Renewable Sources of Energy

UNIT II

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• Energy management is the process of tracking and optimizing energy consumption to conserve usage in a building.

• Energy management is a process that not only manages the energy production from different energy harvesting resources (solar, nuclear, fossil fuel) but also concerns optimal utilization at the consumer devices.

• Energy management is the means to controlling and reducing a building's energy consumption, which enables owners and operators to :

a) Reduce costs - Energy represents 25 % of all operating costs in an office building.

b) Reduce carbon emissions in order to meet internal sustainability goals and regulatory requirements.

c) Reduce risk - The more energy you consume, the greater the risk that energy price increases or supply shortages could seriously affect your profitability. With energy management solutions, you can reduce this risk by reducing your demand for energy and by controlling it so as to make it more predictable.

• There are few steps for the process of energy management:

1. Collecting and analysing continuous data.

2. Identify optimizations in equipment schedules, set points and flow rates to improve energy efficiency.

3. Calculate return on investment. Units of energy saved can be metered and calculated just like units of energy delivered.

4. Execute energy optimization solutions.

5. Repeat step two to continue optimizing energy efficiency.

1. Energy Conservation

• Energy conservation means reducing the consumption of energy by producing or using less of it.

• Energy conservation is “the prevention of the wasteful use of energy, especially in order to ensure its continuing availability”.

• Energy conservation is achieved when growth of energy consumption is reduced, measured in physical terms.

• Energy conservation can be the result of several processes or developments, such as productivity increase or technological progress.

• Energy conservation and Energy Efficiency are separate, but related concepts.

• Energy Conservation is the deliberate practice or an attempt to save electricity, fuel oil or gas or any other combustible material, to be able to put to additional use for additional productivity without spending any additional resources or money.

New Renewable Energy Sources

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• Conventional or traditional energy sources are available in limited quantity on the one hand and on the other hand, their use creates one type of pollution or the other.

• Hence the need of energy should be fulfilled by alternate sources. These are also called renewable or non-polluting energy sources.

• As compared to polluting sources, the alternate energy sources are abundantly available in nature and they do not produce large amounts of pollution if used for various applications.

• Awareness drives monetary benefits in terms of subsidies, tax rebates or exemptions, more funding and encouragement for harnessing as well as improving the efficiency of non¬polluting sources of energy is needed to be done on war footing.

• With more and more population, there will be more and more need of industries, urbanization (transportation, cooking and household uses) will need more energy on a continuous basis.

• Faster and safer transportation will require more energy. The requirements can be met with use of solar energy, wind energy and biomass energy to a large extent.

• At suitable places, other sources like tides, waves, geothermal energy can be used in the 21st century.

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Hydrogen Energy

Hydrogen Energy

• Hydrogen fuel cells produce electricity by combining hydrogen and oxygen atoms. The hydrogen reacts with oxygen across an electrochemical cell similar to that of a battery to produce electricity, water and small amounts of heat.

• Hydrogen is an energy carrier that can be used to store, move and deliver energy produced from other sources.

• Hydrogen is a clean fuel that, when consumed in a fuel cell, produces only water.

• Hydrogen can be produced from a variety of domestic resources, such as natural gas, nuclear power, biomass and renewable power like solar and wind.

• These qualities make it an attractive fuel option for transportation and electricity generation applications. It can be used in cars, in houses, for portable power and in many more applications.

1. Advantages of Hydrogen Energy

1. Hydrogen is renewable

• Hydrogen is a renewable energy source which means we cannot run out of it, at least not on a human timescale. It's a rich source of energy which is all around us.

2. Hydrogen is a clean energy source

• When we burn hydrogen no harmful by-products are released into the atmosphere. In fact, once hydrogen has been used as an energy source, it can be converted to drinking water for astronauts.

3. Hydrogen energy is not toxic

• Hydrogen does not cause damage to human health unlike nuclear energy or natural gas.

4. Hydrogen energy is highly efficient

• Hydrogen is incredibly dense in energy and is able to provide a lot of power. It is 3 times more powerful than most fossil based fuel sources so less hydrogen is required to perform the same tasks. This is why hydrogen is used in space exploration to fuel spaceships, aeroplanes, boats, cars and fuel cells.

2. Disadvantages of Hydrogen Energy

1. Hydrogen is volatile

• Because of its high energy content, hydrogen gas is a highly flammable and volatile substance which makes it a risky fuel to work with.

2. Hydrogen energy is expensive to produce

• Both steam-methane reforming and electrolysis are expensive processes which prevents a lot of countries from committing to mass production. Research and trials are in process to try and discover a cheap and sustainable way to produce enough hydrogen without contributing more carbon into the atmosphere.

3. Hydrogen energy is difficult to store

• Hydrogen is a much lighter gas than gasoline which makes it difficult to store and transport. To be able to store it we need to compress it into a liquid and store it at a low temperature. The high amounts of pressure needed to store hydrogen makes it a difficult fuel to transport in large quantities.

4. Hydrogen can be dangerous

• Hydrogen is incredibly flammable which makes it a dangerous fuel if not handled correctly. There is also no smell to hydrogen so sensors are required to detect leaks.

Solar Energy

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• The solar radiations are intercepted by suitable 'collector system' (flat plate or parabolic collectors) and heat energy available can be used for heating air, water or liquids as required.

• Density of insolation varies from place to place depending on altitude and metrological conditions.

• A solar thermal device consists of collector, distribution (circulation) system, storage and insulation.

• Solar energy is trapped by collector and by simple heat transfer techniques, heat energy is transferred through water, air or other suitable fluid.

• For more temperature and efficiency, number of collectors and parabolic collectors are designed.

Harvesting / Harnessing Solar Energy

• The techniques for collecting, converting and using solar energy is called as harvesting or harnessing. Some important solar harvesting devices are :

1. Solar cells / photovoltaic cells / PV cells
2. Solar heat collectors
3. Solar water heaters
4. Solar cooker
5. Solar water pumps

Solar cells or PV cells

• Solar cells are actually p-n junction diode working on photovoltaic technology i.e. there is direct conversion of solar radiation into Direct Current (DC) electricity.

• Semiconducting materials are most effective in this process of conversion.

• The light energy is converted into equivalent DC energy by solar cells (PV cells). This energy is then stored in some device (battery); so that it can be used whenever needed.

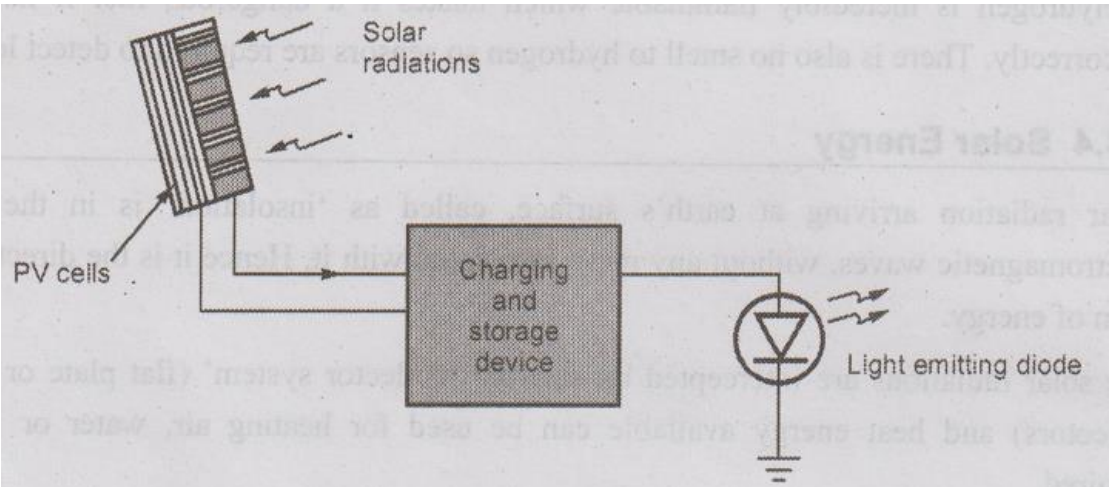

Fig. 3.4.1 : Solar cells

Uses

1. PV cells are commonly used in calculators and watches.

2. PV cells provide power to satellites.

3. Small electric appliances like - solar lamp, radio, street lighting.

4. Industrial applications - water pumping, weather stations.

Solar heat collectors

• A solar heat collector is used for heating modern houses in eastern countries. A solar home or building is designed to collect the Sun's heat through South facing glass windows.

• In solar-heated buildings, sunspaces are built as large heat absorbers. The floors are made of tiles or bricks that absorb heat throughout the day, they release the heat at night when weather is cold.

Uses

1. Solar heat collector used in cold countries for making domestic or commercial places hot.

1. Use of Solar Energy

• Solar energy can be used for following purposes :

1) Air or water heating for industrial processes, use of solar pumps for water pumping.

2) Distillation and desalination of water (solar still).

3) Hot water for cooking, cleaning and similar uses, (solar water heater).

4) Electricity generation by using photovoltaic cells.

5) Solar drying for food and vegetable products for cottage and small scale industries.

6) Other uses like solar cookers, lamps, lanterns, battery charger, etc. for household purpose.

7) Solar cars/vehicles have been designed.

