jolt to all countries. It has left the world bettered. In this way, the present energy crisis has risen out of a very sudden soaring of the prices of oil products.

**Oil Refining:**

In 1951, India had only one oil refinery in Assam Oil Coy. It used to refine only 5 lakh tones of oil in one year. After Independence, 13 refineries were set up in different parts of the country. In January 1997, their refining capacity was 604 lakh tones. Oil refineries are mainly found in Mumbai, Cochin, Barauni, Guwahati, Mathura, Chennai, Haldia, Kayali, etc. In 1996-97, 12 private refineries have been permitted to establish their own units.

**3. Lignite:**

Lignite or brown coal has a lower energy content than black coal. Thermal Power Stations located very close to their mines are the main users. Its production was 13.28 million tones in 2001-02. Its reserves are found mainly at Neyveli in Tamil Nadu.

**4. Nuclear Energy:**

This source of energy has tremendous possibilities. According to an estimate, nuclear power station using uranium as fuel will be cheaper than a conventional station at places located away from deposits of coal by more than 800 km. Fortunately, India is the first country in the world which is developing atomic energy. India possesses sufficient raw material for the production of atomic energy.

Its resources of Thorium are the largest in the world, i.e. 5000 tones. Uranium reserves have also been located in Bihar and Rajasthan. It has been estimated that uranium reserves available in the country are about 5000 to 10000 MW of nuclear power plants. Recent Pokhran Nuclear Blast has established India's capability to go nuclear.

The first atomic plant was set up at Tarapore. Its capacity is 424 MW. The second atomic power house has been set up at Ranapartap Sagar in Rajasthan whose capacity is also placed at 420 MW. The third plant is being constructed at Kalapakam in Tamil Nadu with a capacity of 420 MW. Another station is being built at Narora in Uttar Pradesh with a capacity of 440 MW. There are also plans to build more nuclear power stations. Successful nuclear explosion in 1974 has given a pride of place to our country among the progressive countries of the world. By the end of March 1975, India has built up an installed capacity of 620 MW from its atomic power station. Efforts are being made to develop solar photovaltars, urja gram (rural renewable energy) and urban waste energy in the country.

Therefore, the prospects for the generation of atomic energy are quite bright in our country and the nuclear power seems to be the most economic situation on a long term basis for the country's power programme.

**5. Natural Gas:**

Natural gas has emerged to be the most important source of energy since the last two decades. It can be produced in two ways:

i. Associated gas together with petroleum products from oil fields.
ii. Free gas obtained exclusively from gas fields in Gujarat, Rajasthan, Tripura, Andhra Pradesh and Tamil Nadu.

Gas is used in fertilizer and petro-chemical plants and gas based thermal power plants. Gas Authority of India Limited was set up in 1989 for the construction of pipeline for the movement of gas, oil and petroleum products.

**(a) LPG:**

It is a cooking gas used as fuel. During 1989-90 was produced 2000 tons of gas. Its supply falls short of the demand, so we have to depend on imports.

**(b) LNG**:

It is produced by compressing the gas into liquid. Oil and Natural Gas Corporation (ONGC) is its main producer. Oil India Limited also produces it in small quantity. Its target production for 1990-91 was 824 thousand tones.

**6. Electricity:**

In India, the development of agriculture, industry, urbanization, electrification of villages and trains would not have been possible without electricity. Demand for electricity also comes from households. The following table shows the pattern of utilization of electric power produced and supplied by public sector units. Main sources of power generation:

Thermal Power

Hydro-electric Power

Nuclear Power

i. Thermal Power is generated in India at various power stations with the help of coal and oil. It has been our major source of electric power. Its share in the total installed capacity was 67 percent in 1950-51 which increased to 70 percent in 1992-93. Bulk of the thermal power is derived from coal and only a small fraction comes from oil.

ii. Hydro-electric Power is produced on a large scale through multipurpose river valley projects by constructing big dams over fast flowing rivers. For example, Bhakra Nangal Project, Damodar Valley Project, Hira Kund Project etc. In, 1950-51, installed capacity of hydro-electric was 560 MW which increased to 19,600 MW in 1995-96.

iii. Nuclear Power in India has also developed. Nuclear power stations of Tarapur, Kota (Rajasthan), Kalapakam (Chennai), Narora (UP) are set-up. Its supply accounts for only 3 percent of the total installed capacity. India is in favour of using nuclear power for peaceful purposes.

**Production of Electricity**

Production of electricity was started in 1890 with the establishment of Shivamudram Hydro Electric Power Station in Karnataka. Till 1947 its production did not make any headway. In the post independence period installed plant capacity generation and consumption of electricity have increased considerably. Installed capacity and generation of energy in 2001-02 has been shown in table.

***Installed Plant Capacity and Generation of Electricity***

| Sector | Installed Capacity(Thousand KW) (1950-51) | Energy Generation(Billion KWH) | Installed Capacity(Thousand KW) (2001-02) | Energy Generation(Billion KWH) |
|---|---|---|---|---|
| Hydro Electricity | 0.6 | 26.3 | 2.5 | 73.9 |
| Thermal Electricity | 1.1 | 75.9 | 2.6 | 422 |
| Nuclear Electricity | 1.5 | 2.7 | 6.1 | 19.3 |
| Total | 1.7 | 104.9 | 5.1 | 515.2 |

It is clear from the above table that in 2001-02 installed plant capacity of electricity was 104.9 thousand KW and the generation of energy was 515.2 billion KWH. In India, 78 percent generation of electricity is from thermal power, i.e. coal. Consumption of electricity in India in different uses is evident

**Percentage of Electrical Consumption**

| Year | Domestic | Commercial | Industrial | Agriculture | Railway | Others | Total |
|---|---|---|---|---|---|---|---|
| 2001-02 | 23.9 | 7.1 | 34.6 | 26.8 | 2.6 | 5.6 | 100 |

It is clear from the table that maximum use of electricity is made by industry and then by agriculture. Third place is occupied by domestic use.

### Rural Electrification

The scope of rural electrification in India has been expanding constantly. Under rural electrification, electricity is supplied for two purposes:

i. Production-oriented purpose, viz. minor irrigation, village industries, etc. and
ii. Supply of electricity to rural households. The job of rural electrification has been entrusted to State Electricity Boards.

By 1996 hundred percent villages of about 12 states of the country namely A.P., Gujarat, Haryana, H.P., Karnataka, Kerala, Maharashtra, Punjab, Tamil Nadu, Assam, J & K and M.P., were electrified. Rural electrification in rest of the states is in full swing. By 2001, five lakh four thousand villages were electrified and 1 crore 22 lakh pump-sets were energised.

Under New Economic Policy, private sector has also been allowed to generate electricity. There is urgent need to increase the generation of electricity in India. In the Ninth Plan, 14.5 percent of the total outlay has been allotted for the development of electricity. Rural Electrification Corporation has been set to finance the rural electrification.

### Losses of Electricity Boards

Production and distribution of electricity in India is almost in the hands of Govt. Electricity is distributed by State Electricity Boards. At present, about all Electricity Boards are running into huge losses. They do not have funds to make payment for the electricity purchased by them. In 1990-00, these Boards suffered loss of Rs. 18,081 crore.

There are many reasons for the losses suffered by the Boards:

i. Theft of electricity
ii. Loss of electricity during the course of transmission
iii. Supply of electricity at concessional rates to agriculture, irrigation and small industries. Government gives subsidies to Electricity Boards for supplying electricity to these priority sectors at concessional rates.

In 1999-00, net subsidies worth Rs. 22,494 crore were given. In order to reduce losses of Electricity Boards, the Government is inviting private sector and foreign entrepreneurs for the generation and distribution of electricity.

### 6.5.2. Non-Conventional or Renewable Sources

Top-priority is being accorded by the Government to promote renewable sources of energy so that alternative to the fast exhausting non-conventional sources of energy are found. Use of non-conventional sources of energy can be made in the same manner as conventional sources. In this connection, Government established on 6 September 1982, Department of Non-conventional Energy Sources. This department is a part of Ministry of Energy. The department found the following non-conventional sources of energy in the country:

**1. Bio-Energy**

This type of energy is obtained from organism or organic matter. It is of two kinds:

**a) Bio-Gas:**

It is that source of energy which is obtained from Gobar Gas Plant by putting cow-dung into the plant. Besides producing gas this plant converts gobar into manure. It can also be used for cooking, lighting and generating of electricity. Under the national programme of bio-gas, 23.59 lakh bio-gas plants had already been established ending 1999-2000. They produce more than 225 lakh tonnes of manure. About 1,628 large community or institutional bio-gas plants have been established in the country. Presently there are over 50 lakh gobar gas plants in India.

**b) Bio-Mass:**

It is also a source of producing energy through plants and trees. The purpose of bio-mass programme is to encourage Aforestation for energy, so that fuel for the generation of energy based on gas technique and fodder for the cattle could be obtained. 5.6 MW capacity for the generation of bio-mass energy has been installed.

**2. Improved Chullahs**

In December 1983, National Improved Chullahs Programme was initiated. These chullahs saves lot of fuel, besides they are smokeless. Thus with the use of less fuel more energy is produced. These chullahs have gained enough popularity among rural communities. It is estimated that an improved chullah saves 700 kg of fuel every year.

**3. Solar Energy:**

Solar energy refers to that which is produced by the light of the sun.

**(a) Solar Thermal Programme**

Under this programme, solar energy is directly obtained. Light of the sun is converted into thermal power. Solar energy is used for cooking, hot water, distillation of water, drying of the crops, etc. In 1999-2000, solar energy was being used over an area of 3.4 lakh sq. metres. In 1999-2000, there were 3.1 lakh solar cookers in use.

**(b) Solar Photovoltaic's Programme**

Under the programme photovoltaic cells are exposed to sun light as a result of which electricity is generated at the meeting place of two substances. Photovoltaic cells are those cells which convert light of the sun into electricity. By the year 1999-2000, under this programme light was provided to 975 villages and colonies. It is used for street lighting, community light system, T.V. system, water pumps, domestic lights, etc. A Solar Power Station is being installed at Jodhpur in Rajasthan.

**4. Energy from Urban Wastes**

Urban waste is also used for the generation of power. In Timarpur (Delhi) a power station of 3.75 MW capacities has been set up to generate energy from the town refuge.

**5. Wind Power Development Programme**

Under this programme energy is generated by harnessing wind power. About 2,756 wind-pumps were established for irrigation purposes. Wind-power operated power houses were set up in seven states. Their generation capacity was 1000 MW. 710 MW wind power has been generated in private sector. India has second place in wind power energy generation after U.S.A.

**6. Programme for Alternative Fuels for Surface Transportation:**

Under this programme, motor transport is operated by renewable source of energy in place of petrol or diesel. Some D.T.C. buses in Delhi are being run by alcohol and battery. It saves conventional energy and is also environment friendly.

**7. Urja Gram:**

Under this programme energy needs of the villages are met by such locally available resources. Most of these systems are based on community Bio-gas equipment. The programme has thus far been implemented in about 406 villages.

**8. Programme for Alternate Fuels:**

Motor vehicles using mixture of ethanol (alcohol) are being successfully operated. Battery operated buses are also being successfully operated in Delhi. In order to develop renewable energy sources, Indian Renewable Energy Development agency was formed in 1997. It sponsors and finances research projects on energy.

## 6.6. Development of Atomic Energy in India

At present, three Atomic energy centers are functioning in the country while the fourth is under construction and fifth one is to be installed. The first atomic energy centre was set up in Tarapur. This Plant was established in 1969, on the border line of Gujarat and Maharashtra, near Mumbai. At present, its annual capacity to produce electricity is 42 lakh kilowatts. The second plant is situated in Rajasthan, built on the Rana Pratap Sagar Dam near Kota. The third centre of atomic energy is in Kalapakkam near Madras, in Tamil Nadu state. The optimum capacity of these two plants is equal to that of Tarapur atomic centre. The Kalapakkam atomic energy centre has been set up entirely by the sincere efforts of Indian engineers.

The fourth Atomic energy centre in India is under construction at Narora in Bulandshahar district in West Uttar Pradesh, on the bank of the Ganga. It is decided that this centre will meet the requirements of agriculture sector. Thus India is the first country, where atomic energy is being generated to serve the needs of agriculture.

The proposed fifth atomic energy centre is to be erected on the Tapti River in Kakapara region. The development of atomic energy centers in India has been possible due to the availability of Atomic Research Centre, Atomic Technology and Atomic Minerals in abundance, in Trombay. In India the development of atomic energy has proved really helpful in the discovery of medicines, to improve the quality of seeds and fulfill the peaceful objectives. In recent years, these challenges have led to a major set of continuing reforms, restructuring, and a focus on energy conservation.

**a.** Industry-wise total primary energy use of 87599 petajoules in (2019-20)

- **i.** Electricity, gas, steam & air conditioning supply (26%)
- **ii.** Transportation & Storage (2%)
- **iii.** Other Industries (19%)
- **iv.** Households (7%)
- **v.** Accumulation (3%)
- **vi.** Export (6%)
- **vii.** Agriculture, Forestry & Fishery (2%)
- **viii.** Mining & Quarring (1%)
- **ix.** Manufacturing (34%)

**b.** Total primary energy supply of 882 Mtoe in 2017

- **i.** Coal (44.3%)
- **ii.** Biomass and waste (21.2%)
- **iii.** Petroleum & other liquids (25.3%)
- **iv.** Natural gas (5.8%)
- **v.** Nuclear (1.1%)
- **vi.** Hydroelectric (1.4%)
- **vii.** Other renewable (0.9%)

## 6.7. Gas Balance of India

India ranks third in oil consumption with 4.669 million barrels/day in 2020 after USA and China. During the calendar year 2019, India imported 221.7 million tons of crude oil and 44.4 million tons of refined petroleum products and exported 60.7 million tons of refined petroleum products. India is the second biggest net importer of crude oil and its products after China. India has built surplus world-class refining capacity using imported crude oil for exporting refined petroleum products. The net imports of crude oil is lesser by one fourth after accounting exports and imports of refined petroleum products. Natural gas production was 26.9 billion cubic meters and consumption 59.7 billion cubic meters during the calendar year 2019.

The state-owned Oil and Natural Gas Corporation (ONGC) acquired shares in oil fields in countries like Sudan, Syria, Iran, and Nigeria – investments that have led to diplomatic tensions with the United States. Because of political instability in the Middle East and increasing domestic demand for energy, India is keen on decreasing its dependency on Organization of the Petroleum Exporting Countries (OPEC) to meet its oil demand, and increasing its energy security. Several Indian oil companies, primarily led by ONGC and Reliance Industries, have started a massive hunt for oil in several regions in India, including Rajasthan, Krishna Godavari Basin and north-eastern Himalayas.

India has nearly 63 tcf technically recoverable resources of shale gas which can meet all its needs for twenty years if exploited. India is developing an offshore gas field in Mozambique. The proposed Iran-Pakistan-India pipeline is a part of India's plan to meet its increasing energy demand.

## 6.8. Electric vehicles

### Electric vehicle industry in India

The retail prices of petrol and diesel are high in India to make electricity driven vehicles more economical as more and more electricity is generated from solar energy in near future without appreciable environmental effects. During the year 2018, many IPPs offered to sell solar power below 3.00 Rs/kWh to feed into the high voltage grid. This price is far below the affordable retail electricity tariff for the solar power to replace petrol and diesel use in transport sector.

The retail price of diesel is 101.00 Rs/liter in 2021–22, and the retail price of petrol was 110.00 ₹/liter. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power conversion efficiency) to replace diesel (lower heating value 8572 kcal/liter at 40% fuel energy to crankshaft conversion efficiency) is up to 19 ₹/Kwh. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power conversion efficiency) to replace petrol (lower heating value 7693 kcal/liter at 33% fuel energy to crankshaft conversion efficiency) is up to 28 ₹/Kwh. In 2021-22, India consumed 30.849 million tons of petrol and 76.687 million tons of diesel which are mainly produced from imported crude oil at huge foreign exchange outgo.

Vehicle to Grid (V2G) is also feasible with electricity-driven vehicles for catering to the peak load in the electricity grid. Electricity-driven vehicles would become popular in the future when the energy storage / battery technology becomes more compact, lesser density, longer lasting, and maintenance-free.

**Hydrogen energy**

**Power to gas and List of fuel cell vehicles**

The Hydrogen Energy program started in India after joining the IPHE (International Partnership for Hydrogen Economy) in the year 2003. There are nineteen other countries including Australia, United States, UK, Japan, etc. This global partnership helps India to set up commercial use of Hydrogen gas as an energy source.

Hydrogen is a carbon neutral fuel. Solar electricity prices in India have already fallen below the affordable price (≈ INR 5.00 per kWh to generate 0.041 lb/kWh hydrogen which is equivalent to 0.071 litres of petrol in terms of lower heating value) to make hydrogen economical fuel by sourcing from electrolysis of water to replace petrol/gasoline as transport fuel. Vehicles with fuel cell technology based on hydrogen gas are nearly twice more efficient compared to diesel/petrol-fueled engines. Hydrogen can be generated cheaply by splitting methane using electricity without emitting any greenhouse gas and also extracted from wood gas produced from carbon-neutral biomass. A luxury  Fuel Cell Electric Vehicles (FCEV) car generates one liter of bottled quality drinking water for every 10 km ride which is a significant byproduct. Also FCEV does not emit any particulate matter but removes particulate matter up to PM2.5 from the ambient air. Any medium or heavy duty vehicle can be retrofitted in to fuel cell vehicle as its system power density (watts/litre) and system specific power (watts/kg) are comparable with that of internal combustion engine. The cost and durability of fuel cell engines with economies of scale production line are comparable with the petrol/diesel engines.

The excess power generation capacity available in India is nearly 500 billion units/year presently and another 75,000 MW conventional power generating capacity is in pipeline excluding the targeted 175,000 MW renewable power by 2022. The hydrogen fuel generated by 500 billion units of electricity can replace all diesel and petrol consumed by heavy and medium duty vehicles in India completely obviating the need of crude oil imports for internal consumption. Use of hydrogen as fuel to replace jet fuel by aircraft is also a promising proposition. Converting petrol/diesel driven road vehicles in to fuel cell electric vehicles on priority would save the huge import cost of crude oil and transform the stranded electricity infrastructure into productive assets with major boost to the overall economic growth. Hydrogen spiked CNG is made available in Delhi to reduce pollution emissions from BS-IV compliant buses. Electricity as a substitute for imported LPG and PNG

**Policy framework**

In general, India's strategy is to encourage the development of renewable sources of energy by offering financial incentives from the federal and state governments. With the abundant solar energy resource combined with adequate high head pumped hydroelectric energy storage potential, India is capable to meet the ultimate energy requirements of its peak population from its renewable energy sources alone. In 2021, the government has upped India’s target to 500GW of renewable energy by 2030. Increasing energy consumption associated primarily with activities in transport, mining, and manufacturing in India needs rethinking on India's energy production.

The following trends are manifested in the energy policy to achieve energy self-sufficiency, least pollution, climate change mitigation, and long-term sustainability.

