MODULE-I

Lecture-1

Introduction:- Awareness about the impact of mankind's modern lifestyle on the environment has been rapidly increasing in recent years. Impact arises from pollution, consumption, and destruction of natural resources. This awareness has led to the emergence of green technologies in recent years.

- ➔ Technology refers to the application of knowledge for practical purposes and for human benefit.
- ➔ Green technology is one that takes into account the impact an invention has on the environment.
- ➔ Green technologies include green energy, green IT, green food, green manufacturing, green business, green economics, green supply chain, green logistics, green building, and green nanotechnology
- ➔ Green technology helps to reduce negative effects on the environment while improving the productivity, efficiency, and operational performance of a given technology.
- ➔ The main goal of green technologies is to meet the needs of society in a way that avoids depleting or damaging natural resources on earth.

Key components of green technologies:-

The key components of green technologies are:-

a) **Recycling**: Green technology helps manage and recycle waste material. Recycle objects are made of glass, metal, paper, and plastic. These materials are reusable and should be recycled to prevent further depletion of the earth's resources.

b) **Environmental remediation**: This involves removing contaminates from the soil, air, and water. It is the removal of pollutants or contaminants for the general protection of the environment.

c) **Renewable energy sources:** Green technology includes the conversion of renewable resources to useful energy.

Green technologies and practices have been applied in several areas including green energy, green chemistry, green nanotechnology, and green buildings.

a) **Green energy**: This is perhaps the most urgent use of green technology. Energy is being conserved through the use of green technology. Currently, nonrenewable resources make up 80% of the world's energy requirements, but they are not sustainable. Renewable energy sources include water, biomass, wind, solar, and geothermal.

b) **Green chemistry**: This is also known as sustainable chemistry. It is a philosophy of chemical research and engineering that encourages the design of products and processes that minimize the use and generation of hazardous substances.

c) **Green Nanotechnology:** This is one of the latest in green technologies. Nanotechnology involves the manipulation of materials at the atomic or nanoscale. Green nanotechnology is the application of green chemistry and green engineering principles to nanotechnology.

d) **Green buildings:** The main benefit of building green is reducing a building's impact on the environment and significantly improving building performance. Using green roofs improved the energy performance of buildings because they provide higher thermal inertia, shading, and absorption of solar energy. Green buildings have the potential to substantially reduce energy consumption.

Advantages of Green Technology:-

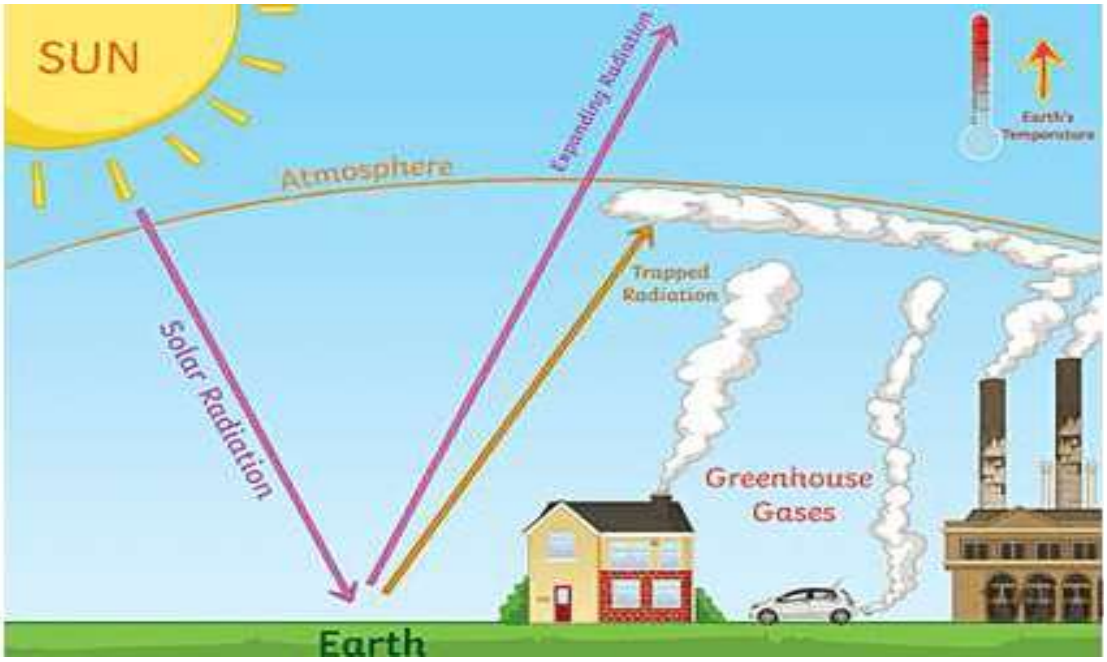
1. Does not emit anything detrimental into the atmosphere
2. Brings economic profits to certain areas
3. Needs less maintenance
4. Uses renewable natural resources that never deplete
5. Slows the impacts of global warming by reducing CO2 emissions
6. Ensures maximum utilization of IT resources in the enterprise
7. Diminishes the number of malignant wastes in the atmosphere
8. Protects our planet from global warming

Disadvantages of Green Technology:-

1. High implementing costs
2. Lack of information
3. No known alternative chemical or raw material inputs
4. No known alternative process technology
5. Uncertainty about performance impacts
6. Lack of human resources and skills

Introduction to Global Warming:- Global warming is the phenomenon of a gradual increase in the temperature near the earth's surface. Human activity—specifically our burning of fossil fuels such as coal, oil, gasoline, and natural gas, results in the greenhouse effect. The heat-trapping pollutants—specifically carbon dioxide, methane, nitrous oxide, water vapour, and synthetic fluorinated gases—are known as greenhouse gases, and their impact is called the greenhouse effect. Global warming occurs when carbon dioxide (CO2) and other air pollutants collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the

earth's surface. Usually, this radiation would escape into space, but these pollutants, which can last for centuries in the atmosphere, trap the heat and cause the planet to get hotter.



Causes of Global Warming

Following are the major causes of global warming:

Man-made Causes of Global Warming

a) Deforestation: Plants are the main source of oxygen. They take in carbon dioxide and release oxygen thereby maintaining environmental balance. Forests are being depleted for many domestic and commercial purposes. This has led to an environmental imbalance, thereby giving rise to global warming.
b) Use of Vehicles: The use of vehicles, even for a very short distance results in various gaseous emissions. Vehicles burn fossil fuels which emit a large amount of carbon dioxide and other toxins into the atmosphere resulting in a temperature increase.
c) Chlorofluorocarbon: With the excessive use of air conditioners and refrigerators, humans have been adding CFCs into the environment which affects the atmospheric ozone layer. The ozone layer protects the earth surface from the harmful ultraviolet rays emitted by the sun. The CFCs have led to ozone layer depletion making way for the ultraviolet rays, thereby increasing the temperature of the earth.
d) Industrial Development: With the advent of industrialization, the temperature of the earth has been increasing rapidly. The harmful emissions from the factories add to the increasing temperature of the earth. In 2013, the Intergovernmental Panel for Climate Change reported that the increase in the global temperature between 1880 and 2012 has

been 0.9 degrees Celsius. The increase is 1.1 degrees Celsius when compared to the pre-industrial mean temperature.

e) Agriculture: Various farming activities produce carbon dioxide and methane gas. These add to the greenhouse gases in the atmosphere and increase the temperature of the earth.
f) Overpopulation: An increase in population means more people breathing. This leads to an increase in the level of carbon dioxide, the primary gas causing global warming, in the atmosphere.

Natural Causes of Global Warming

a) Volcanoes: Volcanoes are one of the largest natural contributors to global warming. The ash and smoke emitted during volcanic eruptions goes out into the atmosphere and affects the climate.
b) Water Vapour: Water vapour is a kind of greenhouse gas. Due to the increase in the earth's temperature, more water gets evaporated from the water bodies and stays in the atmosphere adding to global warming.
c) Melting Permafrost:- Permafrost is frozen soil that has environmental gases trapped in it for several years and is present below Earth's surface. It is present in glaciers. As the permafrost melts, it releases the gases back into the atmosphere, increasing Earth's temperature.
d) Forest Blazes: Forest blazes or forest fires emit a large amount of carbon-containing smoke. These gases are released into the atmosphere and increase the earth's temperature resulting in global warming.