2. Advantages of Solar Energy

1. Solar energy is freely available.

2. It does not produce ash, fumes and noise pollution hence it is clean, noiseless and environment friendly.

3. It saves money in long run.

4. It is renewable form of energy

5. Non polluting. No wastes created by its use.

6. Has lot of domestic applications. Hence advantageous for huge Indian population.

3. Disadvantages of Solar Energy

1. Initial cost is very large.
2. Energy should be stored in batteries.
3. Large space is needed for installation.
4. Energy generated is dependent on solar intensity
5. High temperatures cannot be achieved (> 40 °C). Efficiency of collector goes down with increase in temperature.
6. Clouds affect the amount and quality (efficiency). Hence may not be available when required.

Ocean Thermal Energy Conversion (OTEC)

The warm water acts as a heat source whilst the cold water at about 1000 m acts as a heat sink. This creates a thermal power cycle which can be used to generate electricity.

Ocean Thermal Energy Conversion (OTEC)

• Ocean thermal energy conversion (OTEC) is a source of renewable energy.

• Ocean Thermal Energy Conversion (OTEC) makes use of the naturally occurring thermal gradient of the oceans.

• The warm water acts as a heat source whilst the cold water at about 1000 m acts as a heat sink. This creates a thermal power cycle which can be used to generate electricity.

• The minimum difference required between the heat source and the heat sink is 20 °C.

• The efficiency of OTEC is very low (< 4 %) but the enormous magnitude of this potential energy resource merits its investigation.

• In addition, OTEC could provide a continuous energy supply, unlike many other renewable technologies.

1. Advantages of OTEC System

1. Power from OTEC is continuous, renewable and pollution free.

2. Unlike other forms of solar energy, output of OTEC shows very little daily or seasonal variation.

3. Drawing of warm and cold sea water and returning of the sea water, close to the thermocline, could be accomplished with minimum environment impact.

4. Electric power generated by OTEC could be used to produce hydrogen.

5. Tropical and sub-tropical island sites could be made free from pollution caused by conventional fuels for electricity generation.

6. OTEC system might help in enrichment of fishing grounds due to the nutrients from the unproductive deep waters to the warmer surface waters.

7. A floating OTEC plant can generate power even at mid sea and can be used to provide power for off shore mining and processing of manganese nodules.

2. Limitations of OTEC System

1. Capital investment is very high.

2. Due to small temperature difference in between the surface water and deep water, conversion efficiency is very low about 3-4 %.

3. Low efficiency of these plants coupled with high capital cost and maintenance cost makes them uneconomical for small plants.

Tidal Energy

Tides are caused by the interaction of the gravitational effects of the sun and moon and the Earth's rotation.

Tidal Energy

• Tides are caused by. the interaction of the gravitational effects of the sun and moon and the Earth's rotation. The relative motions of these bodies produce a range of different tide cycles.

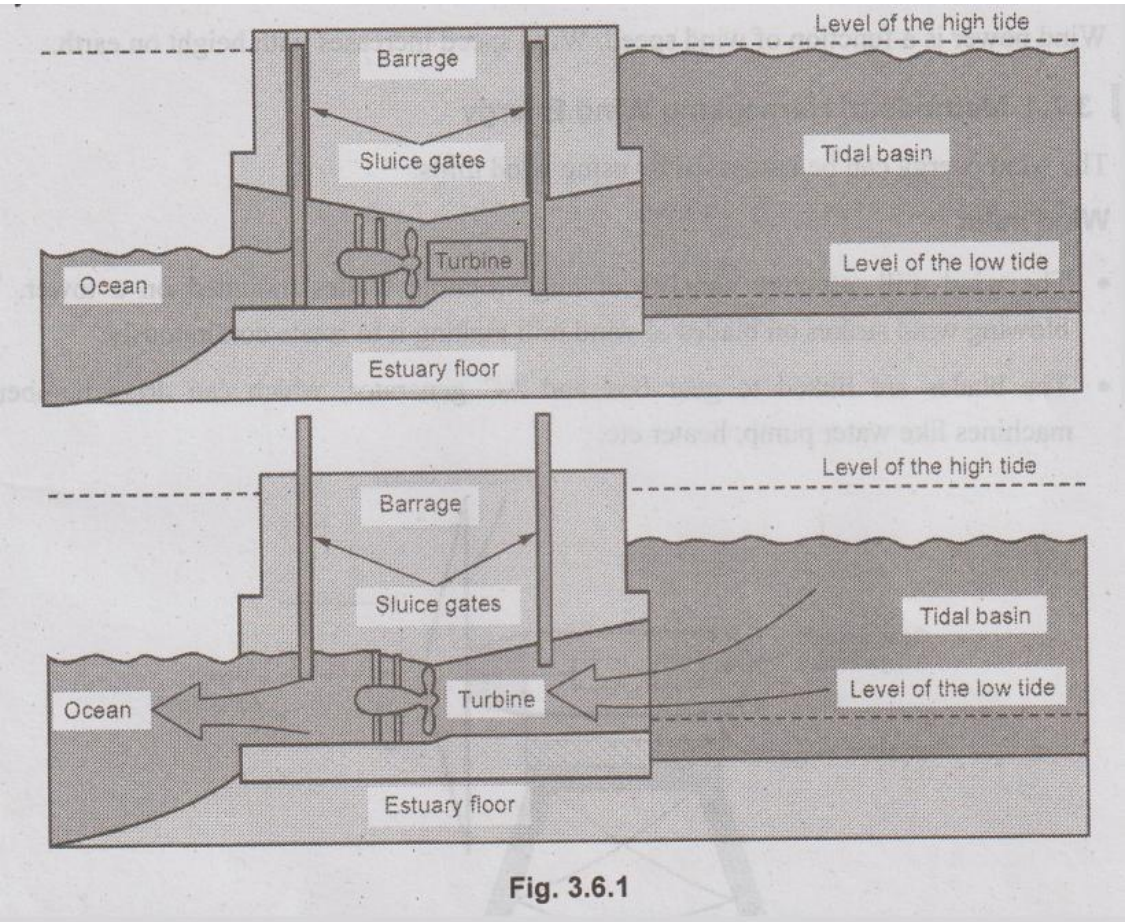

Fig. 3.6.1

• However, in common with all tidal projects, very large capital investment is required. The environmental effects of such projects are considerable and must be individually assessed. They include negative effects on ports, navigation, wildlife and recreation.

Advantages of tidal energy :

1. It is a renewal form of energy.

2. It does not required fuel.

3. It does not produce ash and fume hence clean.

Disadvantages of tidal energy:

1. It requires huge investment for construction.

2. Possibility of damaging equipments frequently.

Wind Energy

Wind energy is kinetic energy of moving air. The uneven absorption of solar radiation by earth's surface causes differences of temperature, density and pressure which produce air movements.

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• Wind energy is kinetic energy of moving air. The uneven absorption of solar radiation by earth's surface causes differences of temperature, density and pressure which produce air movements.

• Wind power is a function of wind, speed. Wind speed increases with height on earth.

1. Methods of Harnessing Wind Energy

• The wind energy can be harnessed by using wind mills.

1. Wind mills

• The wind mill structure consists of huge rotating blades mounted on a tower. The blowing wind strikes on blades of wind mill making it to rotate continuously.

• The blades are linked to gear box and AC generator, which can drive number of machines like water pump, heater etc.