**Electricity sector in India**

The installed capacity of utility power plants is 314.64 GW as on 31 January 2017 and the gross electricity generated by utilities during the year 2015-16 is 1168.359 billion kWh which includes auxiliary power consumption of power generating stations. The installed capacity of captive power plants in industries (1 MW and above) is 50,289 MW as on 31 March 2017 and generated 197 billion kWh in the financial year 2016-17. In addition, there are nearly 75,000 MW aggregate capacity diesel generator sets with units sizes between 100 KVA and 1000 KVA. All India per capita consumption of Electricity is nearly 1,122 kWh during the financial year 2016-17. Ramagundam Thermal Power Station (2600 MW), Telangana

**Megawatt power**

The greenest energy is the energy we do not use. Energy conservation has emerged as a major policy objective, and the Energy Conservation Act 2001, was passed by the Indian Parliament in September 2001. This Act requires large energy consumers to adhere to energy consumption norms; new buildings to follow the Energy Conservation Building Code, and appliances to meet energy performance standards and to display energy consumption labels. The Act also created the Bureau of Energy Efficiency to implement the provisions of the Act. In 2015, Prime Minister Mr. Modi launched a scheme called Prakash Path urging people to use LED lamps in place of other lamps to drastically cut down lighting power requirements and the evening peak electricity load. Energy efficient fans at subsidized prices are offered to the electricity consumers by the electricity distribution companies (DisComs) to decrease peak electricity load. Energy saving certificates (Perfor Archieve and Trade), various renewable purchase obligations (RPO), and renewable energy certificates (REC) are also traded on the power exchanges regularly. Recent amendment to Energy Conservation Act in December 2022 included carbon trading provisions, green fuels mandatory use, etc.

**Rural electrification**

**Rural Electrification Corporation Limited**

As on 28 April 2018, all Indian villages were electrified. India has achieved 100% electrification of all rural and urban households. As of 4 January 2019, 211.88 million rural households are provided with electricity, which is nearly 100% of the 212.65 million total rural households. Up to 4 January 2019, 42.937 million urban households are provided with electricity, which is almost 100% of the 42.941 million total urban households. 89% of households in the country use LPG drastically reducing the use of traditional fuels – fuel wood, agricultural waste and biomass cakes – for cooking and general heating needs.

**SAQ4: Self Assessment Questions**

**Q1.** what percentage of Coal and lignite account for the country's commercial energy consumption.

**Ans.** about 60 percent

**Q2.** In which state lignite reserves in India is maximum?

**Ans.** 80 percent occurring in Tamil Nadu.

**Q3**. The consumption of coal at the end of Sixth Plan?

**Ans.** 139.23 million tones as against the target of 155.70 million tones.

**Q4**. Which was first oil refinery in India ?

**Ans.** In 1951, India had only one oil refinery in Assam Oil Coy.

**Q5.** Where Thorium reserve is the largest in the world?

**Ans.** India i.e. 5000 tones.

**Q6.** Main sources of power generation?

**Ans.** (i) Thermal Power; (ii) Hydro-electric Power and (iii) Nuclear Power

**Q7.** Under New Economic Policy, private sector has also been allowed to generate electricity?

**Ans.** In the Ninth Plan, 14.5 percent of the total outlay has been allotted for the development of electricity.

**Q8.** Power generation capacity available in India is ?

**Ans.** 500 billion units/year presently and another 75,000 MW conventional power generating capacity is in pipeline excluding the targeted 175,000 MW renewable power by 2022.

**Q9**. Bureau of Energy Efficiency was implemented?

**Ans.** In 2015.

## 6.9. Urban and rural energy consumption

The barriers to energy access in rural and urban settings are diverse and need to be examined separately. Initially, energy access efforts were focused on urban areas for reasons of ease of execution and lower costs, mostly due to a greater concentration of potential users in urban areas. Consequently, the great majority of people remaining without access to modern energy services today live in rural areas and much of the current discussion of energy access regard how to provide services to them. However, despite their greater geographical proximity to grid electricity and other supplies of clean energy, people living in poverty in urban areas also lack energy access. This article examines the differences in the effects of energy access in rural and urban settings.

**Urban Energy Access**

About 1 billion people currently live in slums and informal settlements within cities. It is estimated that this figure will double by 2030. These areas often lack access to legal, safe and affordable energy – both in terms of electricity and cooking fuel.

**Urban Electricity Access**

Most of the world's urban population does indeed have access to electricity. In poorer regions of the world, however, access can be illegal, expensive and potentially unsafe. Although these underserved areas may be in cities, power distribution utilities sometime hesitate to operate in informal settlements due to the potential of non-payment of bills, electricity theft and other such risk factors. Additionally, inhabitants of such settlements often lack requisite documentation, security of tenancy, as well as a stable organization for installing infrastructure. They also lack knowledge of the process for legal and safe access to electricity and the financial resources to apply for connection to electricity. Affordability is also a key factor here, as many government efforts for access seem to be rurally focused.

Access to safe, legal, reliable and affordable electricity in urban spaces plays a part in improving socio-economic conditions and reducing vulnerability. For instance, at a community level, access to street lighting within urban communities was seen as increasing residents' safety –both actual and perceived. Electricity access is also likely to create an opportunity for additional income-generating activities to be carried out and allows children to study at home with proper lighting, which is known to improve educational outcomes. Thermal comfort is an issue, especially in dwellings in urban communities that are often built with makeshift materials: access to electricity allows users to alleviate this discomfort to a limited extent.

**Urban Clean Fuel Access**

The availability of clean, safe and sustainable fuel for cooking and heating purposes is also a challenge for the urban poor and thus leads them to burn biomass or kerosene for fuel. The main barriers here are, again, lack of documentation for obtaining connections as well as affordability. Additionally, due to spatial constraints in urban settings, a large amount of this burning of biomass and kerosene is done indoors. Indoor combustion of biofuels leads to increased respiratory illnesses, decreased lung function and increased risk of premature death among women and children in these households. These results contrast with those of people of similar socioeconomic background who used cleaner fuels such as LPG as a primary fuel source. Thus, a shift to cleaner fuels has the direct benefit of improving health outcomes and lowering premature deaths. In addition, more modern fuels like LPG increase efficiency and reduce the time spent on cooking and collecting biomass, thereby freeing up time for other activities. In some cases, well-designed stoves that burn biomass in a more efficient manner have been distributed and have somewhat reduced the ill effects of biomass usage.

**Rural Energy Access**

Eighty Four percent (84%)percent of the people who lack modern energy access live in rural areas. Most people without electricity or access to clean cooking practices are concentrated in the developing parts of Asia and Africa.

**Rural Electricity Access**

The key distinction to be made in the access to electricity between rural and urban areas is that in rural areas it is often the lack of electricity delivery infrastructure, such as grid connectivity, that leads to the lack of access. Issues of affordability, documentation, tenure etc., are secondary.

The impacts of electricity access, in conjunction with other development measures such as road connectivity, potentially have greater influence on improving livelihoods in rural areas. For instance, electricity access allows for the use of electric irrigation pumps which increase agricultural productivity and farm income.

Electricity access provides avenues for education, information access and increases connectivity. For instance, availability of electricity increases usage of cell phones and improves communication with local markets to get better prices for produce. It also improves access to banking and credit systems and knowledge about agricultural best practices. A reduction of migration of skilled and educated workers is also viewed as improving the economic outlook of villages in the long term. In fact, electrification can lead to increased school enrollment, most notably amongst girls. Income diversification is also made possible, particularly for women, along with the opportunity to engage in microenterprise creation and other income-generating activities.

**Rural Clean Fuel Access**

Rural areas in the developing world often lack the infrastructure to supply clean cooking energy, such as LPG, to their populations. At times, the traditional alternative of biomass burning seems more attractive due to the large financial cost of the procurement of LPG/Natural gas, whereas biomass such as wood can be foraged for.

The effects of using traditional fuels are diverse, and only incidentally economic. At the outset, there is the threat of deforestation and land degradation brought on by over-extraction. At an individual level, there is the time cost in foraging for fuel, and the risk of not obtaining any fuel. Further, burning biomass in traditional stoves increases mortality rates through respiratory diseases, leading to health care costs and lowered earning potential. Fuel gathering and cooking is largely done by women and girls who are therefore more exposed to ill effects. This is where governments have stepped in, often successfully, by providing subsidized modified “clean” biomass burning stoves as a stepping-stone towards cleaner cooking practices. Studies in Africa show that clean stoves do indeed reduce the health impacts on women and children. LPG is also being tried, but it needs heavy subsidization for maximum uptake. Another alternative is localized biogas plants that break down animal and farm waste to produce a cleaner gas for cooking. It is to be noted, however, that designing, building, operating and maintaining a biogas plant is not without expense or challenges, especially in water stressed regions.

As we see, urban and rural areas have different issues regarding energy access and are thus impacted differently. While many efforts are ongoing by governments, international organizations, non-profits and others, the challenges of quantifying such issues and impacts are many, beginning the actual definitions of key terms utilized around the world; for example, what qualifies as an urban settlement may differ in each country. Similarly, what constitutes energy access also varies. Furthermore, studies sometimes do not consider other factors, such as road access, that influence developmental outcomes. There also seem to have been far more studies on the impacts of access to energy in rural areas, rather than in urban ones, especially in terms of counterfactual based studies on income, health and education. Thus, there is a need for more high-quality studies to examine the actual impacts of electrification.

## 6.10. The National Green Tribunal Act, 2010 (NGT Act.)

The National Green Tribunal (NGT) has been established on 18.10.2010 under the National Green Tribunal Act. 2010 for effective and expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matters connected therewith or incidental thereto. It is a specialized body equipped with the necessary expertise to handle environmental disputes involving multi-disciplinary issues. The Tribunal shall not be bound by the procedure laid down under the Code of Civil Procedure, 1908, but shall be guided by principles of natural justice.

The Tribunal's dedicated jurisdiction in environmental matters shall provide speedy environmental justice and help reduce the burden of litigation in the higher courts. The Tribunal is mandated to make and endeavor for disposal of applications or appeals finally within 6 months of filing of the same. Initially, the NGT is proposed to be set up at five places of sittings and will follow circuit procedure for making itself more accessible. New Delhi is the Principal Place of Sitting of the Tribunal and Bhopal, Pune, Kolkata and Chennai shall be the other four place of sitting of the Tribunal. An Act to provide for the establishment of National Green Tribunal for the effective and expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of

The NGT facilitates states to provide effective access to judicial and administrative proceedings including redressal, remedies and compensation related to environmental issues as per decision taken in united nation conferences on human health and environment held at Stockholm in June, 1972 and United Nations Conference on Environment and Development (UNCED) held at Rio de Janerio in June 1992.

**Structure of NGT**

The Tribunal comprises of the Chairperson, the Judicial Members and Expert Members. They shall hold office for term of three years or till the age of sixty-five years, whichever is earlier and are not eligible for reappointment.

The Chairperson is appointed by the Central Government in consultation with Chief Justice of India (CJI). A Selection Committee shall be formed by Central Government to appoint the Judicial Members and Expert Members. There are to be least 10 and maximum 20 full-time judicial members and Expert Members in the tribunal.

**Powers & Jurisdiction**

The Tribunal has jurisdiction over all civil cases involving substantial question relating to environment including enforcement of any legal right relating to environment. In October 2021, the Supreme Court (SC) declared the National Green Tribunal's (NGT) position as a "unique" forum endowed with suo motu (on its own motion) powers to take up environmental issues across the country. As per SC, the role of the NGT is not simply adjudicatory in nature; it has to perform equally vital roles that are preventative, ameliorative or remedial in nature. Being a statutory adjudicatory body like Courts, apart from original jurisdiction side on filing of an application, NGT also has appellate jurisdiction to hear appeal as a Court (Tribunal). The Tribunal is not bound by the procedure laid down under the Code of Civil Procedure 1908, but shall be guided by principles of 'natural justice'. While passing any order/decision/ award, it shall apply the principles of sustainable development, the precautionary principle and the polluter pays principle.

NGT by an order, can provide relief and compensation to the victims of pollution and other environmental damage (including accident occurring while handling any hazardous substance), for restitution of property damaged, and for restitution of the environment for such area or areas, as the Tribunal may think fit. An order/decision/award of Tribunal is executable as a decree of a civil court. The NGT Act also provides a procedure for a penalty for non compliance: Imprisonment for a term which may extend to three years, Fine which may extend to ten crore rupees and both fine and imprisonment.

An appeal against order/decision/ award of the NGT lies to the Supreme Court, generally within ninety days from the date of communication. The NGT deals with civil cases under the seven laws related to the environment, these include:

- The Water (Prevention and Control of Pollution) Act, 1974,
- The Water (Prevention and Control of Pollution) Cess Act, 1977,
- The Forest (Conservation) Act, 1980,
- The Air (Prevention and Control of Pollution) Act, 1981,
- The Environment (Protection) Act, 1986,
- The Public Liability Insurance Act, 1991 and
- The Biological Diversity Act, 2002.

Any violation pertaining to these laws or any decision taken by the Government under these laws can be challenged before the NGT. With the establishment of the NGT, India became the third country in the world to set up a specialized environmental tribunal, only after Australia and New Zealand, and the first developing country to do so. NGT is mandated to make disposal of applications or appeals finally within 6 months of filing of the same. The NGT has five places of sittings; New Delhi is the Principal place of sitting maddition to Bhopal, Pune, Kolkata and Chennai.

**Strengths of NGT**

1. Over the years NGT has emerged as a critical player in environmental regulation, passing strict orders on issues ranging from pollution to deforestation to waste management.
2. NGT offers a path for the evolution of environmental jurisprudence by setting up an alternative dispute resolution mechanism.
3. It helps reduce the burden of litigation in the higher courts on environmental matters.
4. NGT is less formal, less expensive, and a faster way of resolving environment related disputes.
5. It plays a crucial role in curbing environment-damaging activities.
6. The Chairperson and members are not eligible for reappointment, hence they are likely to deliver judgments independently, without succumbing to pressure from any quarter.
7. The NGT has been instrumental in ensuring that the Environment Impact Assessment process is strictly observed.

8. Challenges Pertaining to the Functioning of NGT
9. Two important acts - Wildlife (Protection) Act, 1972 and Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 have been kept out of NGT's jurisdiction. This restricts the jurisdiction area of NGT and at times hampers its functioning as crucial forest rights issue is linked directly to environment.
10. The NGT decisions are being challenged in various High Courts under Article 226 (power of High Courts to issue certain writs) with many asserting the superiority of a High Court over the NGT, claiming 'High Court is a constitutional body while NGT is a statutory body'." This is one of the weaknesses of the Act as there is lack of clarity about what kind of decisions can be challenged; even though according to the NGT Act, its decision can be challenged before the Supreme Court.
11. Decisions of NGT have also been criticized and challenged due to their repercussions on economic growth and development.
12. The absence of a formula based mechanism in determining the compensation has also brought criticism to the tribunal.
13. The decisions given by NGT are not fully complied by the stakeholders or the government. Sometimes its decisions are pointed out not to be feasible to implement within a given timeframe.
14. The lack of human and financial resources has led to high pendency of cases - which undermines NGT's very objective of disposal of appeals within 6 months.
15. The justice delivery mechanism is also hindered by limited number of regional benches.

## 6.11. NGT activities

***Landmark Judgements of NGT***

1. In 2012 to set up steel project POSCO a South-Korean steelmaker company signed a MoU with the Odisha government.
2. NGT suspended order and this was considered a radical step in favour of the local communities and forests.
3. In 2012 A. H. Patel vs. Union of India case, NGT gave judgment of complete prohibition on open burning of waste on lands, including landfills – regarded as the single biggest landmark case dealing with the issue of solid waste management in India.

4. In 2013 in Uttarakhand floods case, the Alaknanda Hydro Power Co. Ltd. was ordered to compensate to the petitioner – here, the NGT directly relied on the principle of ‘polluter pays’.
5. In the Save Mon Federation Vs Union of India case (2013), the NGT suspended a ₹6,400-crore hydro project, to save the habitat of a bird.
6. In 2015, the NGT ordered that all diesel vehicles over 10 years old will not be permitted to ply in Delhi-NCR.
7. A December 2016 amendment to EIA 2006 notification — the amendments basically sought to give local authorities powers to grant environmental clearance to builders — was nullified by the NGT, terming it as a “ploy” to circumvent the 2006 rules.
8. Many Projects which were approved in violation of the law such as an Aranmula Airport, Kerala; Lower Demwe Hydro Power Project and Nyamnjangu in Arunachal Pradesh; mining projects in in Goa; and coal mining projects in Chhattisgarh were either cancelled or fresh assessments were directed.
9. In 2017, the Art of Living Festival on Yamuna Food Plain was declared violating the environmental norms, the NGT panel imposed a penalty of Rs. 5 Crore.
10. The NGT, in 2017, imposed an interim ban on plastic bags of less than 50-micron thickness in Delhi because “they were causing animal deaths, clogging sewers and harming the environment”.

There is need for more autonomy and widen NGT’s scope for effective protection of environment in balance with human developmental activities.

## 6.12. Summary

India is largely dependent on fossil fuels imports to meet its energy demands a study says by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. About 80% of India's electricity generation is from fossil fuels. India is surplus in electricity generation and a marginal exporter of electricity in 2017. Since the end of the calendar year 2015 huge power generation capacity has been idling for want of electricity demand. India ranks second after China in renewable production with 208.7 Mtoe in 2016. The carbon intensity in India was 0.29 kg of $CO_2$ per k where in 2016 which is more than that of USA, China and EU. The total manmade $CO_2$ emissions from energy, process emissions, methane and flaring is 2797.2 million tons of $CO_2$ in Year 2021 which is 7.2% of global emission. In 2019-20, the total generation from all renewable energy sources is nearly 20% of the total electricity generation in India.

## 6.13. Terminal Questions

**Q.1:** What are the Indian emission norms in transportation sector?

**Answer**: ----------------------------------------------------------------------------------------------------

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**Q.2:** Give a brief on National programmes to promote biomass energy production in India?

**Answer**: ----------------------------------------------------------------------------------------------------

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**Q.3:** Effectiveness of Solar photovoltaic programmes in India?

**Answer**: ----------------------------------------------------------------------------------------------------

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**Q.4:** Renewable Energy resources available in India?

**Answer**: ----------------------------------------------------------------------------------------------------

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**Q.5:** Rural energy consumption in India?

**Answer**: ----------------------------------------------------------------------------------------------------

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**Q.6:** National green tribunal (NGT) act 2010 and its activities?