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Lecture-2

Effects of Global Warming:-

Following are the major effects of global warming:

i) Rise in Temperature: Global warming has led to an incredible increase in the earth's temperature. Since 1880, the earth's temperature has increased by ~1 degree. This has resulted in an increase in the melting of glaciers, which has led to an increase in the sea level. This could have devastating effects on coastal regions.

ii) Threats to the Ecosystem: Global warming has affected the coral reefs which can lead to the loss of plant and animal lives. An increase in global temperatures has made the fragility of coral reefs even worse.

iii) Climate Change: Global warming has led to a change in climatic conditions. There are droughts at some places and floods at some. This climatic imbalance is the result of global warming.

iv) Spread of Diseases: Global warming leads to a change in the patterns of heat and humidity. This has led to the movement of mosquitoes that carry and spread diseases.

v) High Mortality Rates: Due to an increase in floods, tsunamis and other natural calamities, the average death toll usually increases. Also, such events can bring about the spread of diseases that can hamper human life.

vi) Loss of Natural Habitat: A global shift in the climate leads to the loss of habitats of several plants and animals. In this case, the animals need to migrate from their natural habitat and many of them even become extinct. This is yet another major impact of global warming on biodiversity.

The New Carbon Problem: Accumulation, Long Half-Life, Heating Potential

Dry air on the earth consists of

- Nitrogen (78%)
- Oxygen (21%)
- Argon (0.9%)
- Co2 (0.035%)
- Other Gases

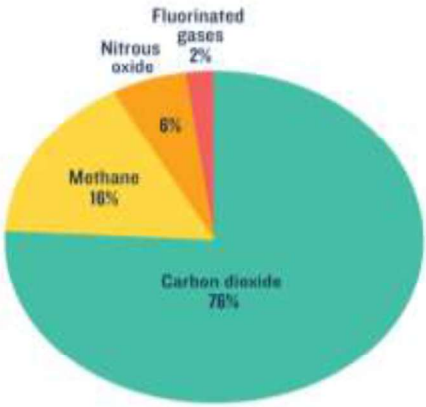
Oxygen comes from photosynthesis. Some oxygen is consumed in respiration, combustion and decomposition, the rest accumulates and supports life on this earth. Air moves from one region to another according to pressure and temperature variations

The three major gases emitted from human and animal activities are given as

1. Carbon dioxide (CO_2) 77% of gases released
2. Nitrous oxide (N_2O) 14% of gases released
3. Methane (CH_4) 8% of gases released

Other three gases which are emitted from industries and are also responsible for ozone depletion together constitute only about 1% of the gases released:-

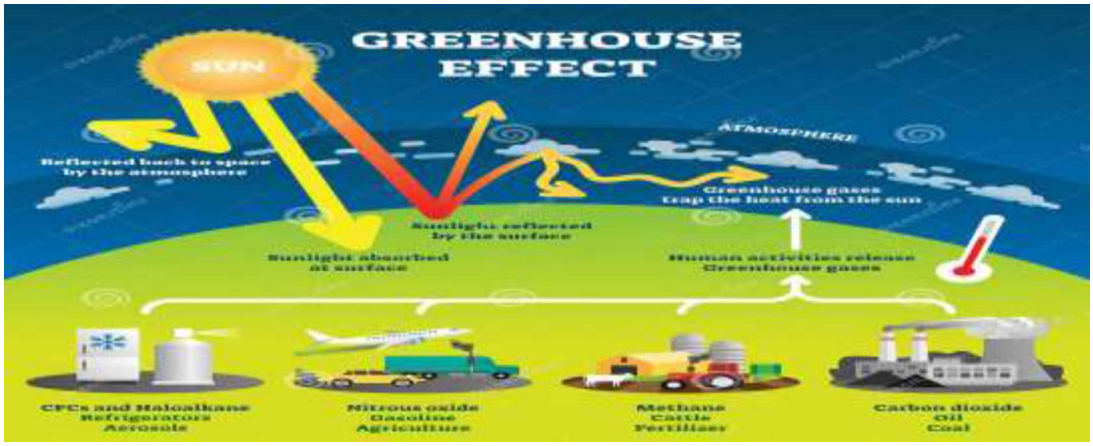
1. Hydrofluorocarbons (HFCs)
2. Perfluorocarbons (PFCs)
3. Sulphur hexafluoride (SF_6)



Water Vapour is also included in the above list as it traps heat in the atmosphere and adds global warming. The above 6 gases are known as **Green House Gases.**

Source of Green House Gases

1. Natural sources (e.g., human and animal respiration, enteric fermentation in animal guts leading to release of methane from animal belching, anaerobic decomposition of organic matter, evaporation from water bodies).
2. Industrial chemicals and solvents used in manufacture.
3. Power generation and power use for industrial, commercial and domestic purposes using fossil fuels like coal, oil and gas.
4. Transport traffic by road, rail, air and sea using fossil fuels like oil, petroleum and gases.
5. Agricultural sources and soils giving nitrous oxide, carbon dioxide, etc



India has been a party to the UN Framework Convention on Climate Change (UNFCCC) which was started in March 1994. The objective of this convention is to achieve the stabilisation of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous interference. The greenhouse gases of concern, identified as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

All countries (including India) are preparing and/or updating source-wise inventories of greenhouse gas emissions from urban and rural areas so that they may prepare or revise their policies and programs for control accordingly.

It is observed that deforestation releases more greenhouse gases (CO_2 , etc.) than either the whole transport sector or the industrial sector. The control of deforestation is of utmost importance. With regard to transportation, it is shown that air travel, globally, accounts for only about 1% of the emission whereas ground travel (by cars, etc.) accounts for the remaining 13.5%

Long Half-life

It was not realized for years that the carbon dioxide, methane and other gases released by us from various activities were accumulating in the atmosphere and leading to a slow change in our climate. The major constituent carbon dioxide (CO_2) has a half-life of about 120–150 years. It means that the carbon dioxide released about 120–150 years ago is still there. Methane(CH_4) has a half-life of 9 to 15 years while nitrous oxide (N_2O) has an estimated half-life of 120 years

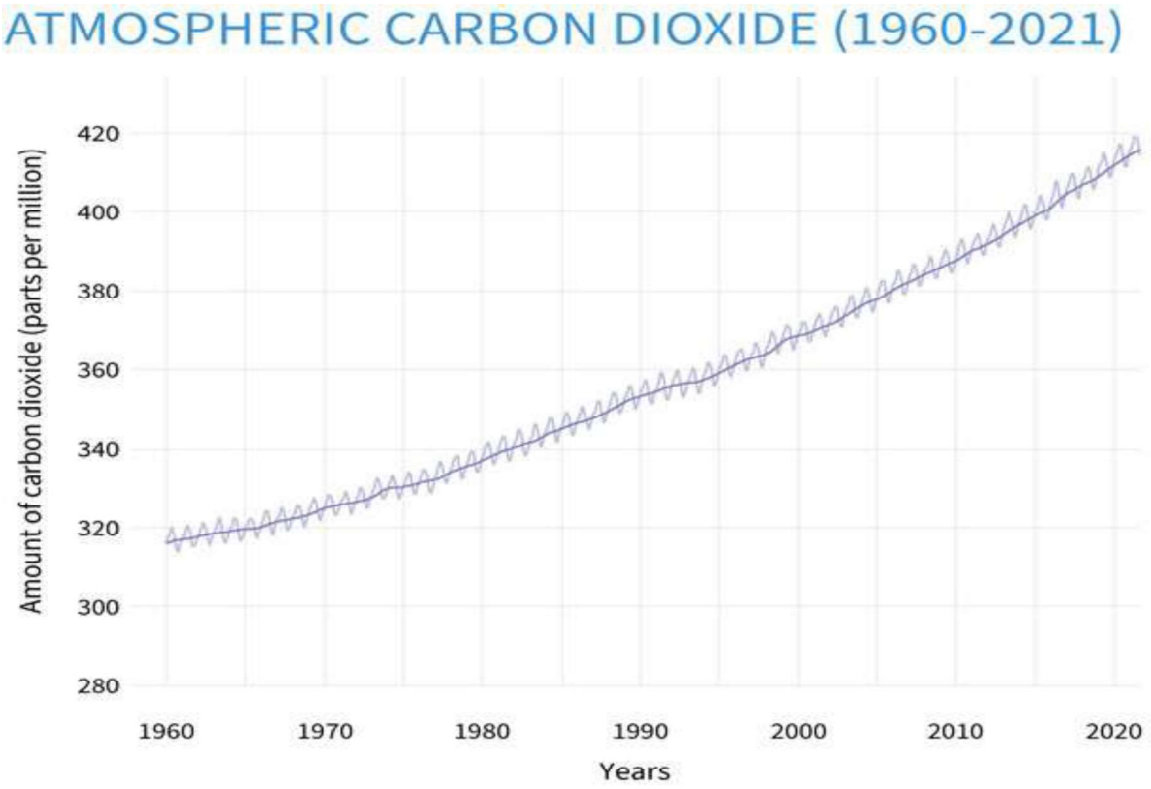
Greenhouse gases warm the earth by absorbing energy and decreasing the rate at which the energy escapes the atmosphere.