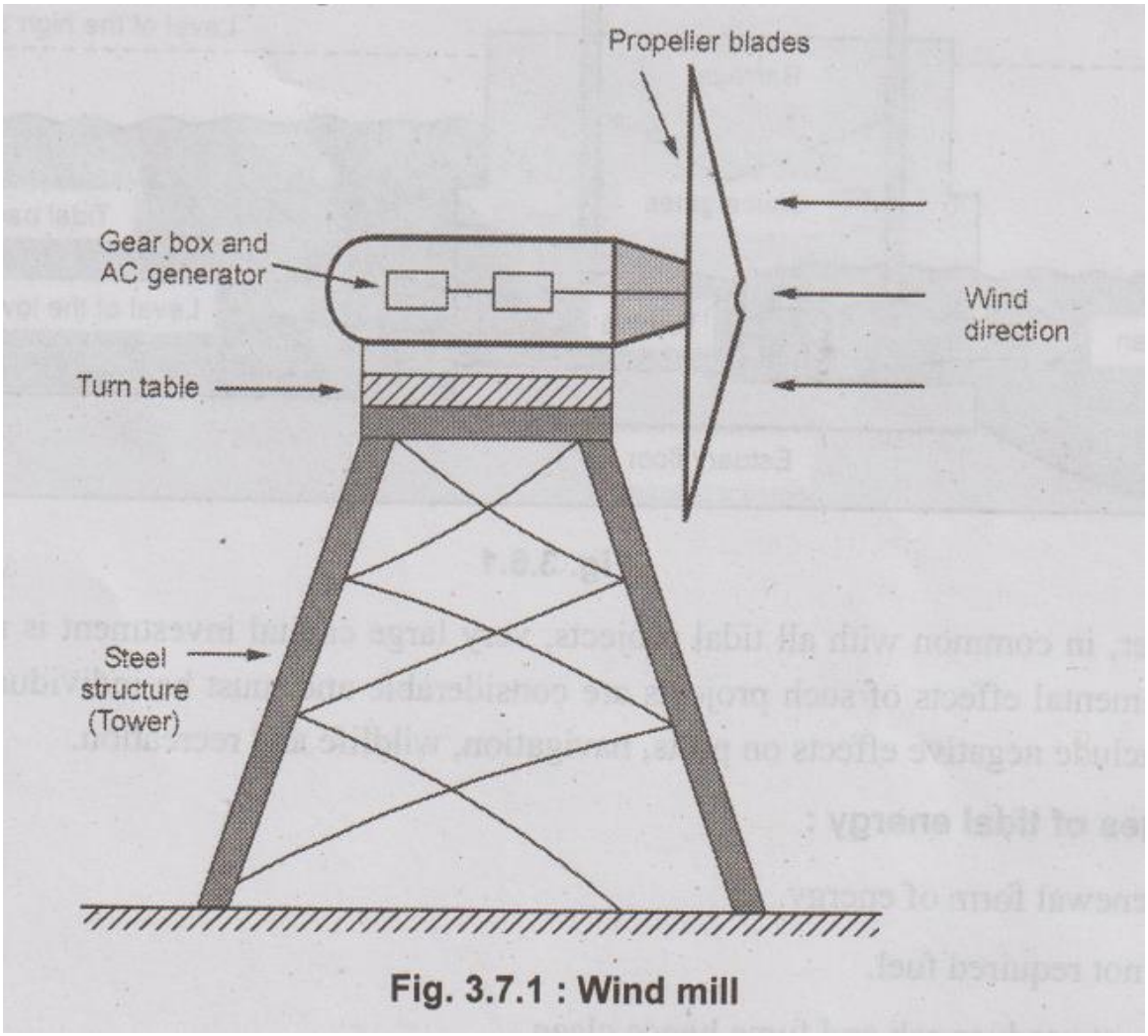


Fig. 3.7.1 : Wind mill

2. Advantages of Wind Energy

1. The entire process of wind power is non-polluting.

2. Wind energy is one of the sustainable source of energy.

3. Wind energy is renewable.

4. Wind energy is available at free of cost.

5. Suitable for remote locations.

3. Disadvantages of Wind Energy

1. Wind is an intermittent source, and the intermittence depends on geographic distribution of wind. Therefore, it can not be used as sole resource of electricity and requires backup or storage system.

2. Storage technology is not fully developed.

3. Damage of local environment by deforestation and hence loss of biodiversity.

4. Birds may get killed.

5. Noise pollution in local area may affect TV reception.

4. Comparison of Solar and Wind Energy

Sr. No.	Solar energy	Wind energy
1.	Can be extensively used anywhere.	Can not be used extensively (depending on the geographical and meterological factor) anywhere.
2.	Energy requirements can be met with satisfactorily with small variations.	As wind speed and direction changes, energy production cannot meet the requirements.
3.	Energy from sun (radiation) can be used for uses like solar heating, solar drying, solar electric generation solar distillation, solar desalination.	Energy from wind cannot be used for such variety of uses.
4.	Hence there are large number of applications from houses to industries.	Applications are limited.
5.	Only depends on clouds (season) and time of day i.e. no solar radiations are available at night,	Does not depend much on the clouds, season, time of day etc. if wind continues to flow.
6.	Installations does not require large open space (top of roof is sufficient).	Huge open space is required for installing wind mills.

ENERGY CYCLES

The energy cycle describes the interactions between energy sources within the Earth's environment. These interactions are very complex, and even small changes in them can lead to significant changes in long-term climate behaviour.

Role of energy in the ecosystem is very important because every organism always has need and take energy in different way from other organism. This process has been done in various energy cycles in the ecosystem. So, in the nature many cycles of ecosystem has several interrelated energy mechanism that affect human and all other organism life. Therefore many energy cycles always functioning in the ecosystem are as:

1- Energy cycle

2- The Water cycle

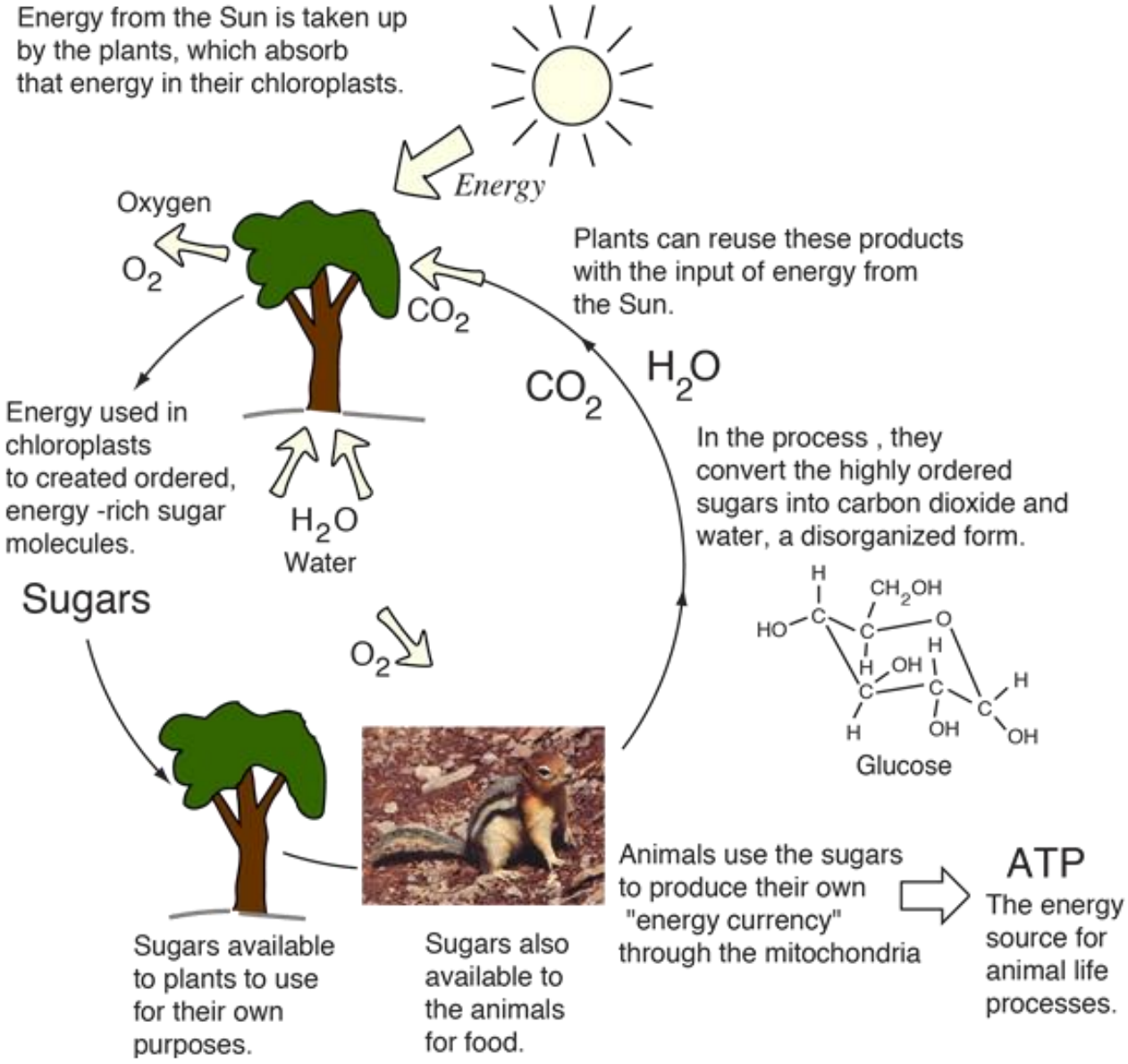
3- The carbon cycle

4- The Oxygen cycle

5- The Nitrogen cycle

The Energy Cycle:

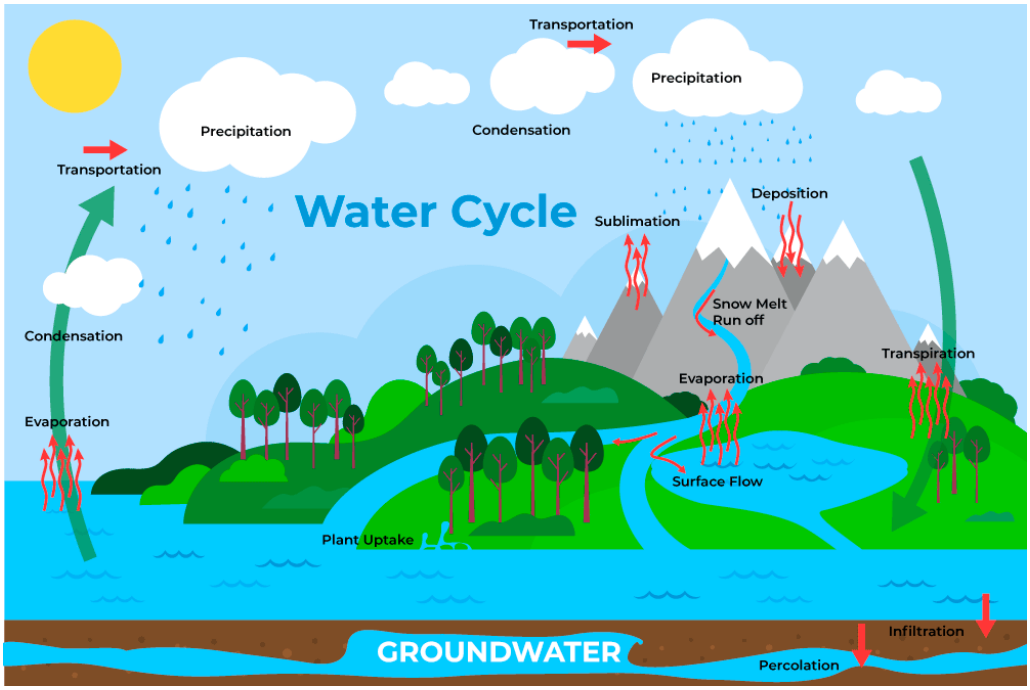
The energy cycle is based on the flow of energy through the ecosystem. The energy from sunlight is converted by plant them into growing new plants material which include the flowers, fruits, branches, trunks and roots of the plants. Since plants can grow by converting the sun energy directly into their tissues. They are known as producer in the ecosystem.