**Answer**: ----------------------------------------------------------------------------------------------------

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## 6.14. Further suggested readings


**1.** Environmental Science, Subhas Chandra Santra, New Central Book Agency, 3rd Edition, 2011.

**2.** Non-conventional Energy Resources, D.S. Chauhan, New Age International.

**3.** Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.

**4.** Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press.

**5.** Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.

**6.** Introduction to Energy and Climate, Developing a Sustainable Environment, Julie Kerr, Taylor & Francis.

SBSEVS-01N

# Energy Resources and Green Technology

*Rajarshi Tandon Open University, Prayagraj*

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***Energy Resources and Green Technology***

# Block- III

# Energy Conservation and Green Energy

## UNIT -7

## Energy Conservation and Green Building

## UNIT-8

## Green Energy

## UNIT-9

## Green Nanotechnology

# Unit-7: Energy Conservation and Green Building

***Contents***



## 7.1. Introduction

Energy conservation and green building are two related concepts that aim to reduce the energy consumption of buildings while promoting sustainable and environmentally friendly practices. Energy conservation refers to the practice of using energy more efficiently and reducing waste, while green building is the design and construction of buildings that are energy-efficient, resource-efficient, and environmentally responsible. The need for energy conservation and green building has become increasingly urgent due to the growing concern about climate change and the depletion of natural resources. Buildings are a significant contributor to greenhouse gas emissions and consume a significant amount of energy. Therefore, energy conservation and green building are crucial for reducing the carbon footprint of buildings and mitigating the impact of climate change. Energy conservation can be achieved through various measures such as using energy-efficient appliances, installing insulation, using renewable energy sources, and optimizing the use of lighting and ventilation systems. Green building, on the other hand, involves the use of sustainable materials, optimizing the building's orientation and design, reducing water consumption, and implementing innovative energy-efficient technologies. Green building certification programs such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) provide guidelines for designing and constructing energy-efficient and environmentally sustainable buildings. These programs offer a framework for evaluating the sustainability of buildings and promote the adoption of best practices in green building design and construction. Energy conservation and green building are essential practices for promoting sustainable development and reducing the environmental impact of buildings. By implementing these practices, we can reduce our carbon footprint, conserve natural resources, and create healthier and more comfortable living and working environments.

**Objectives:**

- To discuss the energy conservation and its needs
- To discuss the methods and benefits of energy conservation
- To discuss the green buildings designs and it's important
- To discuss the Certification of green building

## 7.2. Energy conservation

The principle of energy conservation is a fundamental principle of physics that states that energy cannot be created or destroyed, only transformed from one form to another. By applying this principle to our daily lives and reducing our energy consumption, we can promote sustainability and reduce our impact on the environment.

### 7.2.1. Definition

Energy conservation refers to the practice of reducing energy consumption by using energy more efficiently and minimizing energy waste. It involves taking measures to reduce the amount of energy required to perform a specific task or achieve a particular outcome. The goal of energy conservation is to use less energy to achieve the same level of output or service, thereby reducing the demand for energy and decreasing the environmental impact of energy consumption.

### 7.2.2. Principle

The principle of energy conservation is based on the law of conservation of energy, which states that energy cannot be created or destroyed, only transformed from one form to another. This means that the total amount of energy in a closed system remains constant over time, and energy can only be transferred or converted from one form to another.

The principle of energy conservation applies to all forms of energy, including thermal energy, mechanical energy, electrical energy, and chemical energy. It is a fundamental principle of physics and is essential for understanding the behavior of energy in various physical systems.

In practical terms, the principle of energy conservation means that we can reduce energy consumption by using energy more efficiently and minimizing energy waste. By optimizing the use of energy in our homes, workplaces, and industries, we can reduce the demand for energy and decrease the environmental impact of energy consumption.

Energy conservation measures can include using energy-efficient appliances, installing insulation, using renewable energy sources, and optimizing the use of lighting and ventilation systems. The benefits of energy conservation include cost savings, reduced greenhouse gas emissions, and the preservation of natural resources.

## 7.3. Methods of energy conservation

There are various methods of energy conservation that can be used to reduce energy consumption and minimize energy waste. By implementing these methods, we can promote sustainability; reduce our impact on the environment, and save money on energy bills. Some of the most effective methods of energy conservation include:

### 7.3.1. Energy-efficient appliances:

Choosing appliances that have a high energy efficiency rating can significantly reduce energy consumption. This includes appliances such as refrigerators, air conditioners, and washing machines. Here are some examples of energy-efficient appliances:

- **Energy Star certified refrigerators:** Energy Star is a certification program that identifies energy-efficient products. Energy Star certified refrigerators use 15% less energy than standard models.
- **High-efficiency washing machines:** High-efficiency washing machines use less water and energy than traditional models. They also require less detergent and can help reduce water and wastewater costs.
- **Energy-efficient dishwashers:** Energy-efficient dishwashers use less water and energy than traditional models. They also have features like soil sensors and delayed start options that can help reduce energy consumption.
- **LED light bulbs**: LED light bulbs use less energy and last longer than traditional incandescent bulbs. They also come in a range of color temperatures and can be dimmed to create the desired ambiance.
- **Smart thermostats**: Smart thermostats learn your heating and cooling preferences and adjust the temperature accordingly. They can also be controlled remotely, helping to reduce energy consumption when you're away from home.
- **Energy-efficient HVAC systems:** Energy-efficient Heating Ventilation and Air Conducting (HVAC) systems use less energy and can help reduce utility bills. Features like variable-speed fans and programmable thermostats can help increase energy efficiency.

By using energy-efficient appliances, you can help reduce energy consumption and lower your utility bills. Energy-efficient appliances also contribute to a more sustainable and resilient built environment.

### 7.3.2. Insulation:

Insulation is an essential component of energy conservation in buildings. It helps to reduce heat transfer through walls, floors, and roofs, which can lower heating and cooling costs and improve indoor comfort. Here are some examples of insulation materials commonly used in buildings:

- **Fiberglass insulation**: Fiberglass insulation is made from glass fibers and is available in batts or loose-fill form. It is easy to install and is one of the most common types of insulation used in residential and commercial buildings.
- **Cellulose insulation:** Cellulose insulation is made from recycled paper and treated with fire retardants. It is available in loose-fill form and is an excellent choice for attics and walls.

Spray foam insulation: Spray foam insulation is made from polyurethane and is sprayed onto surfaces to form a tight seal. It is an excellent choice for sealing air leaks and reducing energy consumption.

**Reflective insulation**: Reflective insulation is made from foil-faced paper, plastic, or metal and is designed to reflect radiant heat. It is an excellent choice for attics and walls in hot climates.

**Radiant barrier insulation:** Radiant barrier insulation is made from aluminum foil and is designed to block radiant heat. It is an excellent choice for attics and walls in hot climates.

### 7.3.3. Lighting:

Lighting is an essential part of energy conservation in buildings. Here are some examples of energy-efficient lighting solutions that can help reduce energy consumption:

- **LED lighting:** Light Emitting Diode (LED) lights use less energy and last longer than traditional incandescent bulbs. They also come in a range of color temperatures and can be dimmed to create the desired ambiance.
- **CFL lighting:** Compact Fluorescent Lamp (CFL) bulbs use less energy than traditional incandescent bulbs and last longer. They are available in a range of color temperatures and can be used in a variety of fixtures.
- **T5 fluorescent lighting**: T5 fluorescent lights are energy-efficient and produce a lot of light with very little energy. They are commonly used in commercial buildings and can last up to 20,000 hours.
- **Motion sensors:** Motion sensors can help reduce energy consumption by turning lights off when no one is in the room. They are commonly used in restrooms, conference rooms, and other areas where occupancy varies.
- **Daylight sensors**: Daylight sensors can help reduce energy consumption by automatically dimming or turning off lights when there is sufficient natural light available.
- **Lighting controls:** Lighting controls can help reduce energy consumption by allowing users to adjust the lighting levels according to their needs. This can include dimming controls, timers, and scheduling.

By using energy-efficient lighting solutions and controls, you can reduce energy consumption and lower your utility bills. Energy-efficient lighting solutions also contribute to a more sustainable and resilient built environment.

- **Renewable energy sources:** Installing renewable energy systems such as solar panels or wind turbines can provide a sustainable source of energy and reduce dependence on non-renewable sources.

**7.3.4. Optimization of heating, ventilation, and air conditioning (HVAC) systems:** Proper maintenance and optimization of HVAC systems can significantly reduce energy consumption and improve indoor air quality.

**7.3.5. Behavior changes:** Making simple behavior changes such as turning off lights and unplugging electronics when not in use, can reduce energy consumption and lower electricity bills.

**7.3.6. Building design**: Designing buildings with energy efficiency in mind, such as optimizing building orientation and maximizing natural lighting and ventilation can significantly reduce energy consumption.

### 7.3.7. Transportation:

Transportation is an essential part of energy conservation, especially in urban areas where the majority of people rely on cars and other forms of transportation. Here are some examples of energy-efficient transportation solutions that can help reduce energy consumption:

- **Public transportation:** Public transportation, such as buses, trains, and subways, can help reduce energy consumption by allowing people to travel more efficiently. Many public transportation systems are now using electric or hybrid vehicles, which are more energy-efficient than traditional gasoline-powered vehicles.
- **Carpooling:** Carpooling allows people to share a ride to work or other destinations, reducing the number of cars on the road and the amount of energy used. Many employers offer incentives for carpooling, such as reserved parking spots or discounted parking rates.
- **Biking and walking:** Biking and walking are two of the most energy-efficient forms of transportation. They also provide health benefits and can reduce air pollution.
- **Electric vehicles**: Electric vehicles are becoming increasingly popular, especially in urban areas. They are more energy-efficient than traditional gasoline-powered vehicles and produce zero emissions.

- **Fuel-efficient vehicles**: Fuel-efficient vehicles, such as hybrid or diesel cars, are more energy-efficient than traditional gasoline-powered vehicles. They also produce fewer emissions.
- **Telecommuting**: Telecommuting allows people to work from home or another location, reducing the need for transportation altogether.

  By using energy-efficient transportation solutions, you can reduce energy consumption, lower your carbon footprint, and contribute to a more sustainable and resilient built environment.

## 7.4. Need for energy conservation in India

India is a developing country with a growing population and an expanding economy. As a result, the demand for energy in India is increasing rapidly, and the country is heavily reliant on non-renewable energy sources such as coal and oil. This dependence on non-renewable energy sources has significant environmental, economic, and social implications. Therefore, there is a pressing need for energy conservation in India. Here are some of the reasons why energy conservation is essential in India:

**Environmental concerns:** The use of non-renewable energy sources in India has significant environmental implications, including air pollution, water pollution, and greenhouse gas emissions. Energy conservation measures can help reduce these environmental impacts.

**Economic benefits:** Energy conservation can help reduce energy bills and operational costs for households, businesses, and industries. This can lead to significant savings and improved economic competitiveness.

**Energy security:** India is heavily reliant on energy imports, which makes the country vulnerable to fluctuations in global energy prices. Energy conservation can reduce the demand for energy imports and improve energy security.

**Sustainable development:** Energy conservation is a crucial component of sustainable development. By reducing energy consumption, India can promote sustainable development and ensure that future generations have access to clean and affordable energy sources.

**Social benefits:** Energy conservation measures can improve the quality of life for people in India by reducing air pollution and improving access to affordable energy sources. This can lead to improved health outcomes, reduced energy poverty, and increased social equity.

In conclusion, energy conservation is crucial for promoting sustainable development, improving energy security, and reducing environmental and social impacts in India. By implementing energy conservation measures, India can ensure a sustainable and prosperous future for its citizens.

## 7.5. Benefits of energy conservation

Energy conservation offers numerous benefits for individuals, businesses, and society as a whole. Here are some of the key benefits of energy conservation:

**Cost savings**: One of the most significant benefits of energy conservation is cost savings. By reducing energy consumption, individuals, businesses, and governments can save money on energy bills and operational costs.

**Reduced greenhouse gas emissions**: Energy conservation can help reduce greenhouse gas emissions, which contribute to climate change. By reducing energy consumption, we can decrease our carbon footprint and help mitigate the impacts of climate change.

**Improved air quality:** Energy conservation can also help improve air quality by reducing the emissions of pollutants from power plants and other energy sources. This can lead to improved health outcomes and reduced healthcare costs.

**Increased energy security:** By reducing our dependence on non-renewable energy sources, we can improve energy security and reduce our vulnerability to fluctuations in global energy prices.

**Job creation:** Energy conservation can create new job opportunities in the energy efficiency and renewable energy sectors, leading to economic growth and job creation.

**Sustainable development:** Energy conservation is a crucial component of sustainable development, promoting resource conservation, and reducing our impact on the environment.

**Improved comfort:** Energy conservation measures can improve the comfort of living and working environments by reducing temperature fluctuations and improving indoor air quality.

In conclusion, energy conservation offers numerous benefits, including cost savings, reduced greenhouse gas emissions, improved air quality, increased energy security, job creation, sustainable development, and improved comfort. By adopting energy conservation measures, we can promote a more sustainable, healthy, and prosperous future for ourselves and future generations.

## 7.6. Government initiative for energy conservation

The government of India has launched several initiatives and policies aimed at promoting energy conservation and increasing the use of renewable energy sources. Here are some of the key government initiatives for energy conservation:

**National Mission for Enhanced Energy Efficiency (NMEEE):** The NMEEE was launched in 2010 with the aim of reducing energy consumption by promoting energy efficiency measures in industries, buildings, and transportation.

**Energy Conservation Building Code (ECBC):** The ECBC was launched in 2007 with the aim of promoting energy efficiency in buildings. The code provides minimum energy efficiency standards for new commercial buildings and major renovations.

**UJALA (Unnat Jyoti by Affordable LEDs for All):** UJALA is a government-led initiative launched in 2015 that provides affordable LED bulbs to households across India. This program has helped to reduce energy consumption and save money on energy bills.

**Perform Achieve and Trade (PAT) scheme:** The PAT scheme was launched in 2012 with the aim of reducing energy consumption in energy-intensive industries. The scheme provides incentives for industries to adopt energy efficiency measures and meet energy consumption targets.

**National Solar Mission:** The National Solar Mission was launched in 2010 with the aim of promoting the use of solar energy in India. The mission includes targets for solar power capacity addition, research and development, and manufacturing.

**Pradhan Mantri Ujjwala Yojana:** The Pradhan Mantri Ujjwala Yojana was launched in 2016 with the aim of providing free LPG connections to households below the poverty line. This program has helped to reduce indoor air pollution and improve health outcomes.

**Smart Cities Mission:** The Smart Cities Mission was launched in 2015 with the aim of promoting sustainable development in cities across India. The mission includes energy efficiency measures such as smart grids, energy-efficient buildings, and electric mobility.

In conclusion, the government of India has launched several initiatives and policies aimed at promoting energy conservation and increasing the use of renewable energy sources. These initiatives are crucial for achieving India's sustainable development goals and reducing the country's dependence on non-renewable energy sources.

## 7.7. Definition of green building

A green building is a building designed and constructed with sustainability and environmental impact in mind. A green building is designed to use resources efficiently, reduce waste, and minimize the building's environmental footprint over its entire life cycle. This includes the selection of building materials, construction practices, energy and water use, and waste management. Green buildings are designed to be healthy and comfortable for occupants while reducing the impact on the environment. The aim of green building is to create structures that are energy-efficient, environmentally responsible, and sustainable for future generations. The concept of green building involves designing and constructing buildings that are environmentally responsible, energy-efficient, and sustainable over the long term. The scope of green building encompasses all aspects of the building's life cycle, including design, construction, operation, maintenance, and end-of-life disposal. The scope of green building is constantly evolving as new technologies and practices emerge. The concept of green building has expanded beyond individual buildings to include entire communities and cities that promote sustainable development and reduce environmental impact.


Green building concepts and practices focus on using resources efficiently, reducing waste, and minimizing the building's environmental impact. This includes:

**Energy efficiency:** Green buildings are designed to use energy efficiently, using energy-efficient building systems, appliances, and lighting to reduce energy consumption and costs.

**Water conservation:** Green buildings incorporate water-saving technologies and practices to reduce water consumption and promote water conservation.

**Sustainable materials:** Green buildings use sustainable and environmentally friendly materials, such as recycled content materials, low-emitting materials, and renewable materials, to reduce the impact on the environment.

**Indoor environmental quality**: Green buildings are designed to promote healthy and comfortable indoor environments for occupants, using strategies such as natural ventilation, indoor air quality management, and daylighting.

**Site sustainability:** Green buildings are designed to minimize the impact on the surrounding environment, using strategies such as site selection, stormwater management, and landscape design.

In conclusion, the concept and scope of green building involve designing and constructing buildings that are environmentally responsible, energy-efficient, and sustainable over the long term. Green building encompasses all aspects of the building's life cycle, including design, construction, operation, maintenance, and end-of-life disposal. The aim of green building is to create structures that are healthy, comfortable, and sustainable for occupants while reducing the impact on the environment.

## 7.8. Component of green building

Green buildings are designed and constructed using sustainable and environmentally responsible practices. They are built with the goal of reducing environmental impact, promoting energy efficiency, and providing a healthy and comfortable living or working space for occupants. The components of a green building include:

### 7.8.1. Site selection and design:

Choosing a site that is appropriate for the building's intended use and that minimizes the impact on the environment. Site design should also consider storm water management, landscaping, and access to public transportation.


Some important factors to consider for site selection and design such as

- **Location:** The location of the building is important for reducing transportation-related emissions. Select a site that is well-connected to public transportation and bike lanes.

- **Orientation**: The orientation of the building can impact its energy efficiency. A building should be oriented to maximize solar gain in the winter and minimize it in the summer.
- **Landscaping:** Incorporating green space, such as trees and gardens, into the design can help reduce the urban heat island effect and improve air quality.
- **Water conservation:** Consider installing low-flow toilets and showerheads, as well as water-efficient landscaping to reduce water usage.
- **Energy efficiency:** Incorporate features such as high-efficiency windows, insulation, and lighting to reduce energy consumption.
- **Building materials:** Use sustainable and locally sourced building materials, such as recycled steel and lumber, to reduce the environmental impact of the construction.
- **Waste reduction:** Implement a waste management plan that includes recycling and composting to minimize waste.
- **Indoor air quality**: Choose materials and ventilation systems that promote healthy indoor air quality.
- **Maintenance and operation**: Consider the long-term maintenance and operation of the building and choose systems that are durable and easy to maintain.

By incorporating these factors into the site selection and design process, green building can help reduce the environmental impact of construction and improve the sustainability of the built environment.

**7.8.2. Energy-efficient building envelope**: An energy-efficient building envelope is a critical aspect of green building design, as it can significantly reduce a building's energy consumption and associated carbon emissions. The building envelope is the physical barrier between the inside and outside of a building, including the walls, roof, windows, and doors. Here are some key considerations for designing an energy-efficient building envelope:

- **Insulation:** Proper insulation is critical for reducing heat transfer through the building envelope. Choose insulation materials with a high R-value, which measures resistance to heat flow. Consider using spray foam insulation, which can provide a tight seal and reduce air leakage.

- **Windows:** High-performance windows can help reduce heat loss and gain through the building envelope. Choose windows with low-e coatings, which reflect infrared radiation, and multiple panes, which provide an additional layer of insulation.
- **Air sealing:** Proper air sealing can reduce air leakage through the building envelope, which can account for up to 40% of a building's energy loss. Use a continuous air barrier system, which seals all gaps and cracks in the building envelope.
- **Thermal bridging:** Thermal bridging occurs when heat moves through conductive materials in the building envelope, such as steel studs or concrete slabs. Minimize thermal bridging by using insulation around these materials or choosing alternative construction methods.
- **Roofing:** Choose a roofing material that reflects sunlight and reduces heat absorption, such as a white or light-colored roof. Alternatively, consider a green roof, which can provide additional insulation and reduce the heat island effect.

8. **Ventilation:** Proper ventilation can help regulate indoor temperature and humidity levels, reducing the need for heating and cooling. Consider incorporating natural ventilation, such as operable windows or vents, or a mechanical ventilation system with heat recovery.