Each greenhouse gas is characterized by its atmospheric lifetime and global warming potential. Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). Because CO_2 has a very long residence time in the atmosphere, its emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years. Methane's average atmospheric residence time is about a decade. However, its capacity to absorb substantially more energy than CO_2 gives it a GWP ranging from 20 to 35.

The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases

The accumulation continues to increase at a faster and faster rate as the years go by and population and industrialisation keep on increasing.

In 2005, the average CO_2 concentration in the atmosphere was estimated at 385 parts per million (ppm) and found to be rising by 2 to 3 ppm per year.



Heating Potential

Different gases have different global warming potential (GWP). Thus everything is expressed in terms of 'CO_2 -equivalent' (CO_2 -e) by multiplying its volume by a factor to express its GWP compared to a GWP of 1.0 for CO_2 . For example, compared to CO_2 , methane appears to have 20–30 times greater potential for earth warming than CO_2 .

In India, animals are a prime source of methane (cows, sheep, goats, etc.). There are many old cows in India which live long after they have stopped giving milk, but continue to give methane and carbon dioxide from belching (*The act of expelling air from the stomach through the mouth.*) India is reputed to have the world's largest livestock population totalling around 485 million, collectively emitting 11.5 million tonnes of methane annually.

N_2O from agriculture and soil has to be multiplied by 310 to get its CO_2 -e value.

GAS	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Sulfur hexafluoride (SF_6)	23,900
Perfluorocarbons (PFCs)	6,500
Hydrofluorocarbons (HFCs)	
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140

Question) What happens to the methane GWP if a 20-year averaging time is used?

Ans.) The 20-year GWP is based on the energy absorbed over 20 years, it ignores any impacts that occur after 20 years from the emission. The GWPs are calculated relative to CO2, so the GWPs are based on an 80% shorter time frame that will be larger for gases with atmospheric residence times shorter than that of CO2 and smaller for gases with residence times greater than CO2.

Since CH4 has a shorter atmospheric residence time than CO2, *the 100-year GWP is much less than the 20-year GWP*. The CH4 20-year GWP has been estimated to be 84–87, compared with the 100-year GWP of 28–36.

MODULE-I

Lecture-3

Carbon Emission Factors

Emission factors are commonly used in estimating carbon emissions for the following categories

- Fossil fuels and a few others (coal, oil, LPG, kerosene, wood)
- Electricity usage
- Transport sector (scooters, cars, trucks, petrol/diesel, aircraft fuel)
- Industries, commerce and services
- Agriculture and forestry
- Livestock and animals
- Land use
- Community wastes
- Miscellaneous

Carbon differs from carbon dioxide in terms of molecular weight. Mol wt of C = 12 whereas Mol wt of CO2 = 12 + 32 = 44. Thus, CO2 is 3.666 times heavier than carbon alone.

1. **Fossil Fuels and a Few Others (Coal, Oil, LPG, Kerosene, Wood)**

Adequate fuel deposits are essential for the development of any country. Black coal currently provides about 63% of India's energy requirements.

- Burning coal gives 2.00–2.46 kg of CO_2 per kg of coal burnt (depending on type of coal)
- Burning diesel oil to generate steam and, hence, electricity gives 2.63–2.97 kg of CO_2 per kg of diesel oil burnt
- Burning 1 kg of kerosene gives 2.518 kg of CO_2
- Burning 1 kg of LPG gas gives 0.15–0.19 kg of CO_2
- Burning 1 kg of wood gives approximately 0.17 kg of CO_2 + some carcinogens from the wood (so beware!)

The efficiency of burning fuel is also a factor in the production of CO_2 . Burning anthracite to generate electric power results in 67% more CO_2 emission than burning methane, while brown coal which has more moisture and impurities produces 130% more CO_2 .

Peat and brown coal emit the most carbon, bituminous less, and anthracite lesser still

Power plant emission rates depend on type of fuel used. Their emission rates in terms of tonnes of CO_2 per MWh of power are: lignite—1.3, coal—1.05, diesel—0.65, naptha—0.64, gas—0.42.

2. Electricity Usage

Using 1 kWh of electricity produces 0.37–0.48 kg of CO_2 depending upon the type of fuel oil used to produce electricity

In Mumbai city, India, NEERI estimates that the CO_2 produced varies from 0.05 tonnes per person per year in the slums of Mumbai to 1.4 tonnes per person per year in high-income group housing (NEERI, Personal Communication).

Problem:- A family's electricity usage averages only 300 units (kWh) per month (3,600 units per year). Estimate the CO_2 produced per year by the family. Assume the power plant is gas based. Also estimate CO_2 production if the power plant is coal based

Solution:-

Gas based: CO_2 produced = 300 kWh/month × 12 m/year × 0.43 kg CO_2 /unit = 1,548 kg/year

Coal based: CO_2 produced = 300 × 12 × 1.05 = 3,780 kg/year (nearly 2.5 times more)

3. Transport Sector (Road Vehicles)

For emissions in terms of distance travelled, multiply the average distance travelled by a vehicle by the emission factor for that type of vehicle

Type of Vehicle	ARAI Emission Factor (g/km) (ARAI, 2005)
2-wheeler (Petrol)	45.6
3-wheeler (CNG)	57.71
Motor car (Petrol)	126.5
Truck (Diesel)	166.15

Generally, mass transport systems such as trains and metros give much lesser carbon emissions per person than the motor car, and are to be preferred wherever possible

4. Transport Sector (Airplanes)

Emissions from aircraft travel are quite high and can be computed on the basis of fuel volume consumed and its carbon content released as carbon dioxide upon combustion. Most aircraft run on kerosene and the bulk of fuel used is kerosene.

Carbon dioxide emission from air travel, on per passenger, per kilometre, travelled basis, is the highest compared to other modes of travel. The latest AIRBUS-380 carrying 800 passengers is said to use a little less than 3 L of kerosene per passenger per 100 km. By comparison, in 1985, an average commercial aircraft consumed about 8 L per passenger per 100 km

Some forms of transport such as aircraft depend on high-density fuels (ATF). Combustion of kerosene in the presence of oxygen gives carbon dioxide and water:

$$2C_{13}H_{28} + 40O_2 = 26CO_2 + 28H_2O$$

4. **Emissions from Industry, Commerce and Services**

For India, the total CO_2 -equivalent emission from industries was 412 million tonnes per year in 1997. Nearly 32% was from mineral industries, 28% from metal industries and about 8% from chemical industries and the balance from other industries such as pulp and paper, food and beverage, textiles and leather, mining and quarrying

Specifi c emission factors (EFs) applicable to a few industries are given as follows

- Aluminium: EF = 1.65 tonnes of CO_2 per tonne Al produced
- Cement: EF = 0.5370 tons of CO_2 per tonne of clinker used (estimated in 1994)
- Iron and steel: EF = 1.72 tonnes CO_2 per tonne production (OHV)
- Nitrous oxide (N_2O): Emission from nitric acid production depends on operating pressures. The mean value of N_2O produced in a medium pressure plant was 10.13 kg per tonne of nitric acid, while in a high pressure plant it was only 2.84 kg per tonne. It could be brought down to as low as 0.4 kg N_2O per tonne of nitric acid by use of a non-selective catalytic reducer.
- Methanol: EF = 0.67 tonnes CO_2 per tonne methanol produced. Also, 2.3 kg methane per tonne methanol produced.
- Ethylene: EF = 1.73 tonnes CO_2 per tonne of ethylene produced. Also, 3.0 kg methane per tonne ethylene produced

MODULE-I
Lecture-4

5. Agriculture and Soils

Rice Cultivation: Out of the 150 million hectares globally available for rice cultivation, India accounts for nearly 44 million ha (about 30%) and is thus an important emitter of methane. In India, rice is cultivated under various water management regimes, depending on the availability of water at the site. In hilly areas, rice is cultivated in terraces along the slopes. In other areas, cultivation is on irrigated or rain-fed lands. The methane (CH_4) emission factors vary roughly from 7.0 to 19 grams/m2 depending on the water regime used.