So the energy in the ecosystem can be depicted in the form of a food pyramid or energy pyramid. The food pyramid has large based plants called producers. The pyramid has a narrower middle section that depicts the number and biomass of herbivores animals, which called first order consumers. Man is one of the animals at the apex of the pyramid.

The Water Cycle:

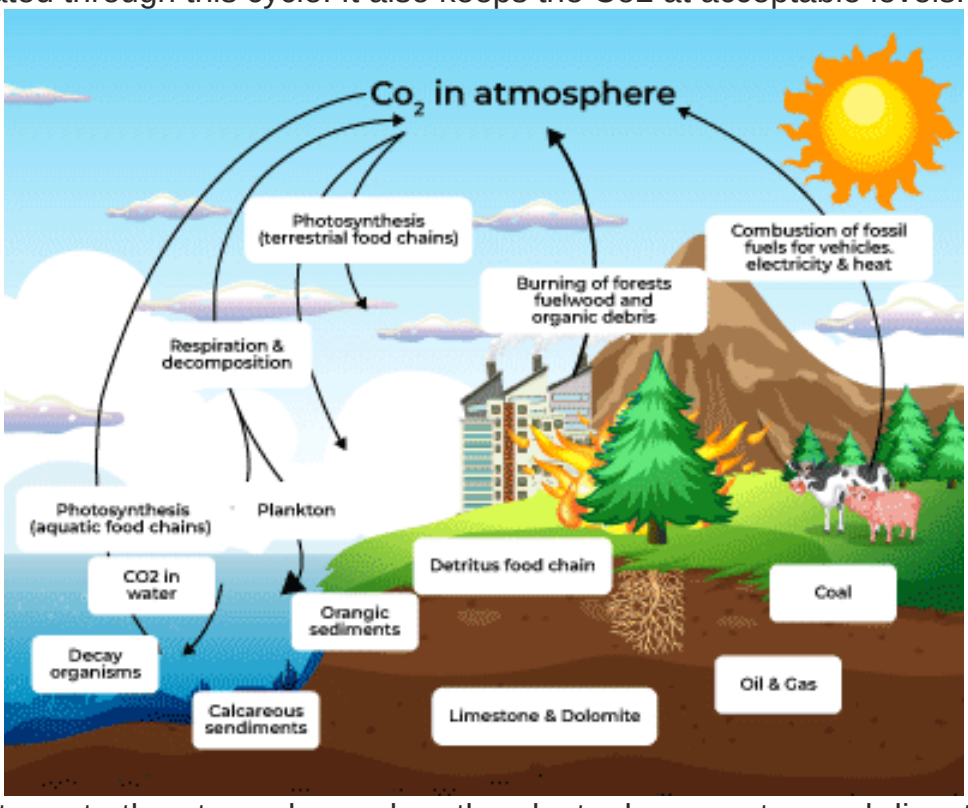
The water is the most important component of ecosystem. All living organism used water to grow and survive in an ecosystem. The water cycle through the atmosphere, soil, rivers, lakes and oceans. When it rains the water runs along the ground and flows into rive r or falls directly in to the sea.



A same parts of the rain water that falls on land percolates into the ground. Water is drawn up from the ground by plats along with the nutrients from the soil. The water is then transferred from the leaves as water vapour and return to the atmosphere. But while this is an endless cycle on which life depends, human activities are making.

The Carbon Cycle:

It is very important to all sea system and ultimately life on earth. On the earth living tissue contains carbon because they contain many types of proteins, fats and carbohydrates. The carbon in these (living or dead) tissues is recycled in the various process. So the carbon cycle, in biology circulation of carbon in various forms through nature. Carbon hold all organic compounds and many of which are essential for life on the earth. The source of the carbon found in living matter is carbon dioxide in the air or dissolved in water. All of mankind depends on the oxygen generated through this cycle. It also keeps the Co2 at acceptable levels.

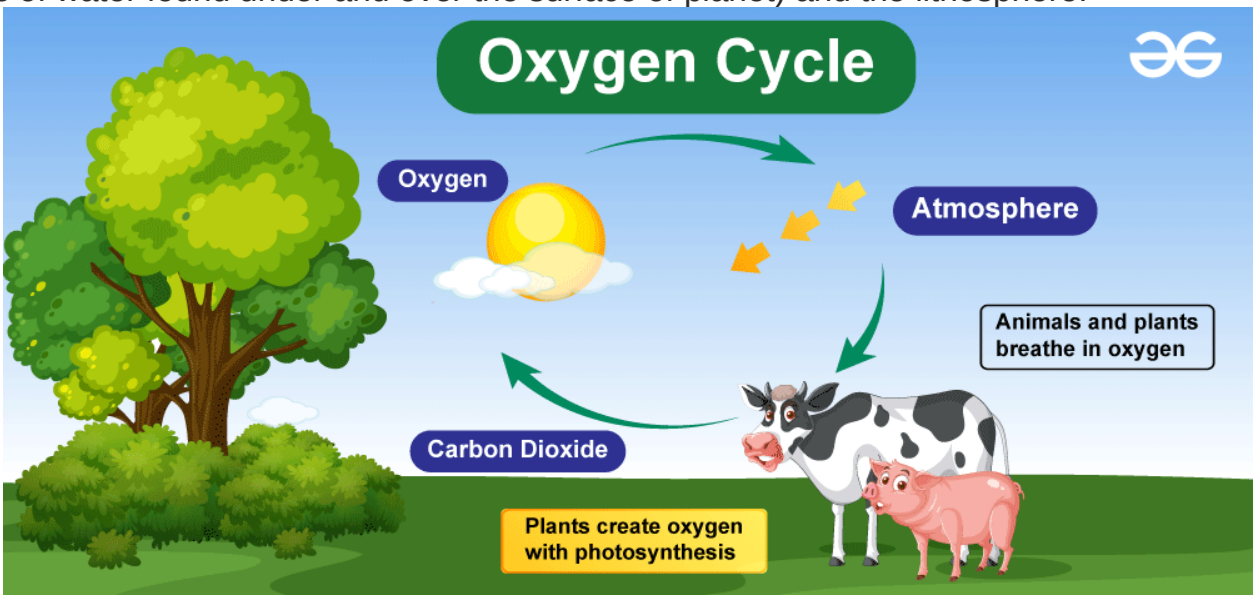


The carbon returns to the atmosphere when the plants decay, eaten and digested by animals or burn in fires, because plant and animals are an integral part of this cycle, because both plants

and animals release carbon dioxide during respiration. They also return fixed carbon to the soil. So as ecosystem change under a changing climate, the carbon cycle will also be change.

The Oxygen Cycle:

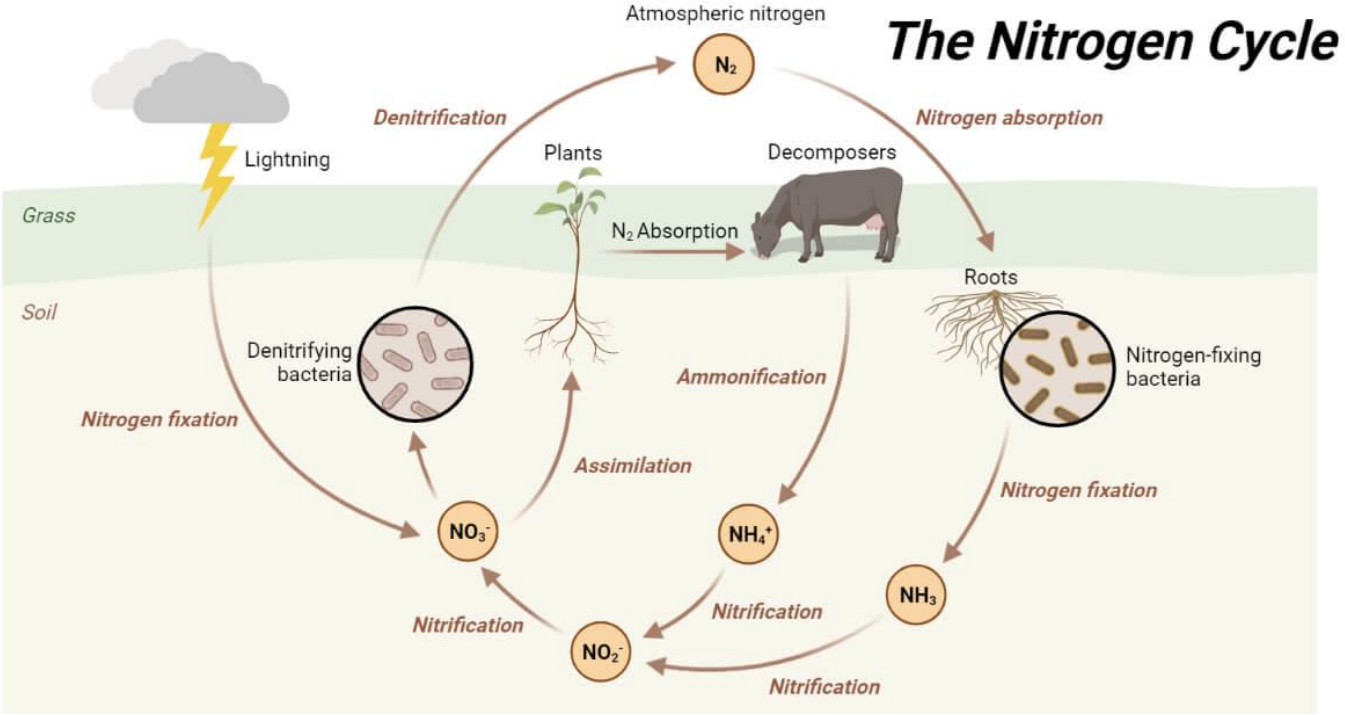
Oxygen is absorbed by plants and animals from the air during respiration. Basically the oxygen cycle is the biogeochemical cycle of oxygen within its four main reservoirs. The atmosphere (air), the total content of biological matter within the biosphere, the hydrosphere (the combined mass of water found under and over the surface of planet) and the lithosphere.