By incorporating these energy-efficient design strategies into the building envelope, a green building can significantly reduce its energy consumption and associated carbon emissions. This can result in lower energy bills, improved occupant comfort, and a healthier environment for all.

### 7.8.3. High-efficiency HVAC systems:

Heating, ventilation, and air conditioning (HVAC) systems are a critical component of green building design, as they can significantly impact a building's energy use and indoor air quality. Here are some key considerations for designing a high-efficiency HVAC system in a green building:

- **Sizing:** Proper sizing of the HVAC system is critical for achieving maximum efficiency. An oversized system can lead to wasted energy and increased costs, while an undersized system may not provide sufficient heating or cooling. Use an energy model to determine the appropriate size for the building's HVAC system.

- **Energy efficiency**: Choose HVAC equipment with a high SEER (Seasonal Energy Efficiency Ratio) or EER (Energy Efficiency Ratio) rating. Consider using equipment with variable speed fans or compressors, which can adjust output based on demand and save energy.
- **Controls:** Proper controls can help optimize the performance of the HVAC system. Consider using programmable thermostats or building automation systems that can adjust temperature and ventilation based on occupancy, weather conditions, and other factors.
- **Zoning:** Divide the building into zones based on occupancy, orientation, or other factors to allow for more precise control of the HVAC system. This can reduce energy use by only heating or cooling areas that are occupied.
- **Ventilation:** Proper ventilation is critical for maintaining indoor air quality. Consider using a heat recovery ventilation system, which can recover heat from exhaust air and use it to preheat incoming fresh air.
- **Maintenance**: Regular maintenance of the HVAC system can ensure that it is operating at maximum efficiency. Schedule routine inspections, cleaning, and filter replacements to keep the system running smoothly.

By incorporating these high-efficiency design strategies into the HVAC system, a green building can significantly reduce its energy consumption and associated carbon emissions while maintaining a healthy indoor environment. This can result in lower energy bills, improved occupant comfort, and a healthier environment for all.

### 7.8.4. Water-efficient fixtures and systems:

Water conservation is an important aspect of green building design, as it can significantly reduce a building's water consumption and associated environmental impact. Here are some key considerations for designing a water-efficient fixture and system in a green building:

- **Low-flow fixtures:** Choose water-efficient fixtures, such as low-flow toilets, showerheads, and faucets. Look for fixtures with a WaterSense label, which indicates that they meet the EPA's criteria for water efficiency.

- **Graywater systems:** Install a graywater system to capture and reuse non-potable water, such as from sinks and showers, for irrigation or toilet flushing. These systems can significantly reduce a building's potable water consumption.
- **Dual-flush toilets**: Consider using dual-flush toilets, which allow users to choose a low-flow flush for liquid waste or a higher-flow flush for solid waste. This can reduce water usage by up to 50%.
- **Leak detection**: Install a leak detection system to monitor water usage and identify leaks early. Even small leaks can waste significant amounts of water over time.
- **Irrigation:** Choose a water-efficient irrigation system, such as drip irrigation or weather-based irrigation controllers, to minimize outdoor water usage.
- **Recirculation systems:** Install a hot water recirculation system to reduce the amount of water wasted while waiting for hot water to reach the tap. This can also reduce energy use by minimizing the amount of time the hot water system needs to run.
- **Stormwater management:** Incorporate green infrastructure, such as rain gardens or permeable pavement, to manage stormwater onsite and reduce the burden on municipal systems.

### 7.8.5. Energy-efficient lighting:

Lighting is a critical component of green building design, as it can significantly impact a building's energy use and occupant comfort. Here are some key considerations for designing an energy-efficient lighting system in a green building, along with examples of energy-efficient lighting technologies:

- **LED lighting**: LED (Light Emitting Diode) lighting is the most energy-efficient lighting technology available today. LEDs use significantly less energy than traditional incandescent or fluorescent bulbs and last much longer. They also offer a range of color temperatures and can be dimmed or controlled by occupancy sensors.
- **Occupancy sensors:** Occupancy sensors can automatically turn lights off when a room is unoccupied, reducing energy waste. They can be particularly useful in spaces like restrooms or conference rooms that are frequently unoccupied.
- **Daylighting:** Incorporating natural daylight into a building's lighting design can significantly reduce the need for artificial lighting. This can be achieved through strategies such as skylights, light shelves, or clerestory windows.

- **Lighting controls:** Lighting controls, such as timers or dimmers, can help optimize the performance of the lighting system and reduce energy consumption. They can also help create a more comfortable and adaptable lighting environment.
- **Task lighting:** Task lighting can be used to provide focused lighting for specific tasks, such as reading or computer work. By providing localized lighting, task lighting can reduce the need for overall ambient lighting and save energy.
- **Solar-powered lighting:** In outdoor or off-grid applications, solar-powered lighting can be a sustainable and energy-efficient lighting solution. Solar-powered lights use solar panels to generate electricity and store it in batteries, which power the lights at night.

By incorporating these energy-efficient lighting strategies and technologies into the building's lighting design, a green building can significantly reduce its energy consumption and associated carbon emissions while improving occupant comfort and productivity. These strategies and technologies can also lead to lower energy bills and a more sustainable and resilient building.

### 7.8.6. Renewable energy systems:

Renewable energy systems are an important component of green building design, as they can significantly reduce a building's carbon footprint and energy costs while promoting energy independence and resilience. Here are some key considerations for designing a renewable energy system in a green building:

- **Solar photovoltaic (PV) systems:** Solar PV systems generate electricity by converting sunlight into electricity using solar panels. They can be installed on rooftops, facades, or on the ground, and can provide a significant portion of a building's electricity needs.
- **Wind turbines:** Wind turbines can generate electricity by harnessing wind energy. They are typically installed in areas with consistent and strong winds, and can be used in conjunction with other renewable energy systems.
- **Geothermal systems:** Geothermal systems use the constant temperature of the earth to heat and cool buildings. They can be used for heating, cooling, and hot water, and can significantly reduce a building's energy consumption.

- **Biomass systems**: Biomass systems use organic materials, such as wood chips or agricultural waste, to generate heat and electricity. They can be used for space heating, hot water, and electricity generation, and can be a sustainable alternative to fossil fuels.
- **Micro-hydro systems**: Micro-hydro systems generate electricity by harnessing the power of flowing water, such as from a small stream or river. They can be used in remote locations or areas with consistent water flow.
- **Hybrid systems**: Hybrid renewable energy systems combine two or more renewable energy technologies to provide a more reliable and efficient energy supply. For example, a building could combine solar PV and wind turbines to provide electricity throughout the day and night.

By incorporating these renewable energy systems into a green building design, a building can significantly reduce its reliance on fossil fuels and associated carbon emissions while promoting energy independence and resilience. These renewable energy systems can also lead to lower energy costs over the life of the building and a more sustainable and resilient energy supply.

### 7.8.7. Sustainable materials:

Sustainable materials are an important component of green building design, as they can significantly reduce a building's environmental impact and promote a more sustainable and resilient built environment. Here are some key considerations for selecting sustainable materials in a green building:

- **Recycled content:** Materials that contain recycled content can significantly reduce the environmental impact of a building by diverting waste from landfills and reducing the need for virgin materials. Examples include recycled steel, glass, and plastic.
- **Renewable materials:** Materials that come from renewable sources, such as wood from sustainably managed forests or bamboo, can reduce the environmental impact of a building and promote the use of renewable resources.
- **Low-emitting materials:** Materials that emit low levels of volatile organic compounds (VOCs) and other pollutants can improve indoor air quality and promote occupant health and comfort. Examples include low-VOC paints, adhesives, and sealants.

- **Energy-efficient materials**: Materials that have high insulating values or reflectivity can improve the energy efficiency of a building and reduce its energy consumption. Examples include insulated concrete forms, cool roofs, and low-e windows.
- **Durable materials:** Materials that are durable and require minimal maintenance can reduce the environmental impact of a building over its lifespan by reducing the need for replacement or renovation. Examples include durable roofing materials, such as metal or tile, and high-performance cladding systems.
- **Local materials:** Materials that are sourced locally can reduce the environmental impact of a building by reducing transportation emissions and supporting the local economy. Examples include locally sourced stone, brick, and timber.

**7.8.8. Indoor air quality**:

Indoor air quality (IAQ) is an important consideration in green building design, as it can significantly impact occupant health, comfort, and productivity. Here are some key considerations for promoting healthy IAQ in a green building:

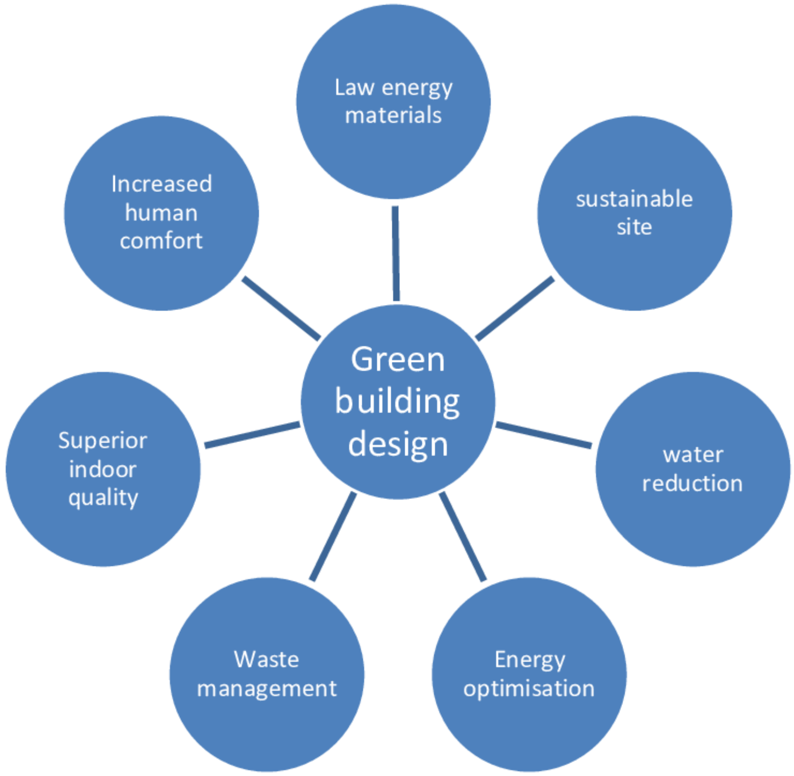
- **Ventilation:** Proper ventilation is essential for maintaining good IAQ in a building. Green building design should include mechanical ventilation systems that provide fresh air and exhaust stale air to remove pollutants. Natural ventilation strategies, such as operable windows and passive ventilation systems, can also be incorporated.
- **Filtration:** Filtration systems can remove pollutants and allergens from indoor air, improving IAQ. High-efficiency particulate air (HEPA) filters and activated carbon filters are effective at removing fine particles and gaseous pollutants, respectively.
- **Low-emitting materials**: As mentioned earlier, selecting low-emitting materials can significantly improve IAQ by reducing the amount of pollutants and VOCs in the air. Indoor finishes, such as flooring, paint, and furniture, should be selected based on their low-emitting properties.
- **Moisture control**: Excessive moisture can lead to mold growth and other IAQ problems. Green building design should incorporate moisture control strategies, such as proper drainage, waterproofing, and humidity control.

- **Radon mitigation:** Radon is a radioactive gas that can enter buildings through soil and cause lung cancer. Green building design should include radon-resistant construction techniques, such as a vapor barrier and vent pipe, to prevent radon infiltration.
- **Monitoring:** IAQ monitoring systems can provide real-time data on indoor air quality and identify potential IAQ problems before they become a health hazard. Monitoring systems can also help optimize ventilation and filtration systems for maximum efficiency and IAQ benefits.

In conclusion, green buildings are designed and constructed using sustainable and environmentally responsible practices. The components of a green building include site selection and design, energy-efficient building envelope, high-efficiency HVAC systems, water-efficient fixtures and systems, energy-efficient lighting, renewable energy systems, sustainable materials, and indoor air quality management. By incorporating these components, green buildings can reduce environmental impact, promote energy efficiency, and provide a healthy and comfortable living or working space for occupants.

### 7.8.9. Design for green building

Green building design involves creating buildings that are environmentally responsible, energy-efficient, and sustainable.




Here are some key considerations for designing a green building:

- **Site selection**: The site selection process should consider environmental factors, such as access to public transportation, proximity to services and amenities, and availability of renewable energy resources. The site should also be evaluated for its impact on the surrounding environment, including wildlife habitats and water resources.
- **Energy efficiency:** Building design should incorporate energy-efficient strategies, such as passive solar design, daylighting, high-performance insulation, and energy-efficient HVAC systems. The design should also consider the use of renewable energy sources, such as solar panels or wind turbines.
- **Water efficiency**: Building design should incorporate water-efficient strategies, such as low-flow fixtures, graywater systems, and rainwater harvesting. The design should also consider the use of drought-tolerant landscaping and other water-saving measures.
- **Sustainable materials:** As mentioned earlier, selecting sustainable materials can significantly reduce a building's environmental impact and promote a more sustainable and resilient built environment.

- **Indoor air quality**: Green building design should incorporate strategies for promoting healthy indoor air quality, such as proper ventilation, filtration systems, and low-emitting materials.
- **Waste reduction:** Building design should incorporate strategies for reducing waste generation and promoting recycling and composting. The design should also consider the use of sustainable building practices, such as modular construction and deconstruction.
- **Lifecycle assessment:** Building design should consider the entire lifecycle of the building, from construction to operation and eventual demolition. The design should incorporate strategies for minimizing the environmental impact of the building throughout its lifecycle.

By incorporating these strategies into green building design, a building can significantly reduce its environmental impact and promote a more sustainable and resilient built environment. Green building design can also lead to lower operating costs, improved occupant health and comfort, and a more resilient and adaptable building.

## 7.10. Green building in India

Green building is a rapidly growing concept in India, as the country faces increasing concerns over energy security, raising energy costs, and environmental degradation. India has a large and rapidly growing construction industry, which has a significant impact on the environment and energy consumption. The government and various private organizations have taken initiatives to promote the construction of green buildings in India.

The Indian Green Building Council (IGBC), a non-profit organization formed in 2001, is a leading organization promoting green building practices in India. The IGBC has developed a rating system for green buildings called LEED India, which stands for Leadership in Energy and Environmental Design. The rating system is based on five categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality.

Several government initiatives have also been launched to promote green building in India. The Bureau of Energy Efficiency (BEE) has launched a scheme called Energy Conservation Building Code (ECBC), which sets minimum energy performance standards for commercial buildings. The Ministry of New and Renewable Energy (MNRE) has launched several programs to promote the use of renewable energy in buildings, such as the Jawaharlal Nehru National Solar Mission and the National Biogas and Manure Management Program.

Private developers in India have also been quick to adopt green building practices. Several real estate developers have incorporated green building features into their projects, such as solar panels, rainwater harvesting systems, and energy-efficient lighting and appliances.

In conclusion, green building practice is gaining momentum in India, as the country faces increasing concerns over energy security, rising energy costs, and environmental degradation. The government and various private organizations have taken initiatives to promote the construction of green buildings in India, and private developers have also been quick to adopt green building practices. With the increasing awareness of environmental issues and the benefits of green building, it is expected that the trend towards green building in India will continue to grow in the coming years.

## 7.11. Certification of green building

Green building certification is a process of assessing and verifying that a building meets certain criteria for environmental sustainability, energy efficiency, and occupant health and comfort. Certification programs provide a framework and set of standards for evaluating and rating the sustainability of buildings. Here are some of the most widely recognized certification programs for green buildings:

- **Leadership in Energy and Environmental Design (LEED):** Developed by the U.S. Green Building Council (USGBC), LEED is a widely recognized certification program for green buildings, with various rating systems for different types of buildings. LEED certification assesses building performance in several areas, including sustainable site development, water efficiency, energy efficiency, materials selection, indoor environmental quality, and innovation.
- **Green Star**: Developed by the Green Building Council of Australia (GBCA), Green Star is a certification program for sustainable buildings in Australia. It evaluates building performance in several areas, including management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions, and innovation.

- **BREEAM:** Developed by the Building Research Establishment (BRE) in the UK, BREEAM is a certification program for sustainable buildings, with a focus on environmental, social, and economic sustainability. It assesses building performance in several areas, including energy and carbon emissions, water, health and wellbeing, pollution, land use, ecology, and materials.
- **WELL:** Developed by the International WELL Building Institute (IWBI), WELL is a certification program for buildings that prioritize the health and wellbeing of occupants. It assesses building performance in several areas, including air quality, water quality, lighting, fitness, comfort, and mind.

In conclusion, green building certification is a process of assessing and verifying that a building meets certain criteria for environmental sustainability, energy efficiency, and occupant health and comfort. There are several widely recognized certification programs for green buildings, including LEED, Green Star, BREEAM, and WELL. By achieving certification, building owners and operators can demonstrate their commitment to sustainability and the health and wellbeing of occupants.

## 7.12. Summary

Energy conservation and green building are two important concepts that are gaining increasing attention worldwide, including in India. Energy conservation refers to the practice of reducing energy consumption and wastage, while green building refers to the construction of buildings that are environmentally sustainable and energy-efficient, and promote the health and wellbeing of occupants. The principle of energy conservation involves reducing energy consumption through various methods, such as improving energy efficiency, using renewable energy sources, and reducing waste. Energy conservation is important because it can help to reduce energy costs, increase energy security, and mitigate the environmental impact of energy use. Green building involves the use of sustainable materials, energy-efficient systems, and practices that reduce the environmental impact of buildings. The concept of green building is becoming increasingly important in India, where the government and private organizations have launched several initiatives to promote the construction of green buildings. Green building certification programs provide a framework for evaluating and rating the sustainability of buildings, with several widely recognized programs including LEED, Green Star, BREEAM, and

WELL. In conclusion, energy conservation and green building are important concepts that can help to reduce energy consumption and promote environmental sustainability. With the increasing awareness of environmental issues and the benefits of energy conservation and green building, it is expected that these concepts will continue to gain momentum in the coming years.

## 7.13. Terminal questions

**Q.1. What is energy? Discuss the energy conservation in India.**

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.2. Write the methods of energy conservation.**

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.3. What is the government initiative for energy conservation in India.**

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.4. Definition the green building. Write the component of green building.**

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.5. Discuss the green building in India.**

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.6. Write the process of certification of green building.**

**Answer:** ----------------------------------------------------------------------------------------------------

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## 7.14. Further suggested readings

**16.** S.C. Bhatia and R. K. Gupta, Textbook of Renewable Energy", WPI Publishing-2019

**17.** Renu, Dhupper, "Textbook on Energy Resources and Management" CBS Publishers & Distributors-2015

**18.** Mahmood Zohoori, Advantages and Disadvantages of Green Technology; Goals, Challenges and Strengths, International Journal of Science and Engineering Applications, ISSN-2319-7560

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# Unit-8: Green Energy



## 8.1. Introduction

To achieve green energy in India Ministry of New and Renewable Energy (Naveen aur Navikarniya Oorja Mantralaya) has been established. Department of Non-Conventional Energy Sources (DNES) was created in 1982 in the Ministry of Energy to look after all the aspects relating to New and Renewable Energy. The Department was upgraded into a separate Ministry of Non-Conventional Energy Sources (MNES) in 1992 and further re-named as Ministry of New and Renewable Energy (MNRE), in October, 2006. Green technology, also known as sustainable technology or clean technology, refers to the development and application of innovative solutions that aim to minimize the negative impact on the environment and promote sustainable development. It encompasses a wide range of practices, products, and systems that are designed to conserve resources, reduce pollution, and mitigate climate change. Technologies that harness energy from renewable sources such as solar power, wind power, hydropower, geothermal energy, and biomass. These sources are sustainable and produce little to no greenhouse gas emissions. Technologies that help reduce energy consumption in various sectors, including buildings, transportation, and industrial processes. This includes energy-efficient appliances, LED lighting, smart grid systems, and advanced insulation materials. In the construction techniques and materials that focus on energy efficiency, sustainable design, and the use of renewable resources. Green buildings incorporate features such as efficient insulation, solar panels, rainwater harvesting systems, and natural ventilation. Green technology plays a crucial role in combating climate change, reducing pollution, and promoting a sustainable future. It has the potential to drive economic growth, create jobs, and improve the overall well-being of communities while minimizing harm to the environment. Governments, businesses, and individuals all have a role to play in adopting and promoting green technology solutions.