Emission from Soil:- Soils are regarded as the major source of nitrous oxide (N_2O). Nitrous oxide emissions from rice-wheat cultivation (including the fallow period) are reported to vary from 0.89 to 1.6 kg per hectare.

Agricultural Residue Burning:- CO_2 emissions from biomass burning (e.g., fuel-wood burning and agricultural crop residue burning) contain substantial volumes of CO_2. In 1994, the crop residue available for field burning in India was estimated to be 150 million tonnes which gave an emission of 102,000 tonnes of methane. Emission factors for some of the residue burning is given below

Residue Burnt	**Emission Factor (g of CH_4 /kg Residue Burnt)**
Rice Husk (wet)	73.0–166.0
Bagasse	61.0
Fuel wood	0.006

6. Enteric Emissions from Livestock

Methane emissions (enteric emissions) from cattle vary with type and feed. For dairy cattle, emissions are 46 kg CH_4 /animal/year while for non-dairy cattle they are half as much. For buffaloes, they are around 55 kg/animal per year. In terms of equivalent CO_2, cow belching results in an enormous amount of about 15,000 L of gas expressed as CO_2 -equivalent per cow.

7. Emissions from Land Use, Land Use Change and Forestry

Term LULUCF signifies land use, land use change and Forestry. This sector is reported to contribute a huge 1.6–1.0 Giga tonnes (i.e., 1.6 thousand million tonnes) of carbon emissions per year accounting for about 20 % of the global CO_2 emissions per year.

8. Municipal Solid Waste (MSW) Disposal Sites

Biogas emissions from municipal solid waste (MSW) disposal sites occur continually for up to 20–25 years or more after waste is freshly deposited. Biogas can be economically pumped out for at least 23 years. The biogas can be collected by a network of pipes buried in the deposited material and connected to a suction pump. Indian solid waste dumpsites give a biogas production of 0.263 m^3 /kg or 263 m^3 /tonne of waste deposited. The fraction of methane gas contained in landfill biogas varies from 0.35 to 0.65 of methane

Methane (tonnes/year) = Total MSW (tonnes/year) × MCF × (DOC) × 0.77 × F
where,
MSW = Municipal solid wastes, tonnes/year
MCF = Methane correction factor = 0.4 for open dumps less in-depth
DOC = Degradable organic carbon (determined for each city) = say 0.10 –0.40
Degradable fraction = 0.77 conversions to methane assumed as 0.077 (default basis)
F = Fraction of methane in landfill biogas = 0.35 to 0.65 (taken as 0.5 on default)

Problem:- Estimate the biogas and methane production per year from a municipal solid waste dump site handling about 2740 tonnes per day. Assume that MCF = 0.4, DOC = 0.3, degradable fraction = 0.77, conversion to methane = 0.077, and F = 0.5.

Solution:- Methane produced = (2740 × 365) T/year × 0.4 × 0.3 × 0.077 × 0.5 = 4620.4 T/year
or, CO_2 equivalent = 4620.4 × 21 = 97,028 T/year

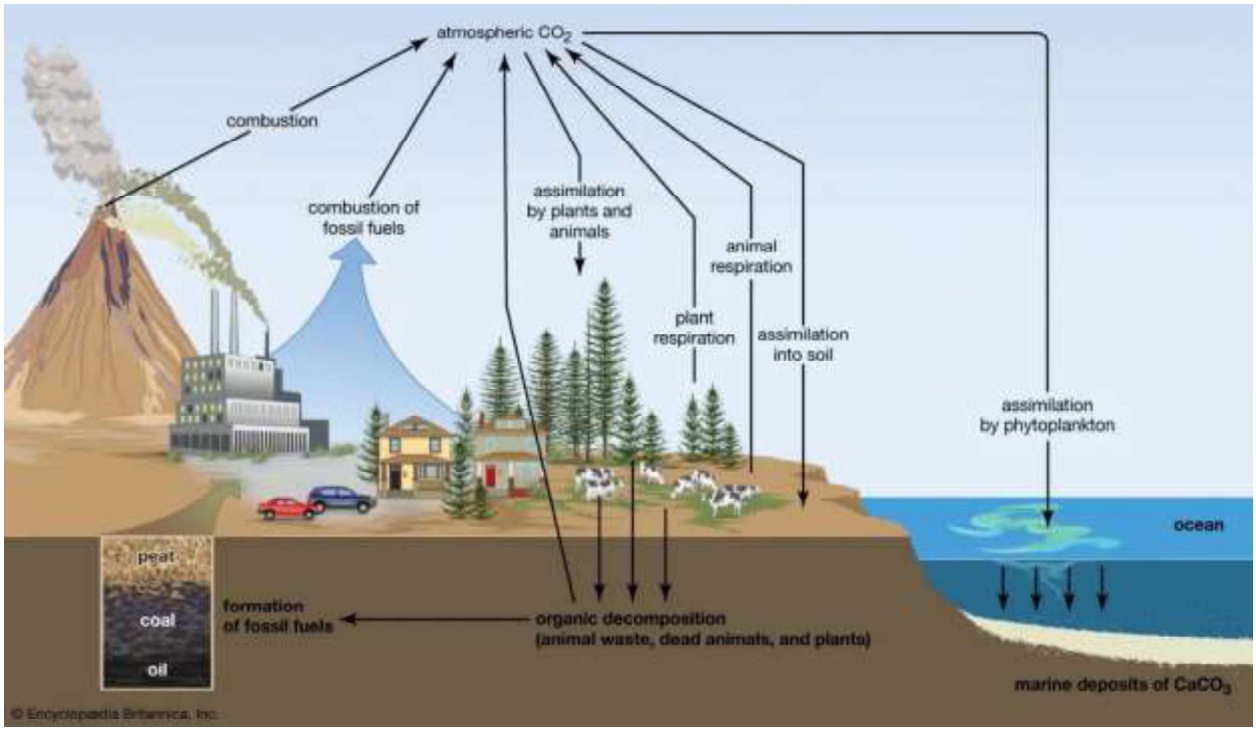
MODULE-I

Lecture-5

Carbon Absorption in Nature

The amount of carbon in the atmosphere at any one time depends on the balance that exists between the sinks and sources. A typical carbon cycle is shown below in the figure.

A carbon sink is any natural reservoir that absorbs more carbon than it releases and thereby lowers the concentration of CO_2 from the atmosphere. Globally, the two most important carbon sinks are vegetation and the ocean. Processes that release CO_2 to the atmosphere are called carbon "sources", while processes that absorb it are called carbon "sinks". A sink absorbs more carbon than it gives off, while a source emits more than it absorbs.



The natural sinks are:

- SOIL: is the Earth's greatest carbon store and active carbon sink
- FORESTS (TREES): Photosynthesis: by terrestrial plants with grass and trees serving as carbon sinks during growing seasons. Photosynthesis accounts for about half of the carbon extracted from the atmosphere. Photosynthesis is a mechanism by which carbon is removed from the atmosphere.
- Photosynthesis equation:

  $6H_2O$ (water) + $6CO_2$ + sunlight energy = $C_6H_{12}O_6$ (glucose) + $6O_2$ (oxygen).

Land plants take most of their carbon dioxide from the air around them while aquatic plants in lakes, seas and oceans use carbon dioxide dissolved in water. Phytoplankton is one of these important plants as they produce up to 50% of the atmospheric oxygen through photosynthesis

- OCEANS: Absorption of carbon dioxide by the oceans via physicochemical and minor biological processes. The world's oceans are absorbing an unprecedented amount of carbon dioxide (CO_2), which is increasing their acidity and possibly threatening the long-term survival of many marine species, especially calcifying organisms including corals, shellfish, and phytoplankton.

Humans produce carbon dioxide and methane far faster than the natural sinks can absorb it leading to an increase in the amount of carbon in the atmosphere.

Methane (CH4) is an important trace gas in Earth's atmosphere. Even though it only makes up 0.00017% (1.7 parts per million by volume) of the atmosphere, methane traps a significant amount of heat, helping the planet remain warm and habitable.

The amount of methane in the atmosphere is the result of a balance between production on the surface and destruction in the atmosphere.

Methane forms when organic matter decomposes in oxygen-poor environments, such as marshes, rice paddies, or the digestive systems of cattle. It also comes from the combustion (burning) of carbon-based fuels.

Each methane molecule holds about 23 times more heat than 1 molecule of carbon dioxide. Methane is 23 times more potent than carbon dioxide as a greenhouse gas, but CO_2 is much more abundant than methane and the predicted growth rate is far greater.