The main driving factor of the oxygen cycle is photosynthesis, which is responsible for the modern earth atmosphere. So the plant life plays an important role in our life, which we frequently do not appreciate. This is an important reason to participate in forestation programs.

The Nitrogen Cycle:

The nitrogen fixing bacteria and fungi in the soil give this important element to plants which absorb it as nitrates. These nitrates are part of the plants metabolism, which help in forming new plant proteins. This is used by the animals that feed on the plants. The nitrogen in them transferred to the carnivores when they feed on the herbivores.



So, the nitrogen cycle describes how nitrogen moves between plants, animals, bacteria, the atmosphere and soil in the ground. So nitrogen is an important element for all lives on earth. This cycle is biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among atmosphere, terrestrial and marine eco system.

Carbon Emission

Carbon dioxide (CO_2) makes up the vast majority of greenhouse gas emissions from the sector, but smaller amounts of methane (CH4) and nitrous oxide (N2O) are also emitted. These gases are released during the combustion of fossil fuels, such as coal, oil, and natural gas, to produce electricity.

Fossil fuels – coal, oil and gas – are by far the largest contributor to global climate change, accounting for over 75 per cent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions.

Carbon Sequestration

Carbon sequestration, the long-term storage of carbon in plants, soils, geologic formations, and the ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas. In response to growing concerns about climate change resulting from increased carbon dioxide concentrations in the atmosphere, considerable interest has been drawn to the possibility of increasing the rate of carbon sequestration through changes in land use and forestry and also through geoengineering techniques such as carbon capture and storage.

Carbon sources and carbon sinks

Anthropogenic activities such as the burning of fossil fuels have released carbon from its long-term geologic storage as coal, petroleum, and natural gas and have delivered it to the atmosphere as carbon dioxide gas. Carbon dioxide is also released naturally, through the decomposition of plants and animals. The amount of carbon dioxide in the atmosphere has increased since the beginning of the industrial age, and this increase has been caused mainly by the burning of fossil fuels. Carbon dioxide is a very effective greenhouse gas—that is, a gas that absorbs infrared radiation emitted from Earth's surface. As carbon dioxide concentrations rise in the atmosphere, more infrared radiation is retained, and the average temperature of Earth's lower atmosphere rises. This process is referred to as global warming.

Reservoirs that retain carbon and keep it from entering Earth's atmosphere are known as carbon sinks. For example, deforestation is a source of carbon emission into the atmosphere, but forest regrowth is a form of carbon sequestration, with the forests themselves serving as carbon sinks. Carbon is transferred naturally from the atmosphere to terrestrial carbon sinks through photosynthesis; it may be stored in aboveground biomass as well as in soils. Beyond the natural growth of plants, other terrestrial processes that sequester carbon include growth of replacement vegetation on cleared land, land-management practices that absorb carbon (*see below* Carbon sequestration and climate change mitigation), and increased growth due to elevated atmospheric carbon dioxide levels and enhanced nitrogen deposition. It is important to note that carbon sequestered in soils and aboveground vegetation could be released again to the atmosphere through land-use or climatic changes. For example, combustion (which is caused by fires) or decomposition (which results from microbe activity) can cause the release of carbon stored in forests to the atmosphere. Both processes join oxygen in the air with carbon stored in plant tissues to produce carbon dioxide gas.

If the terrestrial sink becomes a significant carbon source through increased combustion and decomposition, it has the potential to add large amounts of carbon to the atmosphere and

oceans. Globally, the total amount of carbon in vegetation, soil, and detritus is roughly 2,200 giga tons (1 giga ton = 1 billion tons), and it is estimated that the amount of carbon sequestered annually by terrestrial ecosystems is approximately 2.6 giga tons. The oceans themselves also accumulate carbon, and the amount found just under the surface is roughly 920 giga tons. The amount of carbon stored in the oceanic sink exceeds the amount in the atmosphere (about 760 giga tons). Of the carbon emitted to the atmosphere by human activities, only 45 percent remains in the atmosphere; about 30 percent is taken up by the oceans, and the remainder is incorporated into terrestrial ecosystems.

Carbon sequestration and climate change mitigation

The Kyoto Protocol under the United Nations Framework Convention on Climate Change allows countries to receive credits for their carbon-sequestration activities in the area of land use, land-use change, and forestry as part of their obligations under the protocol. Such activities could include afforestation (conversion of non-forested land to forest), reforestation (conversion of previously forested land to forest), improved forestry or agricultural practices, and revegetation. According to the Intergovernmental Panel on Climate Change (IPCC), improved agricultural practices and forest-related mitigation activities can make a significant contribution to the removal of carbon dioxide from the atmosphere at relatively low cost. These activities could include improved crop and grazing land management—for instance, more efficient fertilizer use to prevent the leaching of unused nitrates, tillage practices that minimize soil erosion, the restoration of organic soils, and the restoration of degraded lands. In addition, the preservation of existing forests, especially the rainforests of the Amazon and elsewhere, is important for the continued sequestration of carbon in those key terrestrial sinks.

Carbon capture and storage

Some policy makers, engineers, and scientists seeking to mitigate global warming have proposed new technologies of carbon sequestration. These technologies include a geoengineering proposal called carbon capture and storage (CCS). In CCS processes, carbon dioxide is first separated from other gases contained in industrial emissions. It is then compressed and transported to a location that is isolated from the atmosphere for long-term storage. Suitable storage locations might include geologic formations such as deep saline formations (sedimentary rocks whose pore spaces are saturated with water containing high concentrations of dissolved salts), depleted oil and gas reservoirs, or the deep ocean. Although CCS typically refers to the capture of carbon dioxide directly at the source of emission before it can be released into the atmosphere, it may also include techniques such as the use of scrubbing towers and “artificial trees” to remove carbon dioxide from the surrounding air.

GREEN ENGINEERING

Green engineering is the design, commercialization, and use of processes and products in a way that reduces pollution, promotes sustainability, and minimizes risk to human health and the environment without sacrificing economic viability and efficiency.

Green engineering embraces the concept that decisions to protect human health and the environment can have the greatest impact and cost-effectiveness when applied early, in the design and development phase of a process or product.

It is the design, commercialization and use of materials, products, devices processes and systems, that are feasible and economical with the objective of minimizing overall environmental impact throughout the entire life cycle of a product or process, from initial extraction of raw materials to ultimate disposal of materials.

Four approaches of Green Engineering:

1. Waste reduction

2. Materials management

3. Pollution prevention

4. Product enhancement

Principles of Green Engineering

- Use of non-hazardous resources
- Prevention of waste
- Easy separation
- Durability of products
- Design for need
- Maximum efficiency
- Renewable rather than depleting
- Holistic approach
- Think beyond

Green engineering processes and products:

- Holistically use systems analysis and integrate environmental impact assessment tools.
- Conserve and improve natural ecosystems while protecting human health and well-being.
- Use life-cycle thinking in all engineering activities.
- Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
- Minimize depletion of natural resources.
- Strive to prevent waste.

Additionally, green engineering:

- Develops and applies engineering solutions while being cognizant of local geography, aspirations, and cultures.
- Creates engineering solutions beyond current or dominant technologies; improves, innovates, and invents (technologies) to achieve sustainability.
- Actively engages communities and stakeholders in the development of engineering solutions.

Sustainable Urbanization:

Sustainability has many definitions but it is understood as maintaining the demands of the current population without compromising on the demands of future populations. Sustainable living is meeting our needs now in a way that people in the future can also meet their needs.

Sustainable urbanism is both the study of cities and the practices to build them, that focuses on promoting their long-term viability by reducing consumption, waste and harmful impacts on people and place while enhancing the overall well-being of both people and place.