**Objective**

After studying this unit learner is able to define

- Aim and scope of green technology
- Concept of green energy and green technology
- Biomass energy production
- Fuel cell technologies and application to waste-to-energy conversion

## 8.2 Aim and scope of green technology

The year 2021 was a landmark year for India's renewable energy or green energy sector in which significant milestones were crossed even while recovering from the Covid-19 pandemic. India achieved one of its Paris 2030 Nationally Determined Contributions (NDC) commitment 9 years in advance after crossing the 40% installed capacity target from non-fossil sources in November, 2021. The country surpassed the 100 GW renewable energy installed capacity excluding large hydro landmark, on August 12$^{th}$, 2021.

India stands at 4$^{th}$ position in the world in terms of installed renewable energy (RE) capacity. The country's renewable energy capacity stood at 104.88 GW as on December 31st, 2021, with 56.31 GW under implementation and 26.82 GW tenders issued.

In India Ministry of New and Renewable Energy (Naveen aur Navikarniya Oorja Mantralaya) following Ministries/Departments, following subjects under Allocation of Business **Rules:**

**i.** Research and Development of Bio-gas and programmes relating to Bio-gas units.

**ii.** Commission for Additional Sources of Energy (CASE).

**iii.** Solar Energy including Photovoltaic devices and their development, production and applications.

**iv.** All matters relating to small/mini/micro hydel projects of and below 25 MW capacity.

**v.** Programmes relating to improved Chulhas and Research and Development thereof.

**vi.** Indian Renewable Energy Development Agency Ltd. (IREDA).

**vii.** Research and Development of other non-conventional/Renewable sources of energy and programmes relating thereto.

**viii.** Tidal Energy.

**ix.** Integrated Rural Energy Programme (IREP).

**x.** Geothermal Energy.

To meet Green Energy objectives, 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. Seventeen Sustainable

Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.


## 8.3. Currently major ongoing schemes

The section outlines achievements under various schemes of the Ministry during the year.

**1) Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) for decentralised solar.**

As on 31.12.2021, 25.25 MW capacity solar power plants were installed under scheme's Component-A, over 75,000 stand-alone solar pumps were installed under Component-B and over 1000 pumps were reported solarised under individual pump solarisation variant of Component-C.

**2) Roof Top Solar (RTS ) Programme Phase-II**

Over 5.87 GW capacity of grid connected RTS plants were installed, as on 31.12.2021, against the 40 GW target.

**3) Central Public Sector Undertaking (CPSU) Scheme for Grid Connected Solar Photovoltaic (PV) Power Projects**

Under this scheme, around 8.2 GW of projects were sanctioned, as on 31.12.2021, against the 12 GW target.

**4) Development of Solar Parks and Ultra Mega Solar Power Projects**

Under this scheme, 50 solar parks with a cumulative capacity of 33.82 GW in 14 States were approved, as on 31.12.2021, against the March, 2022 target of 40 GW.

**5) Domestic manufacturing**

Production Linked Incentive (PLI) Scheme, 'National Programme on High Efficiency Solar PV Modules was approved in April, 2021 with an outlay of Rs. 4500 crores for scaling up indigenous fully integrated manufacturing units. Three successful bids for setting up 8737 MW manufacturing capacity were also awarded in 2021.

**6) Green Energy Corridor**

As on 31.12.2021, works related to installation of transmission towers and their stringing for an aggregate approx. 8468 ckm have been completed, and substations of aggregate capacity of approx. 15268 MVA have been charged.

7) **Human Resource Development Programme**

Under this programme, a total number of 50,537 Suryamitras were trained till December, 2021.

**8) Renewable Energy Research and Technology Development (RE-RTD) Programme**

Various R&D projects were continued with emphasis on cost reduction, reliability and efficiency improvement of renewable energy systems and components.

**SAQ-1- Self Assessment Questions**

Q1. When Ministry of Non-Conventional Energy Sources (MNES) has been established?

Q2. What is the full form of IREDA?

Q3. On what field Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan works?

Research, design, development and technology demonstration for its validation are one of the core requirements for the growth of New & Renewable Energy(Green Energy). Ministry of

New & Renewable Energy (MNRE) supports research, design, technology development and demonstration for renewable energy to develop new and renewable energy technologies, processes, materials, components, products & services, standards and resource assessment so as to originally manufacture new and renewable energy systems and devices. The objective is to make the industry globally competitive and renewable energy generation supply, self-sustainable/profitable and thereby contribute to increase share in total energy mix in the country. R&D Projects received from R&D institutions or universities or industries and NGO's etc. are in the field of Green Energy Such as solar energy, wind energy, solar-wind hybrid, storage, small hydro power, biogas, hydrogen and fuel cells, geothermal energy, etc.

A comprehensive policy framework on Renewable Energy Research and Technology Development Programme is in place to support R&D in new and renewable energy sector, including associating and supporting R&D earned out by industry for market development. Goverment provides up to 100% financial support to Government/non-profit research organizations/ NGOs and upto 50 to 70% to industry. Budget allotted for Renewable Energy Research and Technology Development (RE-RTD) Programme is Rs. 228 crores for FY 2021-22 to 2025-26. The policy framework provides guidelines for project identification, formulation, monitoring, appraisal, approval and financial support. The R&D projects received from R&D of academic institutions, industries, etc. are evaluated through subject experts. The qualifying projects are appraised by R&D Project Appraisal Committees. The projects recommended by the committees are sanctioned to prospective implementing agencies. The projects are monitored by Monitoring Committees. Projects on completion are reviewed in Project Appraisal Committee Meetings for their achievements.

## 8.4. Concept of green energy and green technology

The Research and Development Demonstration (RD&D) efforts are continued with emphasis on cost reduction, reliability and efficiency improvement of renewable energy systems. In accordance with the R&D thrust area of green energy and green technology solar thermal, SPV, biogas, wind, wind-hybrid, storage, small Hydro Power, hydrogen, and fuel cells, geothermal, etc. are included for RD&D activity. Various support is provided for development, demonstration, testing, standardization, and validation of technologies/ systems/ components with emphasis on application oriented R&D, improving efficiency, reliability and cost effective for indigenous development and manufacture. Participation of industry is encouraged in solar thermal; the thrust areas include the development of solar thermal technology for power generation and industrial process/heat, storage systems, hybridization, etc.

In **Solar Photovoltaic** (SPV), thrust is on improving Si PV efficiency, reducing the cost, developing solar cells by using new material, production of Si material from sand, improving modules quality and reliability, development of standard designs for support structure for SPV systems, materials and fabrication technology for solar cells and modules, inverters, power conditioning units, grid integration, etc. In addition, focus would be on storage solutions.

The thrust areas in **biogas** include development of efficient and cost effective designs of biogas plants, standardization of multiple designs of biogas plants, standardization of biogas slurry based bio-fertilizer, bio-manure up-gradation, development of biogas purification systems, development of efficient biogas engine for power generation.

In **wind**, the thrust areas include wind turbine system design, integration, off-shore technology and wind solar hybrid systems. In Small monitoring systems, pumped storage systems, etc.

R&D in **hydrogen and fuel cells** will focus on hydrogen production from various feedstock's, technology for storage and Hydropower (SHP), thrust areas include development of ultra-low head turbines (below 3m), generators, development of efficient and cost effective fuel cells for stationary, transport applications etc.

**SAQ-2- Self Assessment Questions**

**Q1.** Budget allotted for Renewable Energy Research and Technology Development (RE-RTD) for FY 2021-22?

Ans. Rs. 228 crores.

Q2. How much Goverment provides financial support to Government/non-profit research organizations/ NGOs and industry?

Ans. 100% financial support to Government/non-profit research organizations/ NGOs and upto 50 to 70% to industry.

Q3. What is the R&D thrust area of green energy and green technology?

Ans. Solar thermal, SPV, biogas, wind, wind-hybrid, storage, small Hydro Power, hydrogen, and fuel cells, geothermal, etc.

Q4. What is the thrust areas in **biogas** include development ?

Ans. standardization of biogas slurry based bio-fertilizer, bio-manure up-gradation, development of biogas purification systems, development of efficient biogas engine for power generation as well as efficient and cost effective designs of biogas plants, standardization of multiple designs of biogas plants.

## 8.5. Biomass energy production

Biomass is renewable organic material that comes from plants and animals. Government has been promoting Biomass Power and Bagasse Co-generation Programme with the aim to recover energy from biomass including bagasse, agricultural residues such as shells, husks, deoiled cakes and wood from dedicated energy plantations for power generation. A scheme to support promotion of biomass-based cogeneration in sugar mills and other industries was notified on 11.05.2018 and till 31.03.2021. As of now the Bio-energy Programme of MNRE has been continued for the period of FY 2021-22 to FY 2025-26 to only meet the already created liabilities.

The potential for power generation from agricultural and agro-industrial residues is estimated at about 28446 MW based on 228 MMT of surplus biomass which is generated annually. With progressive higher steam temperature and pressure and efficient project configuration in new sugar mills and modernization of existing ones, the potential of surplus power generation through bagasse cogeneration in sugar mills is estimated at around 13866 MW. Thus the total estimated potential for biomass power is about 42312 MW.

**Recent Initiatives**

Biomass Power and Bagasse Co-generation Potential in India was initiated by MNRE. The study was carried out by Administrative Staff College of India, Hyderabad. As per report submitted in March, 2021, Biomass and bagasse cogeneration power potential in the country is about 42 GW.

Sardar Swaran Singh National Institute of Bio-Energy (SSS-NIBE), Kapurthala is an autonomous Institution under the Ministry of New and Renewable Energy (MNRE), Govt. of

India, set up as an apex Institution for carrying out state-of-the-art research and developmental activities, biomass resource assessment, testing, validation and training for promotion of bioenergy in the country.

During the year 2021-22, R&D activities were taken up in the frontier areas including bioethanol and biogas production from agro-residue, biomass cookstove performance, waste biomass conversion to activated carbon, biomass gasification, and solar- biomass hybrid systems. The research carried out was published in reputed journals of the frontier bioenergy area. The Institute took leading role in preparing all technical documents related to bioenergy as entrusted by MNRE time to time. The Institute participated in all technical programs and meetings of the Ministry of New and Renewable Energy, particularly related to bioenergy sector, for discussion on R&D, strategy and policy, progress and dissemination of knowledge and technology in the area. Several projects on different R&D processes for biofuels and bioenergy are going on under different divisions:

**Thermochemical Conversion Division:** During the FY 2021-22, the division explored the scope of biomass hybrid systems and biomass characterization and developed the following projects to cater the ongoing energy requirement of the country:

(a) **Densification of agro-waste and biomass characterization:** The division carried out biomass characterization of more than 50 different types of biomass, using Proximate Analysis, Ultimate Analysis and by estimating Gross Calorific Value of the samples. The results are analyzed to identify suitable biomass for pellets and briquette production.

(b) **Solar Biomass Hybrid dryer:** The division is working on development of Solar Biomass Hybrid drier for drying of agro waste and vegetables in collaboration with Bharat Heavy Electricals Ltd. The R&D focuses on the design of solar thermal system along with biomass combustion chamber for its commercialization.

(c) **Solar Thermal Pyrolyzer for biochar production:** During the year, the division designed a solar thermal energy based pyrolyzer for biochar production has been created. The unique system is designed, which can give biochar along with bio-oil (liquid oil) and syn-gases. It is estimated that the obtained biochar can be further activated for making activated biochar for various applications as carbon capturing.

**Biochemical Conversion Division:** Biochemical Conversion Division has basic facilities of Analytical, Bioprocess, Microbiology and Molecular Biology Laboratories. Various funded and In-house research projects are going on:

**(a) Exploration of Lignocellulolytic Enzymes producing Thermophiles from hot springs of Western Himalayan region for Biorefinery Applications**

The project titled as above under the Department of Science and Technology (DST) Women Scientist Scheme (WOS-B) (KIRAN Division) has been funded by the DST, Ministry of Science and Technology to Dr. Shivika Sharma under the mentorship of Dr. Sachin Kumar with the total project cost of Rs.32.16 lakh for 3 years. The project aims to explore micro-organism from hot springs of Himachal Pradesh for the application in biofuel production.

**(b) Thermophilic anaerobic consortium enrichment for enhanced biogas/ biomethane production:**

Thermophilic anaerobic consortium enrichment for enhanced biogas/ biomethane production, the project is taken up by a Senior Research Fellow under SSS-NIBE Bioenergy Promotion Fellowship. The main focus of the proposed work is to develop the robust thermophilic bacterial consortium for the enhanced biogas yield or biogas component. To further enhance the biogas yield and enrich the methane component, there are various techniques which could be integrated and optimized with the thermophilic anaerobic digestion process accordingly. The scope of the present study is to enhance biogas production via thermophilic anaerobic consortium to harness maximized energy from a particular waste.

**Achievement**

Around 800 Nos of Biomass IPP and Bagasse/non bagasse cogeneration-based power plants with aggregate capacity of 10175 MW have been installed in the country. These plants have been installed mainly in the States of Maharashtra, Uttar Pradesh, Karnataka, Tamil Nadu, Andhra Pradesh, Chhattisgarh, West Bengal and Punjab upto December, 2021. This includes 7562 MW from Bagasse Cogeneration Sector and 1841 MW from Biomass IPP Sector.

i. India has more than 540 Nos of sugar mills, out of which around 370 sugar mills have installed cogeneration power plant capacity of 7562 MW till December, 2021.
ii. Over 200 biomass (non-bagasse) cogeneration plants with aggregate capacity of 772

iii. MW have been installed in the country till December, 2021.

India has emerged as one of the leaders in global energy transition. With the recent massive achievement of touching 158 Gigawatt (GW) of installed capacity, (including large hydro) the country boasts of being 4$^{th}$ largest renewable energy giant in the world. The nation has also embarked on implementing the world's largest renewable energy expansion plan, that is installed capacity of 175 GW by 2022 and 450 GW by 2030. This is a testimony to India's commitment to propagate clean energy sources since the early days of sustainable development and is backed by a series of targeted and strategic initiatives by the Government of India to promote generation and adoption of RE to fuel the country's growth and development.

The Dubai Expo 2020 was a key platform for the Government of India and MNRE to showcase India's achievements in renewable energy (RE) capacity enhancement and future plans for scaling up capacity in existing RE sectors, as well as, initiating and inviting capacity addition in new and emerging areas like green hydrogen, battery storage, electric mobility, to name a few. The events held by MNRE in this week were a valuable opportunity for investors, industry leaders and the Government to mutually explore the potential of renewable energy in India and build on the strong foundation created for this sector through the Government's commitment to climate change mitigation.

**SAQ-3- Self Assessment Questions**

**Q1**. Was the Dubai Expo 2020 a key platform for the Government of India and MNRE?

**Ans.** India's achievements in renewable energy (RE) capacity enhancement and future plans for scaling up capacity in existing RE sectors, as well as, initiating and inviting capacity addition in new and emerging areas like green hydrogen, battery storage, electric mobility, to name a few.

**Q2.** With how much energy the India is 4$^{th}$ largest renewable energy giant in the world?

**Ans.** The nation has also embarked on implementing the world's largest renewable energy expansion plan that is installed capacity of 175 GW by 2022 and 450 GW by 2030.

**Q3.** Which one is an autonomous Institution under the Ministry of New and Renewable Energy (MNRE), Govt. of India?

**Ans.** Sardar Swaran Singh National Institute of Bio-Energy (SSS-NIBE), Kapurthala.

## 8.6. Solar and green battery technology

Today's world is energy driven and batteries have become an vital part as an energy source considering the technological advances in users electronics to electric vehicles, renewable, and smart grids. Batteries are energy limited and require recharging. Recharging batteries with solar energy by means of solar cells can offer a convenient option for smart consumer electronics. Meanwhile, batteries can be used to address the intermittency apprehension of photovoltaic's.

This perspective discusses the advances in battery charging using solar energy. Conventional design of solar charging batteries involves the utilize of batteries and solar modules as two separate units connected by electric wires. Advanced design involves the integration of in situ battery storage in solar modules, therefore offering compactness and fewer packaging requirements with the possible to become less costly. This advancement can be advantageous for user electronics where space, size, and packaging requirements grip greater value. Three major metrics, namely energy density, efficiency and stability have been addressed by presenting relevant challenges and potential opportunities. The integrated devise is still in the early R&D stage. There is a need for inventive designs that explore high-capacity, efficient and steady materials. Meanwhile, to demonstrate its realistic viability, this included design should also focus on real-world applications such as wearable's that demand specific requirements of energy and power.

Three key technical challenges, namely energy density, efficiency, and stability, toward further advancement of integrated PV-battery systems are implemented. Present a perspective on opportunities and future directions, highlighting key strategies on developing such PV-battery systems. Key focus should be on the development of innovative designs that incorporates high-capacity, efficient, and stable materials, emphasizing the demonstration of practical viability of such integrated PV-battery systems.

### Green battery technology

Green battery technology, also known as sustainable or environmentally friendly battery technology, refers to the development and use of batteries that have a reduced environmental impact compared to conventional batteries. Green battery technologies aim to address issues such as resource depletion, pollution, and hazardous waste associated with traditional battery technologies.