On this basis, the weight of oxygen produced is about 1.6 times the weight of algae produced by photosynthesis.

- All living things breathe in oxygen and give off carbon dioxide. During daylight hours, trees, grass, etc., undergo both respiration and photosynthesis.
- During the night time, they undergo only respiration. About 14% of the oxygen produced through photosynthesis is consumed back in respiration, and the rest helps all living things to survive

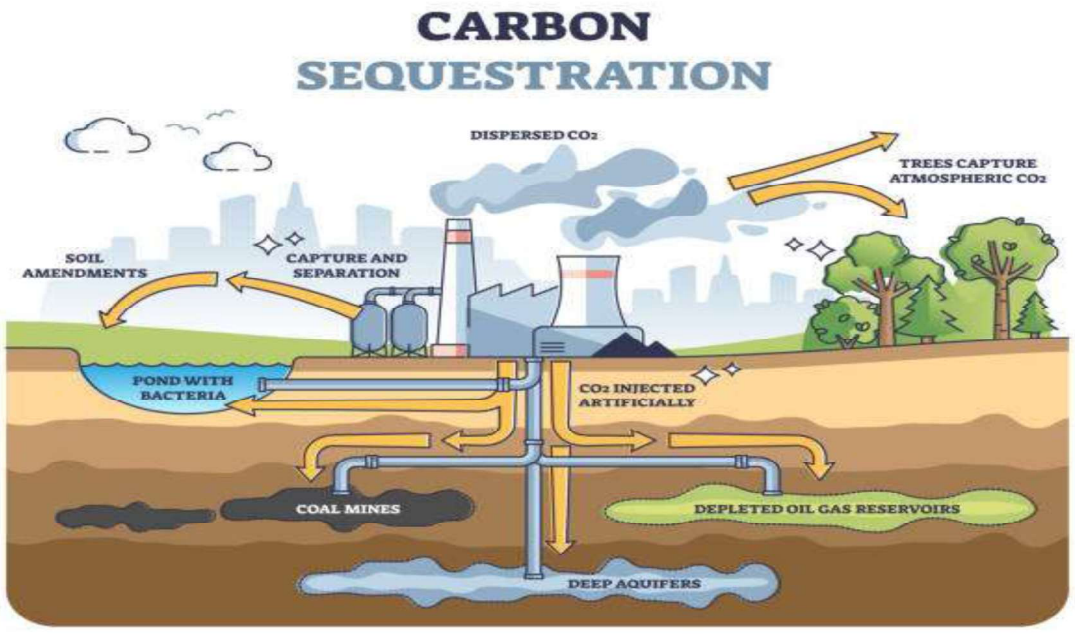
- Some of the vegetation gets buried inside the earth due to natural calamities and with the heat and pressure present there it gets converted over millions of years into coal, oil, etc., collectively called 'fossil fuels'. This is nature's way of reducing carbon from the atmosphere.
- But when the fossil fuels are burnt that carbon is released back to the atmosphere and the circuit is completed. Thus, this cycle takes millions of years to complete.
- Grass, bamboo, and such vegetation, however, constitute a much shorter time cycle as they grow quickly in a few days withdrawing carbon from the atmosphere by photosynthesis and die just as quickly returning the carbon to the atmosphere. They are, in fact, referred to as 'carbon-neutral' items.

Net Accumulation

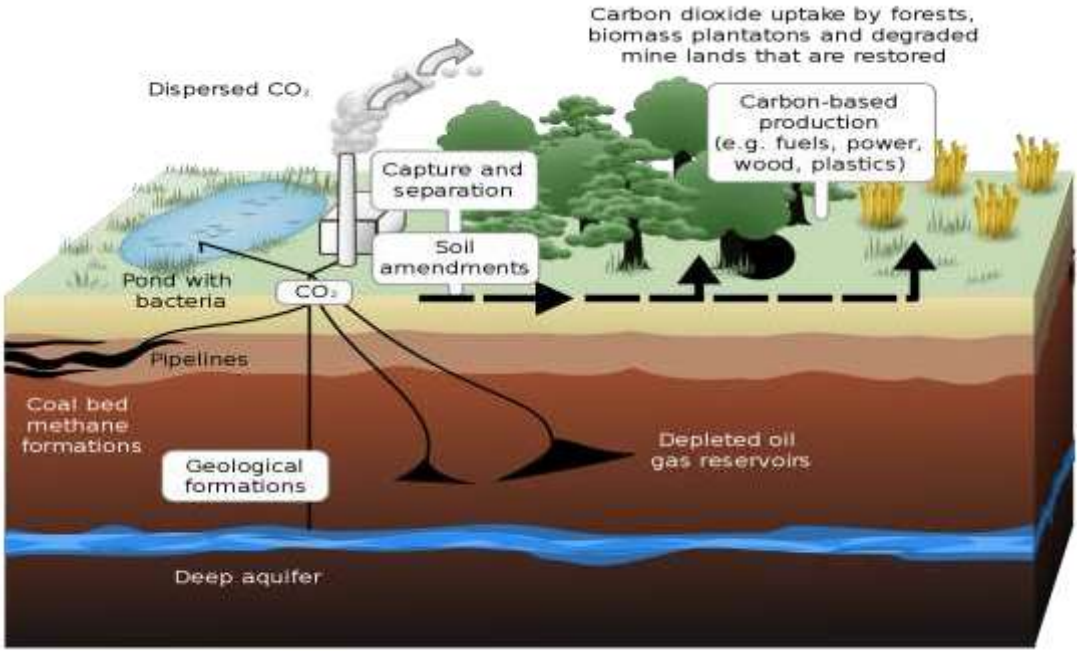
Net accumulation of GHGs can be expressed in terms of 'CO_2 - equivalent' contained in the atmosphere. It is the result of CO_2 produced from all the sources, (∑Sources) less the CO_2 absorbed by the various sinks (∑Sinks), i.e.

$$\sum \text{Sources} - \sum \text{Sinks} = \text{Net accumulation}, \Delta s$$

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change.



The term "Carbon Sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations. Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes.



Geologic carbon sequestration is the process of storing carbon dioxide (CO_2) in underground geologic formations. The CO_2 is usually pressurized until it becomes a liquid, and then it is injected into porous rock formations in geologic basins.

Worldwide storage capacity in oil and gas reservoirs is estimated to be 675–900 Gt CO_2, and in un-minable coal seams is estimated to be 15–200 Gt CO_2. Deep saline formations have the largest capacity, which is estimated to be 1,000–10,000 Gt CO_2

Forests, kelp beds, and other forms of plant life absorb carbon dioxide from the air as they grow, and bind it into biomass. However, these biological stores are considered volatile carbon sinks as the long-term sequestration cannot be guaranteed. For example, natural events, such as wildfires or disease, economic pressures and changing political priorities can result in the sequestered carbon being released back into the atmosphere.

Carbon dioxide that has been removed from the atmosphere can also be stored in the Earth's crust by injecting it into the subsurface, or in the form of insoluble carbonate salts (mineral sequestration). These methods are considered non-volatile because they remove carbon from the atmosphere and sequestering it indefinitely and presumably for a considerable duration (thousands to millions of years).

MODULE-I

Lecture-6

India's Emissions have been Increasing

Carbon dioxide emissions stem from burning fossil fuels and manufacturing cement. They include carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring. India is currently the world's third largest emitter of greenhouse gases after China and the US. Coal power plants, rice paddies, and cattle are major sources of steeply rising emissions levels, although per capita emissions continue to remain below the global average. According to the IEA, in 2018 India's emission level was 2307.78 MtCO2e, an increase of 335.33% from 1990.In 2019, CO_2 emissions for India were 2,597.4 million tonnes. Over the last 50 years, emissions rose substantially from 232.8 to 2,597.4 million tonnes with an annual increase rate that reached a maximum of 11.65% in 2009 but eventually decreased to 1.6% in 2019

YEAR	VALUE	CHANGE IN %AGE
2019	2597.4	1.6
2018	2556.5	5.41
2017	2425.4	4.46
2016	2321.8	1.26
2015	2293.0	2.55
2014	2235.9	8.09
2013	2068.6	3.39
2012	2000.8	7.65
2011	1858.6	5.52
2010	1761.4	5.25
2009	1673.5	11.65
2008	1498.8	Baseline

In 2019, India's CO_2 emission per capita was 1.9 metric tonnes. CO_2 emissions per capita grew from 0.42 Mt to 1.9 Mt over the last 50 years with an all-time increase of 10% in 2009 and an eventual decrease of 0.51% in 2019

YEAR	VALUE	CHANGE IN %AGE
2019	1.9	0.51
2018	1.89	4.25
2017	1.81	3.29
2016	1.75	0.1
2015	1.75	1.36
2014	1.73	6.81
2013	1.62	2.13
2012	1.58	6.3
2011	1.49	4.14
2010	1.43	3.83
2009	1.38	10.08
2008	1.25	Baseline

India is gearing up to improve its Paris Accord pledge and are expected to make a definite decision soon. The Indian government is preparing to lead climate action going forward through major announcements of its actions and intent during COP 26 (held in 2021 in Glasgow, UK) followed by India's presidency of G-20 in 2022.