Sustainable urban systems provide a high quality of life – with economic, social, and environmental benefits distributed equitably across the community – in the face of natural, climate, technological, and societal disruptions.

Problems of urbanization

1. over population
2. Adequate housing
3. Supply of food and other commodities
4. Water availability and decreasing quality
5. Energy demand
6. Pollution
7. Solid waste
8. Sanitation and drainage facility
9. Altered land use

Objectives of Sustainable urban projects

Sustainable urban development project:

1. The conservation of identity, strengthening of neighbourhood and encouragement of its cultural diversity and distinctiveness;

2. The expansion of public transport its interconnection with existing and new developments;

3. The wise use of resources, minimising additional land take up, and the encouragement of moderate degrees of urban density;

4. Safeguarding and interconnecting green spaces with networks working towards quality standards and the conservation of public spaces;

5. The assurance of social harmony and advancement of social and functional interaction;

6 .Safeguarding existing jobs and creating new and innovative ones;

7. Advancing a culture of discourse;

8. Creating long term partnerships between the community, and the public and private sectors;

9. Participation in lifelong learning processes, seeing urban life in its wider context.

Benefits of sustainable urban development

Environmental Benefits

1. Improved air quality: Walking, biking, and public transit can cut transportation emissions, which account for more than 30 percent of the PM2.5 pollution.

2. Smaller carbon footprint: Better urban design can reduce carbon pollution from the transportation sector, which accounts for nearly a quarter of the planet’s energy related greenhouse gas emissions.

3. Decreased car dependence: Bike-sharing programs and dedicated lanes provide alternatives to private vehicles.

Economic Benefits

1. Lower cost for residents: Households can save money through more energy efficient travel due to mode shifting, easier access to goods in mixed-use developments, and lower parking costs.

2. Reduced congestion costs: EmployingThe8Principlescan deliver mobility with density and reduce the economic waste associated with traffic.

3. Higher property values: Studies from around the globe show that walkability and accessibility to transit increase real estate values.

4. Improved productivity: Density boosts productivity and innovation through network effects; by contrast, congestion and pollution harm economic activity and human health.

5. Higher government revenues: By choosing smart development strategies, governments can cut capital, labour, and maintenance costs.

Social Benefits

1. Improved public health: Mixed-use, transit-oriented development increases physical activity, whereas failure to mix land-uses and increased car ownership are associated with higher risks of obesity and colon cancer. Sustainably designed communities also offer safer streets and reduce traffic related injuries.

2. Greater human mobility: Greater mobility saves time wasted in traffic jams and expands economic and life style choices for urban dwellers.

3. Increased equality of access: In a car-centric frame work, low-income residents are often left out of the planning calculus. By building better public transit, sidewalks, and biking paths, those who cannot afford to drive gain greater access to the city.

SUSTAINABLE CITES

Sustainable city is a city designed with consideration for social, economic, environmental impact, and resilient habitat for existing populations, without compromising the ability of future generations to experience the same. The UN Sustainable Development Goal 11 defines sustainable cities as those that are dedicated to achieving green sustainability, social sustainability and economic sustainability.

Most cities today are struggling with environmental degradation, traffic congestion, in adequate urban infrastructure, in addition to a lack of basic services, such as water supply, sanitation and waste management. A sustainable city should promote economic growth and meet the basic needs of its inhabitants, while creating sustainable living conditions for all. Ideally, a sustainable city is one that creates an permanent way of life across the four domains of ecology, economics, politics and culture.

Some of the major problems of Cities in India are

1. Urban Sprawl

2. Overcrowding

3. Housing

4. Unemployment

5. Slums and Squatter Settlements

6. Transport

7. Water

8. Sewerage Problems

9. Waste Disposal

10. Urban Crimes

11. Problem of Urban Pollution

Technological Changes

Industrial Processes: They are procedures to aid in the manufacturing of an item or items, usually carried out on a very large scale involving chemical, physical, electrical or mechanical steps.

Material Selection

- Identification of the design requirements
- Identification of the criteria for material selection
- Evaluation of candidate materials
- Selection of materials

Pollution Prevention

Reduction or prevention of pollution at source is fundamentally different and more desirable than recycling, treatment and disposal.

Reduction or prevention of pollution at source can be done through cost effective changed in production, operation

Six Characteristics and Key Features of a Sustainable City

Smart cities are creating sustainable places with clean technology, parks and pathways, and urban sustainability principles. See the list of key eco city characteristics to learn how to achieve sustainable cities and communities. Cities can do a number of things to support sustainable practices:

1. Make it easy to get around without a car

2. Add Electric Vehicle charging stations

3. Provide access to public resources and green spaces

4. Improve water conservation and wastewater management

5. Support urban farming

6. Implement green architecture

Applications of Hydrogen Energy:

Hydrogen has many actual and potential uses

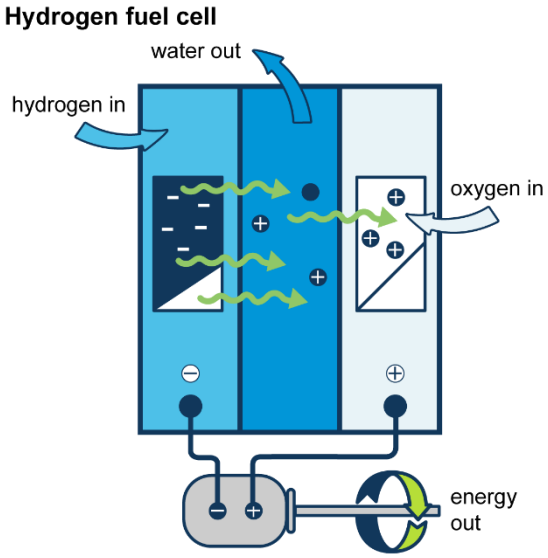
Hydrogen is currently used in industrial processes, as rocket fuel, and in fuel cells for electricity generation and powering vehicles. Operators of several natural gas-fired power plants are exploring the use of hydrogen to supplement or replace natural gas. Hydrogen has the potential for effectively storing energy for electric power generation.

Hydrogen is used in industrial processes

Nearly all of the hydrogen consumed in the United States is used by industry for refining petroleum, treating metals, producing fertilizer and other chemicals, and processing foods. U.S. petroleum refineries use hydrogen to lower the sulfur content of fuels. Biofuel producers also use hydrogen to produce hydro treated vegetable oil (HVO) for use as renewable diesel.

Hydrogen fuel cells produce electricity

Hydrogen fuel cells produce electricity by combining hydrogen and oxygen atoms. The hydrogen reacts with oxygen across an electrochemical cell— similar to a battery—to produce electricity, water, and small amounts of heat.



Hydrogen fuel cells are currently used to power the electrical systems on spacecraft and to supply electricity on earth. Small fuel cells have been developed to power electronic devices, such as laptop computers and cell phones. Several vehicle manufacturers have developed fuel cells to power vehicles. Fuel cells can potentially provide electricity for emergency power in buildings and for remote locations that are not connected to electric power grids.

Fuel cell power plants

As of the end of December 2022, the United States had about 205 operating fuel cell electric power generators at 147 facilities with about 350 megawatts (MW) of total nameplate electric generation capacity. The nameplate capacities range from the largest single-fuel cell, with about 17 MW capacity—the Bridgeport Fuel Cell, LLC in Connecticut—to 10 fuel cells each with 0.1 MW capacity at the California Institute of Technology. The majority of all operating fuel cells use pipeline natural gas as the hydrogen source, but one uses landfill gas and four use biogas from wastewater treatment.

Fuel cells for vehicles

Hydrogen is considered an alternative vehicle fuel under the Energy Policy Act of 1992. The interest in hydrogen as an alternative transportation fuel stems primarily from its potential to

power fuel cells in zero-emission vehicles (vehicles with no emissions of air pollutants). A fuel cell may be two to three times more efficient than an internal combustion engine running on gasoline. Several vehicle manufacturers have hydrogen fuel cell-vehicles available in California and Hawaii. A few test vehicles are available to organizations with access to hydrogen-fueling stations.

The high cost of fuel cells and the limited availability of hydrogen fueling stations have limited the number of hydrogen-fueled vehicles in use today. Production of hydrogen-fueled vehicles is limited because people won't buy those vehicles if hydrogen refueling stations are not easily accessible, and companies won't build refueling stations if they don't have customers with hydrogen-fueled vehicles. The United States has about 56 hydrogen-vehicle-fueling stations, all of which are in California. The State of California's Advanced Clean Cars Program includes assistance for establishing publicly accessible hydrogen vehicle fueling-stations throughout California to promote a consumer market for zero-emission fuel cell vehicles.

Hydrogen can be burned for electricity generation and heating

Hydrogen combustion for electric power generation and for space heating are potential uses of pure hydrogen or hydrogen-rich blends with natural gas. However, use of hydrogen and hydrogen-blends in existing natural gas distribution infrastructure and combustion equipment poses a number of challenges related to materials compatibility and combustion characteristics. Progress has been made with modifying natural gas burners in commercially available combustion turbines to accommodate high-hydrogen blends (up to 100% hydrogen), but continued research, development, and demonstration (RD&D) is needed before hydrogen will qualify for utility-scale power generation. Several power plants in the United States have announced plans to operate on a natural gas-hydrogen fuel mixture in combustion-gas turbines. One example is the Long Ridge Energy Generation Project in Ohio. RD&D is also needed to assess the compatibility of using hydrogen and hydrogen–natural gas blends in heating appliances.