- **Lithium-ion Batteries:** Lithium-ion batteries are widely used in portable electronics and electric vehicles. They offer higher energy density and longer lifespan compared to traditional batteries. Efforts are being made to improve the sustainability of lithium-ion batteries by increasing their recyclability and reducing the reliance on rare and environmentally damaging materials.
- **Solid-State Batteries:** Solid-state batteries are a promising next-generation battery technology. They use solid electrolytes instead of liquid electrolytes, which improves safety, energy density, and cycle life. Solid-state batteries have the potential to reduce reliance on toxic and scarce materials, and they can be manufactured in a more environmentally friendly way.
- **Flow Batteries:** Flow batteries store energy in liquid electrolytes contained in separate tanks. They offer the advantage of decoupling energy and power capacities, allowing for scalability and longer lifespan. Flow batteries can use abundant and non-toxic materials for their electrolytes, reducing environmental impact and facilitating recycling.
- **Sodium-ion Batteries:** Sodium-ion batteries are an alternative to lithium-ion batteries that use sodium ions instead of lithium ions. Sodium is more abundant and less expensive than lithium, making sodium-ion batteries potentially more sustainable. Research is ongoing to improve the energy density and cycle life of sodium-ion batteries for various applications.
- **Zinc-based Batteries:** Zinc-based batteries, such as zinc-air and zinc-manganese batteries, are considered environment friendly due to the abundant availability of zinc and their non-toxic nature. Zinc-air batteries, in particular, offer high energy density and can be used for grid-scale energy storage.
- **Battery Recycling:** Effective recycling of batteries plays a vital role in reducing the environmental impact of battery technologies. Developing efficient recycling processes helps recover valuable materials and reduces the need for mining raw materials. Recycling initiatives are being pursued to recover metals like lithium, cobalt, nickel, and lead from spent batteries.
- **Second-Life Batteries:** Second-life battery applications involve repurposing used batteries from electric vehicles or other applications for stationary energy storage. By extending the

useful life of batteries beyond their initial application, the overall environmental impact of battery production can be reduced.

Green battery technologies contribute to reducing greenhouse gas emissions, minimizing resource depletion, and mitigating environmental pollution associated with conventional batteries. The development and adoption of these technologies are crucial for transitioning to a more sustainable and renewable energy-powered future.

**Traditional versus Advanced PV-Battery Systems**

The traditional battery charging method using PV is a discrete or isolated design that involves operation of PV and battery as two independent units electrically connected by electric wires. The PV battery system, also known as a solar battery system or solar energy storage system, is a combination of solar photovoltaic (PV) panels and energy storage batteries. Such systems tend to be expensive, bulky and inflexible require more space and packaging requirements and undergo energy loss through external wires. Combining energy generation and energy storage into a single unit creates an integrated devise. The integrated devise of PV and battery will serve as an energy sufficient source that solves the energy storage concern of solar cells and the energy density concern of batteries. The PV battery system allows the storage of excess electricity generated by solar panels during periods of sunlight for later use when solar production is low or during peak demand times. PV battery systems offer several benefits, including increased energy independence, improved self-consumption of solar power, and grid resilience. The system starts with the installation of solar PV panels on rooftops or other suitable locations. These panels convert sunlight into electricity through the photovoltaic effect. The electricity generated by the solar panels is in direct current (DC) form. It is converted into alternating current (AC) using an inverter, which makes it compatible with the electrical appliances and the power grid. Excess electricity produced by the solar panels that is not immediately consumed by the building's electrical loads is diverted to charge the battery storage system. The batteries store the energy for later use. An energy management system or controller oversees the flow of electricity between the solar panels, batteries, and the building's electrical system. It optimizes the use of solar power and manages the charging and discharging of the batteries based on energy demand and availability. During periods of low solar production or high electricity demand, such as in the evening or during power outages, the stored energy in the batteries is utilized to power the building's electrical loads. This reduces reliance on the grid and increases self-consumption of solar energy. If the battery capacity is depleted, the system can automatically draw electricity from the grid to meet the demand.

**Benefits of PV Battery Systems:**

1. PV battery systems enable homeowners or businesses to use more of their generated electricity, reducing reliance on the grid and lowering energy bills.
2. PV battery systems can be programmed to discharge energy during peak demand periods when electricity prices are typically higher, allowing for cost savings.
3. It provides backup power to critical loads, ensuring continuity of operations.
4. PV battery systems can help alleviate strain on the electrical grid, contributing to improved grid resilience and stability.
5. PV battery systems facilitate the integration of renewable energy sources into the electrical grid by smoothing out the intermittent nature of solar power and enabling a more balanced supply-demand relationship.
6. PV battery systems are becoming increasingly popular as the cost of solar panels and energy storage technologies continues to decline.

**Overall efficiency of PV system**

Overall efficiency demonstrated with lab-scale integrated PV-battery devices is to justify commercial viability of the integrated PV-battery system. It's important to note that each component of the PV battery system has its own efficiency rating, and the overall efficiency is a combination of these individual efficiencies. The overall efficiency of a PV battery system can vary depending on the quality of the components, design considerations, installation factors, and operating conditions. In practice, the overall efficiency of a PV battery system typically ranges between 70% and 90%. This means that for every unit of solar energy received, the system can effectively convert and store 70% to 90% of that energy for later use. Advances in solar panel technology, inverter efficiency, and battery storage systems continue to improve the overall efficiency of PV battery systems over time. It's worth noting that system efficiency is just one factor to consider when evaluating the performance and benefits of a PV battery system. Other factors such as cost, reliability, durability, and system lifespan should also be taken into account when assessing the overall value and suitability of a system for a specific application.

## 8.7. Fuel cell technologies and waste to energy conversion

A fuel cell uses the chemical energy of hydrogen or other fuels to cleanly and efficiently produce electricity. If hydrogen is the fuel, the only products are electricity, water, and heat. Fuel cells are unique in terms of the variety of their potential applications; they can use a wide range of fuels and feedstocks and can provide power for systems as large as a utility power station and as small as a laptop computer. Fuel cells can be used in a wide range of applications, providing power for applications across multiple sectors, including transportation, industrial/commercial/residential buildings, and long-term energy storage for the grid in reversible systems. Fuel cells have several benefits over conventional combustion-based technologies currently used in many power plants and vehicles. Fuel cells can operate at higher efficiencies than combustion engines and can convert the chemical energy in the fuel directly to electrical energy with efficiencies capable of exceeding 60%. Fuel cells have lower or zero emissions compared to combustion engines. Hydrogen fuel cells emit only water, addressing critical climate challenges as there are no carbon dioxide emissions. Fuel cells have a wide range of applications, from portable and small-scale devices to large-scale power generation. They are used in transportation, including fuel cell vehicles, buses, and trains. Fuel cells are also utilized in stationary power generation for buildings, backup power systems, and off-grid applications. Additionally, they find applications in aerospace, military, and other specialized industries. Fuel cells offer high energy conversion efficiencies compared to traditional combustion-based power generation systems. They can achieve efficiencies above 50% in converting the chemical energy of the fuel into electricity. Fuel cells also have environmental benefits, particularly when hydrogen or other clean fuels are used, as they produce lower or zero emissions of pollutants and greenhouse gases. Fuel cell technology offers an alternative to traditional combustion-based energy systems, such as internal combustion engines, by providing a more efficient and environmentally friendly way to produce electricity. Here are the key components and aspects of fuel cell technology:

- **Fuel Cell Stack:** The fuel cell stack is the core component of a fuel cell system. It consists of multiple individual fuel cells that contain the necessary materials to facilitate the electrochemical reaction. The most common types of fuel cells include proton exchange membrane fuel cells (PEMFC), solid oxide fuel cells (SOFC), molten carbonate fuel cells (MCFC), and alkaline fuel cells (AFC).

- **Fuel:** Different types of fuel cells use different fuels. Common fuels include hydrogen, natural gas, methanol, ethanol, and even gasoline or diesel. Hydrogen is often considered the ideal fuel for fuel cells as it produces only water as a byproduct when reacting with oxygen. However, hydrogen production and infrastructure remain challenges for widespread adoption.
- **Oxidant**: The oxidant, typically oxygen from the air, is needed for the fuel cell reaction. The oxidant can be supplied from the surrounding air, eliminating the need for bulky fuel storage.
- **Electrochemical Reaction:** In a fuel cell, the fuel and oxidant are supplied to separate sides of the fuel cell stack. At the anode, the fuel is oxidized, releasing electrons. At the cathode, the oxidant is reduced, accepting the electrons. This electrochemical reaction generates an electric current that can be used to power electrical devices.

**Waste to energy Generation**

Fuel cell technology can be utilized in waste-to-energy applications to convert the energy content of waste into electricity and heat. By integrating fuel cells into waste management processes, the energy potential of organic waste can be harnessed while minimizing environmental impact. The fuel cell technology is applied in waste-to-energy conservation by several ways:

- **Anaerobic Digestion (AD) Coupled with Fuel Cells:** Anaerobic digestion is a biological process that breaks down organic waste in the absence of oxygen, producing biogas, primarily composed of methane and carbon dioxide. This biogas can be used as a fuel source for fuel cells. Fuel cell systems, such as solid oxide fuel cells (SOFC), can directly utilize the biogas produced from anaerobic digestion to generate electricity and heat. This process maximizes the energy recovery from organic waste while minimizing greenhouse gas emissions.
- **Landfill Gas Utilization:** Landfills produce methane gas as a byproduct of organic waste decomposition. This methane gas can be captured, cleaned, and used as a fuel for fuel cell systems. Fuel cells can efficiently convert the methane gas into electricity and heat,

providing a sustainable energy source and mitigating methane emissions, which is a potent greenhouse gas.

- **Biomass Gasification:** Biomass gasification is a thermochemical process that converts biomass, such as agricultural residues, wood waste, or energy crops, into a synthetic gas called syngas. Syngas, consisting mainly of hydrogen and carbon monoxide, can be utilized in fuel cells for electricity generation. High-temperature fuel cell technologies like molten carbonate fuel cells (MCFC) or solid oxide fuel cells (SOFC) are particularly suitable for biomass gasification applications.
- **Waste-to-Hydrogen Conversion:** Certain waste streams, such as organic waste or wastewater, can be processed through various technologies like gasification or pyrolysis to produce hydrogen gas. This hydrogen can be fed into fuel cells for electricity production. This approach allows for the efficient conversion of waste into a clean and high-energy content fuel.

By employing fuel cell technology in waste-to-energy conservation, several benefits can be realized:

**i.** Fuel cells can convert the energy content of waste into usable electricity and heat, enabling the recovery of valuable energy resources that would otherwise go to waste.

**ii.** Fuel cells utilize renewable fuel sources, such as biogas or hydrogen produced from waste, reducing dependence on fossil fuels and contributing to a more sustainable energy mix.

**iii.** By capturing and utilizing the methane gas produced from waste, fuel cell systems help to mitigate greenhouse gas emissions, as methane is a potent contributor to climate change.

**iv.** Fuel cell systems can be deployed at or near waste management facilities, enabling decentralized electricity generation and reducing transmission losses.

**v.** The integration of fuel cell technology in waste management processes can enhance the overall efficiency and sustainability of waste treatment systems by extracting energy value from waste streams.

**Programme on Energy from Urban, Industrial, Agricultural Wastes and Residues**

The Ministry has been implementing the scheme “Programme on Energy from Urban, Industrial and Agricultural Waste/Residues” aimed at generation of biogas, BioCNG and Power from different wastes, such as Municipal Solid Waste, vegetable and other market wastes, slaughterhouse waste, agricultural residues and industrial wastes & effluents. In addition to Bio-CNG/Biogas, biogas plants generate organic fertilizer as a by-product which is valuable for agricultural fields.

The scheme was valid upto 31st March, 2021. As of now, the Bio-energy Programme of MNRE has been continued for the period of FY 2021-22 to FY 2025-26 to only meet the already created liabilities and no new projects are being sanctioned.

**Progress during the Calendar year 2021**

i. Physical Achievement: As on 31.12.2021, during the calendar year 2021, the capacities added in respect of various output products are given in **Table.1.**

**Table.1:** Progress of product output and capacity addition during calendar year 2021

| Sl. No. | Output Product | No. of plants | Capacity Addition in States |
|---|---|---|---|
| 1 | Biogas | 4 | Telangana, Gujarat |
| 2 | Bio-CNG/CBG | 9 | Andhra Pradesh, Karnataka, Haryana, Tamilnadu and Telangana |
| 3 | Power | 13 | Haryana, Andhra Pradesh, Gujarat, Uttar Pradesh, Madhya Pradesh, West Bengal and Telangana |

**SAQ4: Self Assessment Questions**

**Q1.** Three key technical challenges of integrated PV-battery systems are implemented?

**Ans.** Energy density, efficiency, and stability.

**Q2.** The Ministry has been implementing the scheme on Energy?

**Ans.** Energy from Urban, Industrial and Agricultural Waste/Residues.

Q3. Programme on Energy from Urban, Industrial and Agricultural Waste/Residues" aimed at generation of ?

**Ans.** Biogas, BioCNG and Power from different wastes, such as Municipal Solid Waste, vegetable and other market wastes, slaughterhouse waste, agricultural residues and industrial wastes & effluents.

**Q4.** The Bio-energy Programme of MNRE has been continued for the period?

Ans. FY 2021-22 to FY 2025-26 to only meet the already created liabilities.

## 8.8. Green technology practice in India

India has been actively implementing and promoting green technology practices to address environmental challenges and promote sustainable development. Here are some notable examples of green technology practices in India. India has made significant progress in renewable energy deployment. The country has set ambitious targets for renewable energy capacity, particularly in solar and wind power. It has implemented various policies and incentives to promote renewable energy generation, including feed-in tariffs, competitive bidding, and tax benefits. India is one of the largest solar and wind energy markets globally. The government has initiated several programs to improve energy efficiency across various sectors. The Bureau of Energy Efficiency (BEE) has introduced energy labeling for appliances, such as star ratings for energy-efficient products. The Perform, Achieve, and Trade (PAT) scheme targets energy-intensive industries to achieve energy efficiency targets and offers tradable energy-saving certificates. India is focusing on the adoption of electric vehicles (EVs) to reduce dependence on fossil fuels and combat air pollution. The government has implemented policies and incentives to promote EV manufacturing, charging infrastructure development, and consumer adoption. It aims to have a significant proportion of electric vehicles on Indian roads by 2030. The Green Building Movement has gained momentum in India. The Indian Green Building Council (IGBC) promotes green building practices and certifies buildings based on their sustainability performance. Many new construction projects adopt green building principles, incorporating energy-efficient designs, use of sustainable materials, rainwater harvesting, and waste management systems. The Swachh Bharat Abhiyan (Clean India Campaign) has led to increased focus on waste management practices. The emphasis is on waste segregation, recycling, and waste-to-energy conversion. Many cities have implemented waste-to-energy plants and composting facilities to manage solid waste effectively. With growing water scarcity, India has implemented water conservation practices such as rainwater harvesting, wastewater recycling, and efficient irrigation techniques. The government has launched schemes like Jal Shakti Abhiyan to promote water conservation and recharge of groundwater. India promotes sustainable agricultural practices through organic farming, use of biofertilizers, and precision farming techniques. The government offers subsidies and support to farmers adopting sustainable agriculture practices. Given the challenges of air pollution, India has taken measures to control emissions from industries, vehicles, and biomass burning. Stricter emission standards for vehicles and the implementation of cleaner fuel options like Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) have been instrumental in reducing air pollution. hese are just a few examples of the green technology practices in India. The government, private sector, and civil society are actively working together to promote sustainable development and mitigate environmental challenges through the adoption of green technologies.

## 8.9 Summary

Green energy, also known as renewable energy or clean energy refers to energy sources that have a minimal environmental impact and can be sustainably replenished. These energy sources contribute to reducing greenhouse gas emissions, mitigating climate change, and promoting a more sustainable and environmentally friendly energy system. Clean energy is energy that when used, does not pollute the atmosphere; creating little or no greenhouse gases. Once again, there are clear crossovers between clean energy, green energy and renewable energy. Here's an easy way to differentiate between them: Clean energy = clean air; Green energy = sources from nature and Renewable energy = recyclable sources. Green energy sources include solar power, wind power, hydroelectric power, geothermal energy, and biomass energy. These sources harness natural phenomena and convert them into usable energy without depleting finite resources or emitting harmful pollutants. Green energy is a critical component of the global effort to transition to a low-carbon economy and mitigate the impacts of climate change. The continued development and widespread adoption of green energy sources and technologies are essential for achieving a sustainable and clean energy future.

## 8.10. Terminal Questions

**Q.1:** What is the Aim and scope of green technology?

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.2:** Give Concept of green energy and green technology.

**Answer:** ----------------------------------------------------------------------------------------------------

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**Q.3:** Define Biomass energy and its production.

**Answer:** ---------------------------------------------------------------------------------------------------

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**Q.4:** What is the importance of solar and green battery technology?

**Answer:** ---------------------------------------------------------------------------------------------------

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**Q.5:** What is the Aim and scope of Fuel cell technologies and application to waste-to-energy conversion?

**Answer:** ---------------------------------------------------------------------------------------------------

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## 8.11. Further suggested readings


**7.** Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011

**8.** Non-conventional Energy Resources, D.S. Chauhan, New Age International.

**9.** Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.

**10.** Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press.

**11.** Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.

**12.** Introduction to Energy and Climate, Developing a Sustainable Environment, Julie Kerr, Taylor & Francis.

# Unit-9: Green Nanotechnology

***Contents***



## 9.1 Introduction

Green technology refers to the use of technology to enhance the environmental sustainability of processes producing negative externalities. It also refers to the use of the products of technology to enhance sustainability. It includes making green products and using products in support of sustainability

**Objective**

- Understanding green technology
- Sectors using green tech
- Green nanotechnology necessity of green technology
- Categories of green technology

- Environmental profits of green building
- Goals of green technology

## 9.2. Understanding of green technology

The word GREEN in the name Green technology has dual meaning. On one hand it describes the environment friendly technologies utilized to synthesize materials; on the other hand it refers to the use of natural materials produced by plants and nature. Green nanotechnology has been described as the development of clean technologies, "to minimize potential environmental and human health risks associated with the manufacture and use of nanotechnology products. It also encourages replacement of existing products with new products that are more environment friendly throughout their lifecycle.

**Aim**

Green technology has two goals: producing materials and products without harming the environment or human health and producing products that provides solutions to environmental problems. It uses existing principles of green chemistry and green engineering to make materials and products without toxic ingredients at low temperatures using less energy and renewable inputs wherever possible, and using lifecycle thinking in all design and engineering stages.

In addition to making materials and products with less impact to the environment, green nanotechnology also means using nanotechnology to make current manufacturing processes for non-nano materials and products more environment friendly. For example, nanoscale membranes can help separate desired chemical reaction products from waste materials from plants. Nanoscale catalysts can make chemical reactions more efficient and less wasteful. Sensors at the nanoscale can form a part of process control systems, working with nano-enabled information systems. Using alternative energy systems, made possible by nanotechnology, are another way to "green" manufacturing processes.

## 9.3 Sectors using Green Technology

## 1) Energy applications of nanotechnology

Research is underway to use Nanomaterials for purposes including more efficient solar cells, practical fuel cells, and environment friendly batteries. The most advanced nanotechnology projects related to energy are: storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving (by better thermal insulation for example), and enhanced renewable energy sources.

One major project that is being worked on is the development of nanotechnology in solar cells. Solar cells are more efficient as they get tinier and solar energy is a renewable resource. The price per watt of solar energy is lower than one dollar. Research is going to use nanowires and other nanostructure materials with the hope of to create cheaper and more efficient solar cells than are possible with conventional planar silicon solar cells. Another example is the use of fuel cells powered by hydrogen, potentially using a catalyst consisting of carbon supported noble metal particles with diameters of 1–5 nm. Materials with small nanosized pores may be suitable for hydrogen storage. Nanotechnology may also find applications in batteries, where the use of nanomaterials may enable batteries with higher energy content or supercapacitors with a higher rate of recharging. Nanotechnology is already used to provide improved performance coatings for photovoltaic (PV) and solar thermal panels. Hydrophobic and self-cleaning properties combine to create more efficient solar panels, especially during inclement weather. PV covered with nanotechnology coatings are said to stay cleaner for longer to ensure maximum energy efficiency is maintained.