KYOTO PROTOCOL

The Kyoto Protocol was an international treaty which extended the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that

I) Global warming is occurring

2)Human-made CO_2 emissions are driving it.

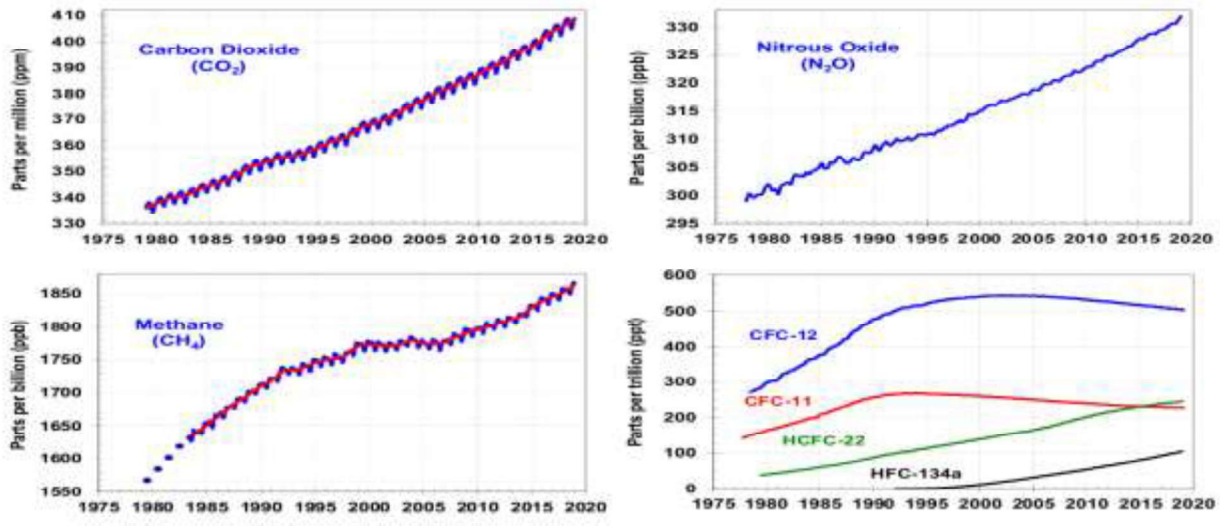
The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005.

The Kyoto Protocol implemented the objective of the UNFCCC to reduce the onset of global warming by reducing greenhouse gas concentrations in the atmosphere to "a level that would prevent dangerous anthropogenic interference with the climate system"

Principle:-

- It was based on the principle of common but differentiated responsibilities
- It acknowledged that individual countries have different capabilities in combating climate change, owing to economic development, and therefore placed the obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of greenhouse gases in the atmosphere.

The main goal of the Kyoto Protocol was to control emissions of the main anthropogenic (human-emitted) greenhouse gases (GHGs) in ways that reflect underlying national differences in GHG emissions, wealth, and capacity to make the reductions



The Protocol's first commitment period started in 2008 and ended in 2012. All 36 countries fully participating in the first commitment period complied with the Protocol. However, nine countries had to resort to flexibility mechanisms by funding emission reductions in other countries because their national emissions were more significant than their targets.
A second commitment period was agreed to in 2012 to extend the agreement to 2020, known as the Doha Amendment to the Kyoto Protocol, in which 37 countries had binding targets
As of October 2020, 147 states had accepted the Doha Amendment. It entered into force on 31 December 2020, following its acceptance by the mandated minimum of at least 144 states, although the second commitment period ended on the same day. Of the 37 parties with binding commitments, 34 had ratified.
Under the Kyoto Protocol, countries are also rewarded financially for certified emission reductions (CER) under the clean development mechanism (CDM).

Copenhagen Meeting:- The Copenhagen Climate Change summit was a gathering of world leaders in the capital of Denmark over a two-week period from 7th - 18th December 2009.
The conference included the 15th session of the Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 5th session of the Conference of the Parties serving as the meeting of the Parties (CMP 5) to the Kyoto Protocol
Another global meeting took place in Copenhagen in 2011. The Copenhagen meeting, worked on an important scheme called the REDD scheme under which payment is made for control of deforestation because considerable deforestation (and consequent carbon emission) is occurring worldwide for the sake of clearing forest land for more agriculture and habitation. Every country will need to have its own equivalent national 'carbon credit' and 'REDD' programs so that an overall increase in sinks occurs, worldwide.

- **Regarding emission control, India argues that it would not like to be bound down by 'caps' on emissions at this stage when so much development has yet to take place in the country.**
- **Energy availability in India today is only 0.53 tonnes oil-equivalent per capita. Thus, at least a six-fold increase in energy availability is needed. A transition to a developed society is not possible with less than six-fold increase in energy.**
- **Any CO_2 released by a country over 200 years ago is still there in the atmosphere to exert its warming effect.**
- **Those countries that industrialised early have historically contributed to the problem since early times and need to do something about it more urgently than others.**

MODULE-I

Lecture-7

HOW DOES CLIMATE CHANGE AFFECT US?

Two things are happening in climate change:-

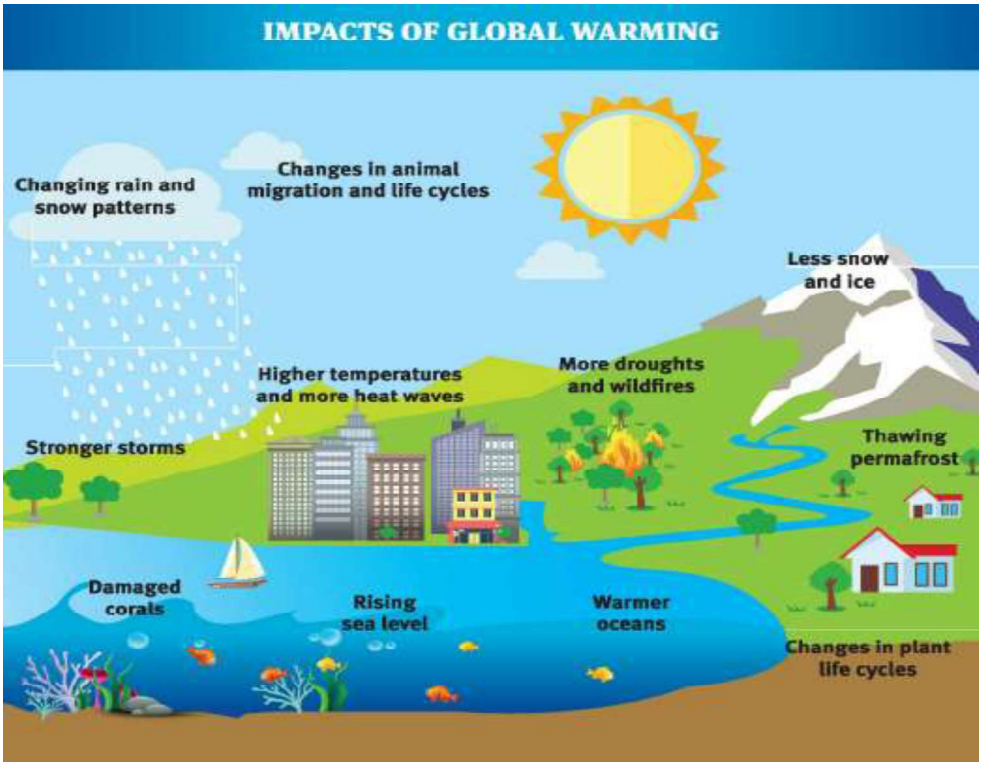
- Extreme weather fluctuations/conditions in different parts of the world (including India)
- Rising sea levels owing to melting glaciers and decreasing snow cover in the Polar Regions.