Hydrogen can be used for energy storage

Hydrogen storage is an important technology to enable hydrogen use across the U.S. economy. Hydrogen may be stored as a:

- *Gas*—Hydrogen can be stored as a gas in large volumes in natural geological formations—salt caverns, lined hard rock caverns, depleted oil and natural gas fields, and aquifers. Gaseous hydrogen may also be stored in relatively smaller volumes in pressurized, stationary or portable tanks, and in dedicated hydrogen gas pipeline infrastructure. Gaseous storage is currently the most common and the most likely option for expanding hydrogen storage for most uses of hydrogen as an energy source.

- *Liquid*—Hydrogen can be liquefied by cooling it to below −423°F (−253°C). The liquefied hydrogen can be stored in super-cooled (*cryogenic*) tanks for transportation applications in fuel cell vehicles or directly as fuel in truck, rail, marine, and rocket engines—NASA has the two largest liquid hydrogen storage tanks in the world. Hydrogen liquefaction and cyrogenic liquid storage is an energy intensive and expensive process.

OCEAN ENERGY RESOURCES

Oceans water movement creates a vast store of kinetic energy (energy in motion) in the various forms of renewable energy viz wave energy, tidal energy, ocean current energy, salinity gradient energy and ocean thermal gradient energy which can be harnessed to generate electricity.

Types of Ocean Energy

- **Tidal Energy-** Like conventional hydroelectric dams, power plants are built on river estuaries and hold back huge amounts of tidal water twice a day which generates electricity when released. India is expected to have 9,000 MW of tidal energy potential.
- **Wave Energy-** This is generated by the movement of a device either floating on the surface of the ocean or moored to the ocean floor.
- **Current Energy-** It is very similar to the wind above the oceans. Underwater turbines, large propellers tethered to the seabed, are moved with the marine currents to generate electricity. According to the **Intergovernmental Panel on Climate Change (IPCC),** given the scale of open ocean currents, there is a promise of significant project scale growth when technologies harness lower-velocity currents.
- **Ocean Thermal Energy**- Oceans are huge heat reservoirs as they cover almost 70% of Earth's surface. The temperature difference between warm surface waters and the cold deeper layers can be used to generate steam and then power.

Ocean Thermal Energy Conversion (OTEC)

The technology which uses ocean temperature differences from the surface to depths lower than 1,000 meters, to extract energy.

Research focuses on two types of OTEC technologies -

- In Closed cycle method, a working fluid (ammonia) is pumped through a heat exchanger for evaporation and the steam runs a turbine. The vapour is turned back to fluid (condensation) by the cold water found at the depths of the ocean where it returns to the heat exchanger.
- In Open cycle method, the warm surface water is pressurized in a vacuum chamber and converted to steam which runs the turbine. The steam is then condensed using cold ocean water from lower depths.

It has high (94%) capacity factor which makes it the best power source and although it has a high initial cost, low maintenance and regular power supply makes it an attractive alternative.

OTEC is supplied by an infinite supply of solar energy and the stored energy in it after sundown makes it a 24 hour power supplier.

There are no emissions from the OTEC power plants so air quality will not be degraded.

- **Osmotic Energy**- This technique produces energy from the movement of water across a membrane between a saltwater reservoir and fresh water reservoir. It is also called Salinity Gradient Energy.

Salient Features

- **Predictable and Reliable:** Unlike wind, ocean energy sources are more predictable. The endless flows create a reliable supply source for future availability.
- **Global presence:** Tidal streams and ocean currents are available almost everywhere across the globe.
- **Energy-rich:** Moving water is more than 800 times denser than moving air, which multiplies the kinetic energy by the same factor and opens up the scope of huge amounts of energy.
- **Unlimited usage area:** Land is a scarce resource for many regions so on-shore solutions have to compete and can extend to a limit but ocean energies are provided by the vast and deep oceans ending the competition.

Limitations

- **Deployment is currently limited** in our country and already deployed technologies are underutilised.
- Either there is **not much research done** on the technologies or most are currently at the initial stage of R&D, demonstration and commercialization.
- **Uncertainty of the marine environment** and **commercial scale risks** like- corrosion of materials due to the salinity of seawater, offshore maintenance difficulties, the environmental impact on landscapes and the marine ecosystem and competition from other marine activities such as fishing.

Potential

- Total identified potential of **Tidal Energy** is about **12455 MW,** with potential locations identified at **Khambat & Kutch regions,** and large backwaters, where barrage technology could be used.
- The total theoretical potential of **wave energy** is estimated to be about **40,000 MW.** This energy is however less intensive than what is available in more northern and southern latitudes.
- **OTEC** has a theoretical potential of **180,000 MW** in India subject to suitable technological evolution.
- Ocean energy has the potential to grow fully, **fuelling economic growth, reducing carbon footprint** and **creating jobs** not only along the coasts but also inland along its supply chains.

TIDAL ENERGY

What Are Tides?

The gravitational forces of the sun and the moon combined with the rotation of the earth result in an alternate rise and fall of the sea levels. In one particular place, it usually occurs twice on a lunar day. The rise of the sea level is called the high tide, whereas the fall is called the low tide. When the earth and moon’s gravitational field is in a straight line, the influences of these two fields become very strong and cause millions of gallons of water to flow towards the shore resulting in the high tide condition. Likewise, when the moon and earth’s gravitational fields are

perpendicular to each other, the influences of these fields become weak, causing the water to flow away from the shore resulting in a low tide condition.

When the moon is perfectly aligned with the earth and the sun, the gravitational pull of the sun and the moon on the earth becomes much stronger and the high tides much higher and the low tides much lower during each tidal cycle. This condition occurs during the full or new moon phase. Such tides are known as spring tides. Similarly, another tidal situation emerges when the gravitational pull of the moon and sun are against each other cancelling their effects. This results in a smaller difference between the low and high tides due to the smaller pulling action on the seawater, thereby resulting in weak tides. These weak tides are known as neap tides. Neap tides occur during the quarter moon phase.

Introduction to Tidal Energy

Tidal energy is a form of hydropower that converts the energy obtained from tides into useful forms of power, similar to electricity. Tides are created by the gravitational effect of the moon and the sun on the earth causing cyclical movement of the swell. One of the strengths of employing power from tidal ranges and tidal aqueducts over other forms of renewable energy is that the process is entirely predictable.

Tidal range technologies make use of the perpendicular difference in height between high drift and low drift. Systems take the form of tidal drum fires or lagoons that use turbines in the hedge or lagoon to induce electricity as the drift cataracts into a force. When the drift outside the hedge recedes, the water retained can also be released through turbines, which generate electricity.

Tidal sluice creators draw energy from water currents in an analogous way to wind turbines drawing energy from air currents. Still, because water is 832 times further thick than air, the eventuality for power generation by an individual tidal turbine can be lesser than that of also rated wind energy turbines.

Tidal energy is a form of renewable energy which is created by converting energy from tides into electricity using colorful styles. Tides are more predictable than the wind and thus the sun. Although tidal energy is renewable energy, it has traditionally suffered from fairly high cost and limited vacuity of web spots with sufficiently high tidal ranges or flow rapidity, therefore constricting its total vacuity. Still, numerous recent technological developments and advancements, both in design and turbine technology indicate that the entire vacuity of tidal power could also be important above preliminarily assumed which profitable and environmental costs could also be brought down to competitive situations.

The Rance Tidal power factory in France is the world’s first large-scale tidal energy station. It became functional in 1966. It was the most important tidal power factory in terms of affairs until the Sihwa Lake Tidal power factory opened in South Korea in August 2011.

The Principle behind Tidal Energy

Tidal energy is generated from the Earth’s oceanic tides. These tidal swells are the forces that form due to gravitational magnets wielded by elysian bodies. These forces produce corresponding movements or currents within the world’s abysses.

Due to the strong magnet to the abysses, a bulge within the water position is made, causing a short-lived increase in-water position. Now due to Earth’s gyration, this huge volume of ocean water meets the shallow water conterminous to the oceanfront and creates a drift. This natural

miracle is repetitious and takes place in an unerring manner, due to the harmonious gyration of the moon's route around the earth.
A tidal creator is needed to convert the energy of tidal overflows into electricity. The eventuality of a point for tidal electricity generation is directly commensurable to lesser tidal variation and better tidal inflow rapidity. These together can dramatically increase tidal energy generation. As we know Earth's tides take place due to the gravitational force of Earth with the Moon and Sun, so the tidal energy is virtually indefatigable and classified as a renewable energy resource. The movement of tides causes a loss of energy within the Earth-Moon system.

Tidal Energy Generator

The energy obtained from the rise and fall of tides is called tidal energy.

Tidal barrages or dams are constructed across a narrow opening to the sea. Water rushes into the dam when the sea level rises. This moves the blades of the turbines which are attached at the opening of the dam. This results in the generation of electricity.

Uses of Tidal Energy

Tidal Energy is a renewable source of energy like Solar, Geothermal, and Wind energy. Here are some of the uses of Tidal Energy.

1. **Tidal Electricity**

   The most important use of tidal energy is the generation of Electricity, called Tidal Electricity. The electric power generated from the tides is reliable as tides are predictable and uniform in nature.