## 2) Nano-remediation and water treatment

Nanotechnology offers the potential of novel nanomaterials for the treatment of surface water, groundwater, wastewater and other environmental materials contaminated by toxic metal ions, organic and inorganic solutes and microorganisms. Due to their unique activity toward recalcitrant contaminants, many Nanomaterials are under active research and development for use in the treatment of water and polluted sites.

The present market of nanotech based technologies applied in water treatment consists of reverse osmosis (RO), nanofiltration, and ultrafiltration membranes. Definitely, among emerging products one can name nanofiber filters, carbon nanotubes and various nanoparticles.

Nanotechnology is expected to deal more efficiently with contaminants which convectional water treatment systems struggle to treat, including bacteria, viruses and heavy metals. This efficiency generally stems from the very high specific surface area of nanomaterials, which increases dissolution, reactivity and sorption of contaminants.

**3) Environmental remediation**

Nanoremediation is the use of nanoparticles for environmental remediation. Nanoremediation has been widely used for groundwater treatment with additional extensive in wastewater treatment. Nanoremediation has also been tested for soil and sediments cleanup. Even more preliminary research is exploring the use of nanoparticles to remove toxic materials from gases.

Some nanoremediation methods are particularly the use of nano-zerovalent iron for groundwater cleanup, have been eployed at full-scale cleanup sites. Nano-remediation is an emerging industry by 2009. During nanoremediation, a nanoparticle agent must be brought into contact with the target contaminant under conditions that allow a detoxifying or immobilizing the reaction. This process typically involves a pump and treats process or in situ application. Scientists have been researching the capabilities of buckminsterfullerene in controlling pollution as it may be able to control certain chemical reactions. Buckminsterfullerene($C_{60}$) has been demonstrated as having the ability of inducing the protection of reactive oxygen species and causing lipid peroxidation. This material may allow for hydrogen fuel to be more accessible to consumers.

**4) Water cleaning technology**

I RingwooditE Co. Ltd was formed Thermonuclear Trap Technology (TTT) for the purpose of cleaning all sources of water from pollution and toxic contents. This patented nanotechnology uses a high pressure and temperature chamber to separate isotopes that should by nature not be in drinking water to pure drinking water as to the by the WHO´s established classification. This method has been developed among others by Professor Vladimir Afanasiew, at the Moscow Nuclear Institution. This technology is targeted to clean Sea, river, lake and landfill waste waters. It even removes radioactive isotopes from the sea water, after Nuclear Power Stations catastrophes and cooling water plant towers. By this technology pharmaca rests are being removed as well as narcotics and tranquilizers. Bottom layers and sides of lake and rivers can be returned after being cleaned. Machinery used for this purpose is much similar to those of deep sea mining. Removed waste items are being sorted by the process and can be re used as raw material for other industrial production.

**5) Water filtration**

Nanofiltration is a relatively recent membrane filtration process used most often with low total dissolved solids water such as surface water and fresh groundwater, with the purpose of softening (polyvalent cation removal) and removal of disinfection by-product precursors such as natural organic matter and synthetic organic matter. Nanofiltration is also becoming more widely used in food processing applications such as dairy, for simultaneous concentration and partial (monovalent ion) demineralization.

Nanofiltration is a membrane filtration based method that uses nanometer sized cylindrical through pores that pass through the membrane at 90°. Nanofiltration membranes have pore sizes from 1-10 Angstrom, smaller than that used in microfiltration and ultra filtration, but just larger than that in reverse osmosis. Membranes used are predominantly created from polymer thin films. Materials that are commonly used include polyethylene terephthalate or metals such as aluminum. Pore dimensions are controlled by pH, temperature and time during development with pore densities ranging from 1 to 106 pores per $cm^2$. Membranes made from polyethylene terephthalate and other similar materials, are referred to as "track-etch" membranes named after the way the pores on the membranes are made."Tracking" involves bombarding the polymer thin film with high energy particles. These results in making tracks that are chemically developed into the membrane, or "etched" into the membrane, which are the pores. Membranes created from metal such as alumina membranes, are made by electrochemically growing a thin layer of aluminum oxide from aluminum metal in an acidic medium.

Some water-treatment devices incorporating nanotechnology are already in the market, with more in development. Low-cost nanostructure separation membranes methods have been shown to be effective in producing potable water in a recent study.

**6) Nanotechnology to disinfect water**

Nanotechnology provides an alternative solution to clean germs in water a problem that has been getting worse due to the population explosion, growing need for clean water and the emergence of additional pollutants. One of the alternatives offered is antimicrobial nanotechnology stated that several nanomaterials showed strong antimicrobial properties through diverse mechanisms, such as photocatalytic production of reactive oxygen species that damage cell components and viruses. There is also the case of the synthetically-fabricated nanometallic particles that produce antimicrobial action called oligodynamic disinfection, which can inactivate microorganisms at low concentrations. Commercial purification systems based on titanium oxide photocatalysis also currently exist and studies show that this technology can achieve complete inactivation of fecal coliforms in 15 minutes once activated by sunlight.

There are four classes of nanomaterials that are employed for water treatment and these are dendrimers, zeolites, carbonaceous nanomaterials, and metals containing nanoparticles. The benefits of the reduction of the size of the metals (e.g. silver, copper, titanium, and cobalt) to the nanoscale such as contact efficiency, greater surface area, and better elution properties.

**7) Cleaning up oil spills**

The U.S. Environmental Protection Agency (EPA) documents more than ten thousand oil spills per year. Conventionally, biological, dispersing, and gelling agents are deployed to remedy oil spills. Although, these methods have been used for decades, none of these techniques can retrieve the irreplaceable lost oil. However, nanowires can not only swiftly clean up oil spills but also recover as much oil as possible. These nanowires form a mesh that absorbs up to twenty times its weight in hydrophobic liquids while rejecting water with its water repelling coating. Since the potassium manganese oxide is very stable even at high temperatures, the oil can be boiled off the nanowires and both the oil and the nanowires can then be reused.

In 2005, Hurricane Katrina damaged or destroyed more than thirty oil platforms and nine refineries. The Interface Science Corporation successfully launched a new oil remediation and recovery application, which used the water repelling nanowires to clean up the oil spilled by the damaged oil platforms and refineries.

**8) Removing plastics from oceans**

One innovation of green nanotechnology that is currently under development are nanomachines modeled after a bacterium bioengineered to consume plastics, Ideonella sakaiensis. These nano-machines are able to decompose plastics dozens of times faster than the bioengineered bacteria not only because of their increased surface area but also because the energy released from decomposing the plastic is used to fuel the nano-machines.

**9) Air pollution control**

In addition to water treatment and environmental remediation, nanotechnology is currently improving air quality. Nanoparticles can be engineered to catalyze, or hasten, the reaction to transform environmentally pernicious gases into harmless ones. For example, many industrial factories that produce large amounts harmful gases employ a type of nanofiber catalyst made of magnesium oxide ($Mg_2O$) to purify dangerous organic substances in the smoke. Although chemical catalysts already exist in the gaseous vapors from cars, nanotechnology has a greater chance of reacting with the harmful substances in the vapors. This greater probability comes from the fact that nanotechnology can interact with more particles because of its greater surface area.

Nanotechnology has been used to remediate air pollution including car exhaust pollution, and potentially greenhouse gases due to its high surface area. Based on research done by the Environmental Science Pollution Research International, nanotechnology can specifically help to treat carbon-based nanoparticles, greenhouse gases, and volatile organic compounds. There is also working being done to develop antibacterial nanoparticles, metal oxide nanoparticles, and amendment agents for phytoremediation processes. Nanotechnology can also give the possibility of preventing air pollution in the first place due to its extremely small scale. Nanotechnology has been accepted as a tool for many industrial and domestic fields like gas monitoring systems, fire and toxic gas detectors, ventilation control, breath alcohol detectors and many more. Other sources state that nanotechnology has the potential to develop the pollutants sensing and detection methods that already exist. The ability to detect pollutants and sense unwanted materials will be heightened by the large surface area of nanomaterials and their high surface energy. The World Health Organization declared in 2014 that air contamination caused around 7 million deaths in 2012. This new technology could be an essential asset to this epidemic. The three ways that nanotechnology is being used to treat air pollution are nano-adsorptive materials, degradation by nanocatalysis, and filtration/separation by nanofilters. Nanoscale adsorbents being the main alleviator for many air pollution difficulties. Their structure permits a great interaction with organic compounds as well as increased selectivity and stability in maximum adsorption capacity. Other advantages include high electrical and thermal conductivities, high strength, high hardness. Target pollutants that can be targeted by nanomolecules are $(NO)_x$, $(CO)_2$, $(NH)_3$, $N_2$, VOCs, Isopropyl vapor, $(CH)_3$ OH gases, $N_2O$, $H_2S$. Carbon nanotubes specifically remove particles in many ways. One method is by passing them through the nanotubes where the molecules are oxidized; the molecules then are adsorbed on a nitrate species. Carbon nanotubes with amine groups provide numerous chemical sites for carbon dioxide adsorption at low temperature ranges of 20°-100° degrees Celsius. Van der Waals forces and π-π interactions also are used to pull molecules onto surface functional groups. Fullerene can be used to rid of carbon dioxide pollution due to its high adsorption capacity. Graphene nanotubes have functional groups that adsorb gases. There are plenty of nanocatalysts that can be used for air pollution reduction and air quality. Some of these materials include $(TiO)_2$, Vanadium, Platinum, Palladium, Rhodium, and Silver. Catalytic industrial emission reduction, car exhaust reduction, and air purification are just some of the major thrusts that these nanomaterials are being utilized within. Certain applications are not widely spread, but other are more popular. Indoor air pollution is barely on the market yet, but it is being developed more efficiently due to complications with health effects. Car exhaust emission reduction is widely used in diesel fueled automobiles currently being one of the more popular applications. Industrial emission reduction is also widely used. It is a integral method specifically at coal fired power plants as well as refineries. These methods are analyzed and reviewed using SEM imaging to ensure its usefulness and accuracy.

## 10) Nanotechnology for sensors

Perpetual exposure to heavy metal pollution and particulate matter will lead to health concerns such as lung cancer, heart conditions, and even motor neuron diseases. However, humanity's ability to shield themselves from these health problems can be improved by accurate and swift nanocontact-sensors able to detect pollutants at the atomic level. These nanocontact sensors do not require much energy to detect metal ions or radioactive elements. Additionally, they can be made in automatic mode so that they can be readably used at any given moment.

Additionally, these nanocontact sensors are energy and cost effective since they are composed with conventional microelectronic manufacturing equipment using electrochemical techniques.

**11) Some examples of nano-based monitoring include:**

Functionalized nanoparticles able to form anionic oxidants bonding thereby allowing the detection of carcinogenic substances at very low concentrations. Polymer nanospheres have been developed to measure organic contaminates in very low concentrations. Peptide nanoelectrodes have been employed based on the concept of thermocouple. In a 'nano-distance separation gap, a peptide molecule is placed to form a molecular junction. When a specific metal ion is bound to the gap; the electrical current will result conductance in a unique value. Hence the metal ion will be easily detected." Composite electrodes, a mixture of nanotubes and copper, have been created to detect substances such as organ phosphorus pesticides, carbohydrates and other woods pathogenic substances in low concentrations.

## 9.4. Green nanotechnology necessity of green technology

Although green nanotechnology poses many advantages over traditional methods, there is still much debate about the concerns brought about by nanotechnology. For example, since the nanoparticles are small enough to be absorbed into skin and/or inhaled, countries are mandating that additional research revolving around the impact of nanotechnology on organisms be heavily studied. In fact, the field of eco-nanotoxicology was founded solely to study the effect of nanotechnology on earth and all of its organisms. At the moment, scientists are unsure of what will happen when nanoparticles seep into soil and water, but organizations, such as Nano Impact Net, have set out to study these effects.

## 9.5. Green Building

The design, construction, operation and maintenance of buildings normally require enormous amounts of energy, water and raw materials, generating large quantities of waste and causing air and water pollution. Whereas **green building** is the only answer through creating healthier and more resource-efficient models of construction, renovation, operation and maintenance. Green Architecture and sustainable buildings are considered a modern trend in architectural thinking which manipulates the relationship between the building and the environment. Generally office buildings are one of the highest types of buildings in energy consumption compared to other building. So it is very important for an architect to implement specific strategies in order to decrease energy consumption, especially in this type of building, by using renewable energy sources such as solar energy, wind energy, and other sources which contribute to electric energy rationalization.

**What is Green Building?**

**A Green building** or **sustainable building** is a structure which is designed, constructed, operated or reused in an ecological and energy-efficient manner.

**Concept of Green Buildings**

The concept of Green building integrates a variety of strategies during the period of Design, Construction, Maintenance, and Operation of buildings. Construction is an element of civilization which is increasing continuously and thereby requires lots of natural or manmade materials to fulfill the demand. Manufacturing of construction materials like Cement, Conventional brick, steel, etc.

These materials produce a large amount of $CO_2$ and other greenhouse gases which are hazardous in nature and cause environmental and health-related problems. So it is today's demand to acquire good construction practice and energy efficient material which helps in less production of greenhouse gases and save energy.

**Principle of Green Buildings**

The green building design process begins with a deep understanding of the site in all its beauties and complexities. An ecological approach to design aims to integrate the systems being introduced with the existing on-site ecological functions performed by nature. These ecological functions provide habitats respond to the movements of the sun, purify the air as well as catch, filter, and store water.

Designers can create features in their buildings that represent the functions of particular ecosystems. Species that thrive in natural ecosystems may also utilize habitats created in manmade structures. Creating new habitats on structures in urbanized areas is especially important to support bio-diversity and a healthy ecosystem.

The objective is to evolve a strategy to reduce the energy used in buildings so as to reduce energy costs and greenhouse gas emissions into the earth's atmosphere.

The concept of Green Buildings envisions a new approach to saving water, energy, and material resources in the construction and maintenance of buildings and can reduce or eliminate the adverse impact of buildings on the environment and occupants. Design considerations of Green building Results in Reduced site disturbance, Wastewater management, and Stormwater management. Landscape and Exterior Design to reduce heat islands, Light Pollution Reduction, and Reduced Car dependence through car parking provision. A green building is designed, constructed, and operated to minimize the total environmental impacts while enhancing user comfort and productivity.

### 9.5.1. Features of Green Building

A green building includes environmental considerations in each stage of the building construction and focuses on the design, construction, operation and maintenance. Green buildings typically include superior air quality, abundant natural light, access to views, and noise control which benefits building occupants, making these buildings better places to work or live.

**Highlighted features of Green Building-**

1. Air tightness and vapors barrier in building walls and surfaces
2. Waste reduction
3. Enthalpy recovery of exhaust air
4. Low solar heat gain coefficient of glass
5. Daylight-controlled lighting systems
6. Occupancy sensors
7. Water-efficient fittings
8. Rain-water harvesting
9. Materials recovery facility (MRF)
10. Vegetation

11. Site sustainability
12. Geothermal Heating and Cooling
13. HEPA (High-efficiency particulate arrestance)
14. $CO_2$ Controlling ventilators
15. VSD (Variable Speed Drives)
16. Use of solar panels
17. Solar thermal collectors
18. Greywater/Blackwater Recycling
19. LED
20. Wind Turbines

- **Air tightness and vapors barrier in building walls and surfaces-**
    - Walls that are able to keep out moisture and humidity from outside will make the building naturally cooler, because of this, air-conditioning systems will not have to work so hard to cool down the building and thus lowers electricity costs.
- **Waste Reduction-**
    - Pollution control measures adopted and implemented on the project sites during construction activities, Green buildings aim to reduce the amount of material being sent to landfills during construction.
- **Enthalpy recovery of exhaust air-**

A device called an enthalpy wheel recovers cooled air from the inside and uses the coolness of this “spent” air to cool fresh air from outside. The process also dehumidified the air from outside. This is a cost-efficient way to improve indoor air quality and lessen energy

- **Low solar heat gain coefficient of glass-**

**Solar heat gain coefficient (SHGC)** is the amount of solar radiation that enters through glass and is released as beat inside buildings. The lower SHGC, the less solar heat it transmits, and the cooler the building. This also lowers electricity costs because air conditioning systems don’t have to do all the work.

- **Daylight-controlled lighting systems**

This type of lighting system has a sensors that can detect daylight. During the day, the sensor switches off the lights since there is enough light from the sun. When the sun sets, the system will switch the light on. This way, the use of artificial lighting during the daytime is reduced.

- **Occupancy sensors-**

This lighting system only turns on when it senses people in the room. This technology can also be found in escalators that activate only when there are people riding on them.

- **Water-efficient fittings-**

The latest faucets and flush mechanisms use less water to do the same thing.

- **Rain-water Harvesting-**

A structure catches rainwater and then stores it in big containers. The water can then be used to water plants, flush toilets, or supply cooling towers.

- **Materials recovery facility (MRF)**

An MRF is where the building's garbage is segregated into biodegradable, recyclable, non-recyclable, and special or hazardous waste. Biodegradable waste can be composted and used as fertilizer for the building's plants.

- **Vegetation-**

A significant portion of the building's unpaved area is devoted to vegetation. This helps reduce the heat urban island effect-when concrete surfaces so common in urban areas absorb heat from the sun and radiate it to the surroundings. Plants also help absorb some rainwater which would otherwise go to sewers and drainage, later on contributing to flooding.

- **Site Sustainability**

The building's design, construction, and operation practices should have minimum impact on ecosystems and water resources.

- **Geothermal Heating and Cooling-**

The underground is an excellent heat sink in summer and an excellent heat source in winter. Geothermal heat pumps take advantage of this providing heating and cooling for buildings with a lower kWh consumption than other methods. Indoor heating and cooling are provided normally with hydronic piping, air-handling units, and air ducts. The geothermal heat pump uses a secondary piping circuit that goes underground to collect or reject heat as needed.

- **HEPA (High-efficiency particulate arrestance)-**

HEPA filters are among the best available capturing 99.97% of particles with a size of 0.3 microns or more. These filters remove many pollutants and allergens from the air and improve indoor air quality.

- **$CO_2$ Controlling Ventilators-**

Since human metabolism produces carbon dioxide occupancy can be correlated with the $CO_2$ concentration in room air. Ventilation can be controlled with $CO_2$ sensors, reducing airflow in proportion to occupancy to attain energy savings.

- **VSD (Variable Speed Drives)-**

Variable speed drives (VSD) are devices that modify the voltage and frequency supplied to a motors allowing it to operate below-rated rpm. VSDs are very useful in motors that drive fans and pumps, these devices are often subject to part-load conditions. They are also known as variable frequency drives (VFD).

- **Use of solar panels-**

Solar panels are among the most promising building upgrades if you have plenty of rooftop areas. They normally come with a 10-year warranty for manufacturing defects and a 25-year warranty for energy generation in addition to having simple maintenance needs. The payback period of solar panels only represents a small fraction of their service life. Simple maintenance. The main requirement is keeping panel surfaces clean and free of shadows. May be eligible for incentives from the government or utility companies.