According to scientists of the Indian Institute of Science, Bangalore (2010), the world has already warmed by 1^0 C. If nothing is done to reduce carbon in the atmosphere, it will warm further by another degree Centigrade to become 1.7 to 2^0 C by 2030.

As the temperature changes, wind patterns also change, thus rainfall patterns change.

Some parts of the world face droughts or dry spells while others face floods and heavy rains. Some face cyclones and hurricanes.

Snow melt due to temperature rise may or may not affect the sea level depending on where the snow was originally located. Glaciers and melted snow located on land above sea level (e.g., Greenland) will flow into the sea as new water increases its level.



THE MANY IMPACTS OF CLIMATE CHANGE

The impacts of climate change are:-

a. Health-Related Impacts:- According to WHO, some of the health impacts are, for e.g, temperature-related illnesses and even death, extreme weather-related health effects, air pollution-related health effects, water and food-borne illnesses, vector-borne and rodent-borne diseases.

The incidence of malaria, dengue and other vector-borne diseases in coastal areas will increase.

Pathogen and insect population dynamics are affected by temperature and humidity.

b. Habitat-related Impacts:- This occurs mainly in coastal areas owing to cyclones, hurricanes and the like and due to the submergence of large tracks of coastal lands as the sea level rises. Many species may get wiped out and people displaced. Sea islands and deltas, in particular (Maldives, Bangladesh, etc.), will perhaps vanish under the sea. Millions of people living in low-elevation coastal zones of China (80 million) and India (30 million) will become homeless, and several million in Japan, Indonesia, Vietnam, Egypt and the Netherlands will have to move.

Another habitat-related problem is a reduction in species diversity. It is claimed that a species can survive temperature changes if they occur relatively slowly giving time to move away to more optimum temperatures, either up a mountain or horizontally up a latitude. Each species has its optimum range of temperature for good growth.

The habitat-related impact is likely to be severest at the North and South poles where snow melt has started and may increase over the years. Many species (such as polar bears) that thrive in very cold temperatures will find themselves stranded in the summer.

c. Storm Drainage:- Adverse effects will occur on the natural drainage (rainwater runoff) of coastal towns. Proper drainage is essential for controlling all mosquito infections. Many areas of coastal cities such as Mumbai will need pumping to clear accumulated rain waters.

d. Agriculture:- Every one-degree rise in temperature is said to reduce wheat production by 4 to 5 million tonnes per year.

India's famous mango crop output is also reported to be suffering owing to climate change. In India, the gross per capita water availability due to various causes is expected to decline from 1820 cum per year in 2001 to 1140 cum per year in 2050. As more than half of the agricultural land in India is rain-fed, climate change in the form of drought will be devastating for the country

e. Risks to Conventional Businesses from Climate Change:- The overall 'risks' to various businesses will be enormous owing to the occurrence of extreme events and rising sea level. For instance, life and property insurers will have to insure against the risk of floods,

droughts, health problems, damage to property, etc. Insurance premiums will increase. Medical and hospital personnel will often be overloaded with accident work (victims of floods, heat waves, cold waves, etc.).

Security and Political Risks:- People will be fleeing low-lying lands such as Bangladesh, Maldives, Lakshadweep, Andaman, etc. There will, thus, be pressure on India in terms of land, water and food security. This will lead to certain dangers and political insecurity as well.

MODULE-I

Lecture-8

PLANNING FOR THE FUTURE

Can the World Control Carbon Emissions?

It has been estimated that the total annual global carbon dioxide emissions have to be less than 30 billion tonnes by 2050 so that the carbon dioxide concentration stabilises at about 450 ppm in the atmosphere by that time, and the average temperature increase is limited to 2^0C to keep the impact acceptable. With 'business as usual, the emissions will double by 2050. The difficulty comes from the fact that all the countries of the world are developing industrially, their populations are growing and their lifestyles are becoming more and more affluent. We need to pay more attention to control methods, have more 'sinks' and less deforestation.

USE OF PROMOTIONAL AND PUNITIVE MECHANISMS FOR REDUCING CARBON IN ATMOSPHERE

A. Promotional: **Carbon Credits for Reducing Carbon Emissions**

New challenges nearly always produce new markets, and the ongoing climate crisis and rising global emissions are no exception. The concept of carbon credits came into existence as a result of increasing awareness of the need for controlling emissions.

A carbon credit is "a certificate showing that a government or company has paid to have a certain amount of carbon dioxide removed from the environment".

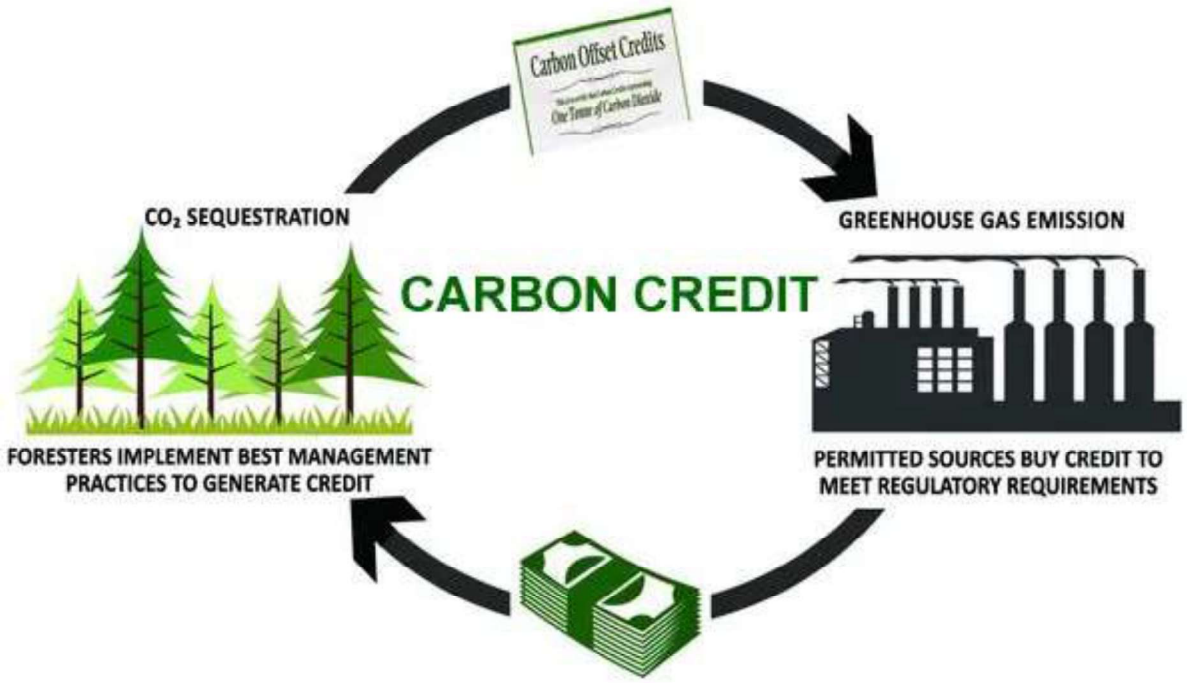
A **carbon credit** is a generic term for any tradable certificate or permit representing the right to emit a set amount of carbon dioxide or the equivalent amount of different greenhouse gas (tCO_2e).

The Kyoto Protocol of 1997 and the Paris Agreement of 2015 were international accords that laid out international CO_2 emissions goals. The number of credits issued each year is typically based on emissions targets. Credits are frequently issued under what's known as a "cap-and-trade" program. Regulatory bodies or governments set caps on the emission of greenhouse gasses. But for some companies, a sudden reduction in emissions is not viable financially. Therefore they can purchase the carbon. Companies that are able to reduce the emission of greenhouse gases are usually credited with Carbon Credits.

Carbon credits are issued by national or international governmental organizations.

Let's say two countries, Country 1 and Country 2, are only allowed to emit 1000 tons of carbon. However, Country 1 is on track to emit 1200 tons of carbon this year, while Country 2 will only be emitting 800 tons.

To avoid a penalty comprised of fines and extra taxes, Country 1 can make up for emitting 200 extra tons of CO_2 e by purchasing credits from Country 2, who has extra emissions room to spare due to producing 200 tons less carbon this year than they were allowed to.



Purpose of Carbon Credit:-The Carbon Credits are verifiable, measurable, emission reductions from the certified action projects for the climate. These projects aim to reduce greenhouse gas emissions.

There are two types of Carbon Credits

- Voluntary emissions reduction (VER): A carbon offset that is exchanged involuntary market for credits.
- Certified emissions reduction (CER): credits created through a regulatory framework with the aim of offsetting emissions from a project.