2. Grain Mills

Tidal Energy has been in use for hundreds of years. Just like the Wind Mills, Tidal Energy was used for the mechanical crushing of grains in grain mills. To crush grains. Here, the movement of the turbines powered by tidal energy was used.

3. Energy Storage

Tidal Energy is also used to store energy in hydroelectric dams, which act as large energy storage. Tidal Barrages and reservoirs can be modified to store energy.

4. Provide Protection to Coast During High Storms

Tidal Barrages are capable to prevent damage to the coast during high storms. They also serve to create easy transport between the two arms of an estuary or a bay.

Advantages of Tidal Energy

- Renewable: Tidal energy is a renewable source of energy. It is generated by the combined effects of the gravitational force of the moon and the sun and the rotation of the earth.
- The power generation in tidal energy is possible due to the difference in the potential energies of the tides. Different kinds of power generators like stream generators, tidal barrages, and dynamic tidal power (DTP) use this.
- Green: Tidal power is an environmentally friendly source of energy. It does not produce any harmful gas. One of the major benefits of tidal energy is that it utilizes a very small space for energy production.
- Predictable: Tidal currents or waves are highly predictable. High and low tide develops with the ocean as per some renowned cycles. This makes it easier to develop a system with exact dimensions to produce energy, as we already have knowledge of what kind of waves the equipment will be exposed to.
- This is the reason that the tidal stream generators are similar to that of wind turbines.
- Effective at Low Speeds: It is possible to generate electric power at very low speeds because the density of water is much more than that of air. Power can also be generated at a water speed of about 1 m/s.
- Tides are fluently predictable
- Affordable to maintain
- Reliable and renewable source of energy
- High energy viscosity than other renewable energy forms
- It produces no hothouse feasts or other waste
- Vertical-axis turbines and coastal turbines are affordable to make and have a lower environmental impact
- Tidal turbines are 80% effective, which is more advanced than solar or wind energy creators.
- Drumfires reduce the damage of high tidal surges on the land.

Turbines inside the shower harness the power of tides the same way a swash levee harnesses the power of a swash. The shower gates are open as the drift rises. At high drift, the shower gates are near, creating a pool, or tidal lagoon. The water is also released through the shower's turbines, creating energy at a rate that can be controlled by masterminds.

In the United States, there are legal enterprises about aquatic land power and environmental impact. Investors aren't enthusiastic about tidal energy because there's not a strong guarantee that it'll make plutocrats or benefit consumers. Masterminds are working to ameliorate the technology of tidal energy creators to increase the quantum of energy they produce, to drop their impact on the terrain, and to find a way to earn a profit for energy companies.

Disadvantages of Tidal Energy

1. Environmental Challenges: Tidal energy has some adverse effects on marine life. The rotating blades of the turbine are veritably dangerous. It can accidentally kill swimming ocean life, although systems like the one in Strangford feature a security medium that turns off the turbine when marine creatures approach.
2. Tidal Turbines: In tidal turbines, the primary concern regarding tidal energy harnesses is the blade strike and trap of marine organisms. As high-speed water increases the threat of marine lives being pushed near or through these biases.
3. Tidal Shower: Making a shower may change the oceanfront within the bay or creek, affecting a large ecosystem that depends on tidal apartments. Inhibiting the inflow of water in and out of the bay may beget fresh turbidity and lower saltwater. It can end in the death of fish that act as a vital food source to catcalls and mammals.
4. Tidal Lagoon: Generally, the threat associated with tidal lagoon is blade strike on fish trying to enter the lagoon, the aural affair from turbines, and changes in sedimentation processes.

GEO THERMAL ENERGY

Geothermal energy is the thermal energy generated and **stored inside the Earth's crust**. The Earth's centre remains at the same temperature as the Sun, which is nearly constant due to the continuous process of nuclear fusion. Due to such high temperature and pressure, some rocks melt, resulting in the mantle's upward motion (as they become lighter with the heat). These molten rocks formed in the Earth's crust are pushed upward where they get trapped in certain regions called 'hot spots.' When underground water comes in contact with the hot spot, steam is generated. Sometimes this hot water-formed region finds outlets at the surface. When this hot water gushes out of one of these outlets, it is called hot springs.

Harnessing the Geothermal Energy

To harness geothermal energy, a hydrothermal convection system is used. In this process, a hole is drilled deep under the earth, through which a pipe is inserted. The steam trapped in the rocks is routed through this pipe to the earth's surface. This steam is then used to turn the blades of a turbine of an electric generator. In another method, the steam is used to heat water from an external source which is then used to rotate the turbine.

Geothermal power plants

Geothermal power plants are used in order to generate electricity by the use of geothermal energy (the Earth's internal thermal energy). They essentially work the same as a coal or nuclear power plant, the main difference being the heat source. With geothermal, the Earth's heat replaces the boiler of a coal plant or the reactor of a nuclear plant.[2] Click here to learn how this heat is produced.

Hot water or steam is extracted from the Earth through a series of wells and feeds the power plant. In most geothermal plants the water pulled up from the ground is returned back to the subsurface. The rate of water used is often larger than the rate of water returned, so make-up water supplies are generally needed.

Types

There are 3 main types of geothermal power plants, with the flash cycle being the most common. The choice of plant depends on how much geothermal energy is available, and how hot the resource is. The hotter the resource, the less fluid needs to flow from the ground to take advantage of it, the more useful it is. Some details of each plant may be seen below.

Dry steam plants

These plants use dry steam that is naturally produced in the ground. This steam travels from the production well to the surface and through a turbine, and after transferring its energy to the turbine it condenses and is injected back into the Earth. These types are the oldest types of geothermal power plants, the first one was built back in 1904 in Italy. Because this type of power plant requires the highest temperatures they can only be used where the temperature underground is quite high, but this type requires the least fluid flow.

The dry steam plants at the Geysers in northern California, first drilled in 1924, are the largest geothermal source of electricity. At their peak production in the late 1980s they produced a whopping 2 GW of electricity - the equivalent of two large coal or nuclear power plants. However due to high rates of extraction, power has since declined to 1.5 GW of capacity, with an average output of less than 1 GW

Flash cycle steam plants

These types are the most common due to the lack of naturally occurring high-quality steam.[2] In this method, water must be over 180°C, and under its own pressure it flows upwards through the well. This is a lower temperature than dry steam plants have. As its pressure decreases, some of the water "flashes" to steam, which is passed through the turbine section. The remaining water that did not become steam is cycled back down into the well, and can also be used for heating purposes. The cost of these systems is increased due to more complex parts, however they can still compete with conventional power sources.

Binary cycle plants

Binary power plants are expected to be the most commonly used type of geothermal power plant in the future, as locations outside of the known hot spots begin to use geothermal energy. This is because binary cycle plants can make use of lower temperature water than the other two types of plants. They use a secondary loop (hence the name "binary") which contains a fluid with a low boiling point, such as pentane or butane. The water from the well flows through a heat exchanger which transfers its heat to this fluid, which vaporizes due to its low boiling point. It is then passed through a turbine, accomplishing the same task as steam

Applications of Geothermal Energy

Generation of electricity: Geothermal power plants are usually installed within a two-mile radius of the geothermal reserve. The steam from these reserves is either directly used to rotate the turbines of an electrical generator or is used to heat water which then produces steam for the process.

1. Farming: In cold countries, geothermal energy is used to heat greenhouses or to heat water that is used for irrigation.
2. Industry: Geothermal energy is used in industries for the purpose of food dehydration, milk pasteurizing, gold mining, etc.
3. Heating: Geothermal energy is used to heat buildings through district heating systems in which hot water through springs is directly transported to the buildings through pipelines.

Advantages of Geothermal Energy

- Renewable resource: Geothermal energy is free and abundant. The constant flow of heat from the Earth makes this resource inexhaustible and limitless to an estimated time span of 4 billion years.
- Green energy: Geothermal energy is non-polluting and environment-friendly as no harmful gases are evolved with the use of geothermal energy, unlike the use of fossil fuels. Also, no residue or by-product is generated.
- Generation of employment: Geothermal power plants are highly sophisticated and involve large-scale research before installation. This generates employment for skilled and unskilled labourers at a very large scale at each stage of production and management.
- Can be used directly: In cold countries, geothermal energy is used directly for the melting of ice on the roads, heating houses in winters, greenhouses, public baths, etc. Although the initial cost of installation is very high, the cost for maintenance and repair is negligible.

Disadvantages of Geothermal Energy

- Transportation and transmission: Unlike fossil fuels, geothermal energy cannot be transported easily. Once the tapped energy is harnessed, it can only be used efficiently in nearby areas. Also, with the transmission, there are chances of the emission of toxic gases getting released into the atmosphere.
- High installation cost: The installation of geothermal power plants to get steam from deep under the Earth requires a huge investment in terms of material and human resources.
- Intensive research required: Before setting up a plant, extensive research is required, as the sites can run out of steam over time due to a drop in the temperature due to excessive or irregular supply of inlet water.
- Limited to particular regions: The source of geothermal energy is available in limited regions, some of which are highly inaccessible, such as high-rise mountains and rocky terrains, which renders the process economically infeasible in many of the cases.
- Impact on the environment: Geothermal sites are present deep under the earth, so the process of drilling may result in the release of highly toxic gases into the environment near these sites, which sometimes prove fatal to the workforce involved in the process.