- **Solar thermal collectors-**

Solar radiation is used directly for domestic hot water instead of electricity generation. With this building upgraded, you can rely less on your gas-fired water heater. They may be a slight pumping cost in taller buildings since water has to reach the rooftop, but it is much less than the ongoing cost of a water heater. However, Solar thermal collectors also harness sunlight.

- **Greywater/Blackwater Recycling-**

The concepts of greywater are used to describe water that has already been used in plumbing fixtures. Blackwater includes water from all fixtures while greywater excludes the water discharged from toilets. While grey water is polluted with cleaning agents and grease, it can be collected and reused for purposes such as flushing toilets or outdoor watering. Blackwater can also be recycled for some purposes but it requires special treatment.

- **LED**

LED uses over 30% less power consumption than fluorescent, over 50% less than HID and over 80% less than radiant. LED also Reduced the cooling load for AC and refrigeration equipment. LEDs have a Long service life and almost no maintenance is required.

- **Wind Turbines**

A single wind turbine results in a lower cost per kilowatt. Electricity generation is enhanced with a taller tower since airflow is more stable as height increases. Smaller turbines are closer to the ground and susceptible to the turbulence caused by trees and constructions. Electricity savings, zero generation cost after the payback period. May be eligible for incentive from the government or utility companies.

### 9.5.2. Green Building Materials used in Construction

The materials used while constructing a green building are listed and described below-

1. Earthen Materials
2. Engineered Wood
3. Bamboo

4. Structural insulated panels (SIPs)
5. Insulated Concrete Forms
6. Cordwood
7. Straw Bale
8. Earth Bags
9. Slate Roofing
10. Steel
11. Thatch
12. Composites
13. Natural Fiber
14. Polyurethane
15. Fiberglass
16. Cellulose
17. Cork
18. Natural Clay
19. Non-VOC Paints
20. Natural Fiber Floor
21. Fiber Cement
22. Stone
23. Triple-Glazed Windows
24. Paper Insulation
25. Solar Ties
26. Compressed Earth Brick Block
27. Marble slurry bricks
28. Ferro cement wall panels
29. Compressed Earth block
30. Sand Lime Brick

**1. Earthen Materials-**

Earthen materials like adobe, cob, and rammed earth are being used for construction purposes, for good strength and durability- chopped straw, grass, and other fibrous materials, etc. are added to the earth. Even today structures built with cob can be seen in some remote areas.

**2. Engineered Wood-**

Wood is one of the most famous building materials used around the world, But in the process of conversion of raw timber to wood boards, most percentage of the wood may get wasted. This wastage can also be used to make structural parts like walls, bounds, doers, etc in the form of engineered wood. Unlike solid wood engineered wood contains different layers of wood, usually, the middle layers are made of wood scraps, softwood, wood fibers, etc.

**3. Bamboo-**

Bamboo is one of the most used versatile and durable materials used in construction. These trees grow more rapidly irrespective of climatic conditions. So, it makes it economical as well. They can be used to construct frames, walls, floors, etc. They provide a good appearance to the structures. Bamboo is such a promising building material for modern buildings since it is a combination of tensile strength, lightweight, and fast growing renewable nature. Used for framing buildings and shelters, bamboo can replace exclusive and heavy imported materials and provide an option to concrete and rebar construction, especially in difficult to reach areas, post disaster rebuilding and low-income areas with access to naturally locally-sourced bamboo.

**4. Structural insulated panels (SIPs)-**

Structural insulated panels (SIPs) consist of two sheets of oriented thread boards or flake boards with a foam layer between them. They are generally available in larger sizes and are used as walls for the structure. Because of their large size, they need heavy equipment to install however, they provide good insulation.

**5. Insulated Concrete Forms-**

Insulated Concrete Forms contains two insulation layers with some space in between them. This space contains some arrangements for holding reinforcement bars after placing reinforcement, concrete is poured into this spaces. They are light in weight, fire resistant, low density and have good thermal and sound insulation properties.

**6. Cord Wood-**

If wood is plentifully available and easily accessible to the site of construction, cordwood construction is recommended. It requires short and round pieces of wood which are laid one above the other width-wise and are bonded together by a special mortar mix. They are strong, environmentally friendly and also give a good appearance to the structure.

**7. Straw Bale-**

Straw bale is another green building material which can be used as framing material for buildings because of its good quality insulating properties. They can also act as sound proof materials. Non-load bearing walls of the straw bale can be used as fill material in between columns in beams framework is recommended. Since, air cannot pass through them straw bales also have some resistance to fire.

**8. Earth Bags-**

Earthbags also called sandbags are also used to construct walls of a structure. Their types of structures can be seen in military bases near banks of water resources, etc. In general bags made of burlap are recommended but they may not very easily and hence, polypropylene bags are used nowadays.

**9. Slate Roofing-**

Slate is a naturally twisted rock which is used to make tiles. Slate tiles have high durability and they are used as roofing materials. Slate roofing is preferred when it is locally and cheaply available.

**10. Steel-**

Steel roof panels and shingles are highly durable and they can be recycled again and again. So, these are the best choices for green roofing materials.

**11. Thatch-**

Thatch is nothing but dry straw dry water reed, dried rushes, etc. These are the oldest roofing materials which are still in use in some remote location of the world and even in cities for aesthetic attractions. It is cheaply available for roofing and is a good insulator material.

**12. Composites-**

Roof panels made of composite materials such as foam or cellulose layer sandwiched between two metal sheets or two plastic sheets also come under green building materials. They are light in weight inexpensive and provide good insulation for the structure and saves energy.

**13. Natural Fiber-**

Natural fibers like cotton and wool can also be used as insulation materials. Recycled cotton fibers or wool fibers are converted into a batt and installed in preformed wooden frame sections.

**14. Polyurethane-**

Polyurethane foam is available in the form of spray bottles. They are directly sprayed onto the surface or wall or to which part padding is required. After spraying it expands and forms a thick layer which hardens later on. They offer excellent insulation and prevent leakages of air.

**15. Fiber Glass-**

Fiberglass is also used for insulation purposes in the form of fiberglass batts. Even though it contains some toxic binding agents, because of its super insulation property at low cost it can be considered a green building material.

**16. Cellulose-**

Cellulose are a recycled product of paper waste and it is widely used around the world for insulation purposes in structure. It acts as a good sound insulator and is available for cheaper prices in the market.

**17. Cork-**

Cork is also a good insulator. Boards or panels made of cork are available in markets. A great amount of electrical energy can be saved by corkboard insulation in winter. These corkboards are also good for sound insulations too.

**18. Natural Clay-**

Plastering of walls can be done using natural clay rather than other gypsum-based plasters. Natural clay plaster with good workmanship gives a beautiful appearance to the interior.

**19. Non- VOC Paints-**

Non-VOC paint or green paints is recommended over Volatile Organic Compounds (VOC) containing paints. The presence of Volatile Organic Compounds (VOC) in paint reacts with sunlight and nitrogen oxide resulting in the formation of ozone which can cause severe health problems for the occupants. Whereas if non-VOC paint is not available then paint with very low-VOC content in it is preferable.

**20. Natural Fiber Floor-**

Naturally occurring materials like bamboos, wools, cotton fiber carpets, cork, etc. can be used for flooring purposes.

**21. Fiber Cement-**

Fiber cement boards are made of cement, sand and wood fibers. For exterior siding fiber cement boards are a good choice because of their cheap price, good durability and good resistance against fire.

**22. Stone-**

Stone is a naturally occurring and long-lasting building material. Some Stones structures built hundreds of years ago are still in the existence without much abrasion. Stones are good against weathering hence they can be used to construct exterior walls, steps, exterior flooring, etc.

**23. Triple Glazed Window-**

It is a super efficient material that stops heat to enter into the building from direct sunlight.

**24. Paper Insulation-**

Made of recycled newspapers and cardboard which is insects resistant and fire retardant.

**25. Solar Ties-**

Act as a protective covering for buildings and spend a large portion of the day absorbing energy.

**26. Compressed Earth Brick Block-**

Use to construct a building that is artistic, efficient and easy to build. Energy efficient excellent surface finish Cost efficient technology plastering is not required good thermal insulation.

**27. Marble Slurry Bricks-**

Use for walling as an alternative to conventional clay bricks these are energy efficient high volume utilization of wash stronger than clay bricks, fire resistant basic high load bearing capacity.

**28. Ferro cement wall panels-**

Use for walling is particularly suitable where speedy construction is required. These are energy-efficient, cost-effective technology regularity in shape and size components that can be retrieved for construction.

**29. Compressed Earth block-**

It is a highly compressed earth block or brick. These bricks are mechanically pressed with a pressure of about 3,000 psi at this pressure original volume of soil reduces by about half.

Compressive earth blocks are inexpensive and best for non-load-bearing structures. A coat of Polycarbonate varnish is required to avoid erosion due to wet weather.

**30. Sand Lime Brick-**

Sand lime brick is a pressed brick made of 90% of sand and 10% of hydrated lime and kept in an autoclave for steam curing. These bricks are of uniform shape and size which requires less mortar for masonry.

### 9.5.3. Standards of Green Building

Four of the largest and most recognized green labeling programs are:

1. LEED
2. Energy Star
3. Green Globe
4. Green Seal

Each administered by different organizations, has its own rating criteria and focuses most heavily on different issues. By looking at all four of these one can begin to see overlaps and shortcomings. One can begin to develop a more holistic approach to defining a truly green material.

**1. LEED-**

**LEED** is an internationally recognized green building certification system. LEED provides third-party verification that a community or building was designed and built using strategies aimed at improving performances in energy savings, water efficiency, $CO_2$ emissions/ reductions, improved indoor environmental quality and stewardship of resources and sensitivity to their impact. It developed by the U.S. Green Building Council, LEED provides a framework for implementing measurable green building designs, construction, operations and maintenance solutions. It works throughout the building lifecycle. Certification is achieved through the third-party independent Green Building Certification Institute.

**LEED Rating Systems are applicable to-**

- New Construction
- Existing Buildings- Operations + Maintenance
- Commercial Interiors
- Core and Shell
- Schools
- Retail
- Healthcare
- Homes

- Neighborhood
- Development

**2. Energy Star-**

A government backed organization focusing on improving energy efficiency administered by the US Environmental Protection Agency and the US Department of Energy. Standards for Energy Star-rated buildings are set by the EPA. Their motto is “Energy efficiency comes first”.

Founded in 1992, Energy Star began as a labeling program that only rated consumer products. Products like be household appliances and air conditioning units with the Energy Star label now save between 20% and 30% of energy.

**3. Green Globe-**

A guidance and assessment od program that offers realistic and achievable ways to increase the sustainability of commercial buildings, Administered by the Green Building Initiative in the US.

**The most important components of the Green Globe program are:**

- Comprehensive environmental assessment protocol
- Software tools that speed and ease online assessment
- Best practices guidance for green construction and operations
- Experienced green building assessors

**4. Green Seal-**

A non-profit third-party certifier and standards development party. The largest US-based ecolabelling organization The U.S. member of GEN (Global Ecolabelling Network), which consists of 26 of the world’s leading eco-labeling programs. Develops standards from green cleaning products to lodging Green Seal uses life cycle assessments, evaluating products from raw materials extraction to manufacturing and use to disposal or recycling. If a product meets Green Seal standards it will be awarded the Green Seal. This organization works with the marketplace in an effort to create a “more sustainable world”.

**How Can We Make Our Buildings Green-**

There are a number of ways to make buildings green. These include:

1. Taking an intelligent approach to energy
2. Safeguarding water resources
3. Minimizing waste and maximizing reuse
4. Promoting health and wellbeing

**1. Taking an intelligent approach to energy-**

Minimizing energy to use in all stages of a building's life cycle, making new and renovated buildings easier and less expensive to run, and helping building users learn to be efficient too. Integrating renewable and low carbon technologies to supply buildings energy needs, once their design has maximized inbuilt and natural efficiencies.

**2. Safeguarding Water Resources-**

Exploring ways to improve drinking and wastewater competence and management, harvesting water for safe indoor use in innovative ways and generally minimizing water use in the buildings. Considering the impact of buildings and their surroundings on storm-water and drainage infrastructure ensuring these are not put under undue stress or prevented from doing their job.

**3. Minimizing waste and maximizing reuse-**

- Using fewer, more durable materials and generating less waste, as well as accounting for a building's end-of-life stage by designing for demolition waste recovery and reuse.
- Engaging building users in reuse and recycling.
- Promoting Health and well-being-
- Bringing fresh air inside, delivering good indoor air quality through ventilation, and avoiding materials and chemicals that create harmful or toxic emissions.
- Incorporating natural light and views to ensure building users' comfort and enjoyment of their surroundings, and reducing lighting energy needs in the process.
- Designing for ears as well as eyes. Acoustics and proper sound insulation play important roles in helping concentration, recuperation, and peaceful enjoyment of a building in educational, health, and residential buildings.

- Creating the right indoor temperature through passive design or building management and monitoring.
- Recognizing that the urban environment should preserve nature, and ensuring diverse wildlife and land quality are protected or enhanced, by remediating and building on polluted land or creating new green spaces.
- Looking for ways we can make our urban areas more productive, bringing agriculture into our cities.
- Adapting to our changing climate, ensuring resilience to events such as f flooding, earthquakes, or fires so that our buildings stand the test of time and keep people and their belongings safe.
- Designing flexible and dynamic spaces, anticipating changes in their use over time, and avoiding the need to demolish, rebuild or significantly renovate buildings to prevent them from becoming obsolete.
- Creating diverse environments that connect and enhance communities, asking what a building will add to its context in terms of positive economic and social effects, and engaging local communities in planning.
- Ensuring transport and distance to amenities are considered in the design, reducing the impact of personal transport on the environment, and encouraging environmentally friendly options such as walking or cycling.
- Exploring the potential of both ‘smart’ and information communications technologies to communicate better with the world around us. For example smart electricity grids that understand how to transport energy where and when it is needed.
- Seeking to lower environmental impacts and maximize social and economic value over a building’s whole life-cycle (from design, construction, operation, and maintenance, through to renovation and eventual demolition).
- Ensuring that embodied resources, such as the energy or water used to produce and transport the materials in the building are minimized so that buildings are truly low impact.

### 9.5.4. Advantages of Green Buildings

**Major benefits of Green Buildings-**

Environmental Benefits

- Reduced operational energy
- Reduced water requirement
- The lesser volume of wastewater generation
- Resulting in lesser water pollution
- Less material usage Longer building life
- Lower maintenance costs use less natural resources as compared to a normal building

**Economical Benefits**-

- Green buildings are generally costlier than normal buildings but only at the initial stage while the overall costs are much lesser than the normal buildings
- They consume less resources and improve the productivity of occupants
- Green buildings also entail higher real estate value.
- Incentives are also given by local government bodies in order to achieve a sustainable future
- Cost savings on utility bills for tenants or households (through energy and water efficiency)
- Lower construction costs and higher property value for building developers.

**Social Benefits**

Green building benefits go beyond economics and the environment and have been shown to bring positive social impacts too.

Many of these benefits are around the health and well-being of people who work in green offices or live in green homes.

- Green Buildings have been proven to have a positive impact on the health of residents as they provide a balanced and optimal eco-system for residents, they have a positive effect on the productivity and well-being of those who occupy the building.
- Research suggests that better indoor air quality (low concentrations of CO, and pollutants, and high ventilation rates) can lead to improvements in the performance of an employee by up to 8 percent.

**Advantages of Green Technology:**

- It does not emit anything harmful for the environment.
- It has become popular as consumers of the technology are becoming more environment conscious. This will give benefits to investors at long run in certain areas.
- It requires less cost for maintenance. This reduces operating cost and hence overall cost on the long run.
- As it uses renewable natural resources and hence we will never run out of vital resources such as water and electricity.
- It will slow down effects of global warming due to reduction in $CO_2$ emissions.

## 9.6. Goals of green technology

The goal of green nanotechnology involves developing products that advantage the environment moreover directly or indirectly. Nanomaterials or products directly can clean hazardous waste sites, desalinate water, treat pollutants or sense and monitor environmental pollutants. Indirectly, lightweight nanocomposites for automobiles and other means of transportation could save fuel and reduce materials used for production, nanotechnology enabled fuel cells and light emitting diodes (LEDs) could reduce pollution from energy generation and help conserve fossil fuels, self-cleaning nanoscale surface coatings could reduce or eliminate many cleaning chemicals used in regular maintenance routines and enhanced battery life could lead to less material use and less waste. Green Nanotechnology takes a broad systems view of nanomaterials and products, ensuring that surprising consequences are minimized and that impacts are anticipated throughout the full life-cycle.

## 9.7. Limitations of green processes and technology

- High implementing costs.
- Lack of information.
- No known alternative chemical or raw material inputs.
- No known alternative process technology.
- Uncertainty about performance impacts and lack of human resources and skills business at a competitive company decides to adhere to strict, self-imposed pollution standards.

- Since these buildings depend on the sun for energy, they need to be located in a position that will have the best sun exposure which may demand placing them opposite other neighborhood homes.
- The materials to build such buildings can be hard to find especially in urban areas where preserving the environment is not the people's first option. Shipping these materials can then cost a lot more than a standard building.
- These buildings run on heat to generate power, so they are not designed for hot areas they do not have any ventilation systems, so air conditioners will be required.
- One of the most common disadvantages of Green Building is the additional cost incurred. This is due to the increase in the quality of construction methods and materials used.
- Apart from the initial cost of green building, finding a mortgage company or bank that offers loans for a building that is not built in the traditional way may be difficult.
- The time taken to complete a green building can also be viewed as a disadvantage. Green building projects encourage the use of recycled materials and trying to source these can add to the time to complete a certain stage of the build that the contractor and client haven't allowed for in the project.

## 9.8. Disadvantages of Green Technology

1. Initial investment or implementation cost is very high.
2. People are still not familiar with the technology and hence will take time to adopt it for larger population.
3. The technology is still evolving and many of the products are at R&D stage. Hence people are unaware of performance results.
4. Lack of skilled human resources are available to install or implement the green technology based products or systems.
5. In most of the countries policies have not been finalized for the green technology based systems.

## 9.9. Summary

Green technology has two goals: producing materials and products without harming the environment or human health and producing products that provide solutions to environmental problems. It uses existing principles of green chemistry and green engineering to make materials and products without toxic ingredients at low temperatures using less energy and renewable inputs wherever possible and using lifecycle thinking in all designs and engineering stages.

## 9.10. Terminal Questions

**Q.1:** What do you understand by green technology?

**Answer:**--------------------------------------------------------------------------------------------------
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**Q.2:** Give brief on Sectors using green techechnology.

**Answer:**--------------------------------------------------------------------------------------------------
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**Q.3:** Is Green nanotechnology necessity of green technology?

**Answer:**--------------------------------------------------------------------------------------------------
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**Q.4:** What are the Environmental profits of green building?

**Answer:**--------------------------------------------------------------------------------------------------
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**Q.5:** Define Goals of green technology?

**Answer:**--------------------------------------------------------------------------------------------------
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**Q.6:** What are the limitations of green processes and technology?

**Answer:**--------------------------------------------------------------------------------------------------
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## 9.11. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.

4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.
5. Introduction to Energy and Climate , Developing a Sustainable Environment, Julie Kerr, Taylor & Francis eBooks