India is one of the fastest-growing markets in the world, generating approximately 30 million Carbon Credits. This is the second-highest transacted volume in the world. The carbon reduction 'credit' is paid for by a beneficiary located in a developed country in Europe which benefits from this reduction towards meeting the target set by his/her own country for reducing carbon emission.

A UN sponsored agency in London is designated to certify emission reductions (CERs)* and validate the trading under UN's CDM which funds it. They have teams to visit factories and ensure claims are justified and sustainable before payment is made.

Examples:-

- The Aditya Birla group's Grasim Industries which manufactures cement aims to reduce 1% of its carbon dioxide emissions per year. It has earned ` 17 crores so far by selling credits in Europe.

- A Fluoride manufacturing company in Gujarat has made a process change which earns it nearly $1 million/year
- Hindustan Unilever has just patented a process for soap-making using 'mixers' instead of steam (which requires boilers and fuel). 15,000 carbon credits, 10 years.
- Delhi Metro and Indian Railways are installing more efficient electrical coaches and signalling systems so as to reduce CO_2 emissions, and earn CERs. The Delhi Metro is estimated to have reduced the equivalent of 51,000 cars on the roads.
- Small farmers in Africa are reported to be planting trees (with a farmer's patience) so that they can harvest timber or fruit and also profit from selling 'carbon credits' on the world market.

B. Punitive Measures to Reduce Carbon Emissions

The Carbon Tax: A **carbon tax** is a tax levied on the carbon emissions required to produce goods and services. They are designed to reduce carbon dioxide (CO_2) emissions by increasing prices of the fossil fuels that emit them when burned. This both decreases demand for goods and services that produce high emissions and incentivizes making them less carbon-intensive. There are countries visualizing a carbon tax to promote the use of cleaner fuels in their respective countries. New Zealand aims to levy a carbon tax at the rate of US $24.74 per tonne of carbon dioxide emitted. International airlines flying over Europe are also likely to come under such a punitive measure. Airlines landing or taking off from European airports may be soon required to pay a Carbon Emission Tax based on their aircraft emissions. As of 2019, carbon taxes have been implemented or scheduled for implementation in 25 countries while 46 countries put some form of price on carbon, either through carbon taxes or emissions trading schemes.

MODULE-I
Lecture-9

THE GENERAL APPROACH IN PLANNING FOR THE FUTURE

The general approach adopted world over for planning counter-control measures are:

1. Adaptive measures
2. Mitigative measures.

1. Adaptive measures are taken individually at each country level for the benefit of protecting its own people, to forestall the harsh ill effects of climate change.
   Adaptive measures depend on the country's topography, ability and affordability to undertake them.
   The measures are country-specific and are taken by each country at its own cost for the benefit of its own people.

2. Mitigative measures are measures adopted by each country to fulfill their global obligations to satisfy their 'common but differentiated responsibilities' by meeting protocols set by other agencies for decreasing use of fossil fuels, increasing use of renewable energy, etc., and for developing other mechanisms (afforestation, etc.) for reducing GHGs globally. The developing countries want the developed countries to pay for the mitigative measures, and also provide the necessary technology at no cost, as their historical emissions over the past several years (when they developed unrestrictedly) have caused the problem in the first place.

Developing Countrywide Adaptive Measures for Safety of Local People

A few of the broad adaptation strategies desirable for all countries to develop are indicated in the following:

- Better knowledge on impacts and vulnerabilities so that they can plan their control measures better
- Improved disaster preparedness and management, including monitoring and an efficient and rapid communications system
- Improved healthcare facilities and systems including their extension services
- Good governance including responsible decision-making and community empowerment.

Adaptive Measures in India depend upon the actual location i.e.

a. Coastal
b. Inland
c. Himalayan

a. Adaptive Measures in Coastal Region:-

- **Flooding of low-lying lands** is expected to occur in coastal areas. These areas have to be identified now and people living in such areas have to be warned and moved in course of time.
- **Flooding due to rain (storm runoff)** also occurs in some parts of urban areas of coastal cities. To clear this runoff, more pumping stations (and, therefore, more electric power) will be needed.
- **Wells in coastal areas will turn brackish**. Agriculture and mangroves in these areas will be affected by saline intrusion.
- **More storage of grain** will be needed to tide over difficult food periods.
- **Foundations of buildings will need special protection** against seawater ingress and resultant corrosion.
- **Increased control measures** against accumulated pools of water and easier availability of medical facilities be needed as Malaria, dengue, etc., will increase with flood and cause health problems.
- **Political and security problems** will have to be expected and some steps need to be taken as migration of people will occur from low-lying coastal areas to higher areas to avoid rising sea levels.

b. Adaptive Measures in the Inland Region:-

- **Flooding of low-lying lands**: Rapid snow melting will cause flooding of low-lying lands adjacent to the river banks. These areas have to be identified now and people living in such areas will have to be warned and moved in course of time
- **Flooding due to rain** also occurs in some parts of urban areas of cities on river banks. To clear this runoff, more pumping stations (and, therefore, more electric power) will be needed. For example in Bihar, the Kosi River (known as the river of sorrow) leads to flooding and much damage. People have turned to grow 'makhana' or fox nut which grows well in water-logged farms/ponds. It has become a flourishing business today.
- In Assam's flood-prone districts, people have learnt to survive floods by building their houses on stilts, planting more flood-tolerant crops, and innovating more flood-holding systems,

- **Wells in Inland areas will have too much or too little water in them**. Agriculture in these areas will demand a renewed need for irrigation to tide over difficult periods of snow and manage the new water situation.
- Agricultural practices will have to change in drier areas (such as Rajasthan). Crops requiring less water will have to be cultivated.
- **More storage of grain** will be needed to tide over difficult food periods.
- **Water conservation and recycling will be needed**
- **Increased control measures** against accumulated pools of water and easier availability of medical facilities be needed as Malaria, dengue, etc., will increase with flood and cause health problems.
- **Political and security problems** will have to be expected and some steps need to be taken as migration of people will occur from low-lying coastal areas to higher areas to avoid rising sea levels.

c. Adaptive Measures in the Himalayan Region:-

- The Himalayan area is important for India as it provides sustenance to the main land mass by feeding its three major rivers, the Ganges, Indus and Brahmaputra, with waters that help to provide drinking water to millions of people, and waters for various industrial, hydropower and irrigation purposes.
- The Himalayan area also has its unique ecosystem and biodiversity, its agriculture and spectacular tourism.
- Climate change may affect snow melt, endanger river flows and bring drought.
- Himalayas may need integration with forest preservation programs and need better monitoring and understanding of various phenomena.

MODULE-I

Lecture-10

Developing Mitigative Measures for Global Reduction of Carbon

For a country like India, we cannot take mitigative measures alone. Mitigative measures must help poverty alleviation at the same time. The mitigative-cum-poverty-alleviation measures suggested below should be taken:-

a. Low cost and easy measures

b. The principal or thrust programme: 'Improving the Indian Economy by uplifting its villages'

c. The support programs

a. **Low cost and easy measures:-** We can make a beginning with those items which do not cost much and will benefit both the country and the world. The following four sub-programmes can be undertaken:

1. Make some lifestyle changes at personal and community levels
2. Use efficient instruments and appliances (as certified by BEE) to save on electricity
3. Promote 'green buildings' and 'green areas'
4. Conserve water resources.

1. Make some lifestyle changes at personal and community levels: Most of the changes occurring at the personal level are due to the people's general desire to cut electricity and other fuel costs. For example, people are changing over from incandescent bulbs to compact fluorescent lights (CFLs) and even to the more expensive LED ones, to save on electric bills. Like the 'Bijli Bachat Yojna' that started in Maharashtra.
2. Use efficient instruments and appliances (as certified by BEE) to save on electricity: People are becoming more and more conscious of using efficient electrical gadgets such as those certified by the Bureau of Electrical Energy (BEE) so as to save on the cost of electricity.
3. Promote 'green buildings' and 'green areas': Architects and engineers are increasingly promoting 'green' buildings and green areas with the objective of saving on electric consumption, water, etc.,
4. Conserve water resources: We should augment our water resources by plain water conservation, rainwater harvesting, groundwater recharge and reuse of wastewater for the purpose of irrigation.

b) **The principal or thrust programme- 'Improving the Indian Economy by uplifting its villages':**
To improve the Indian economy and at the same time reduce carbon emissions, the following four thrust areas have to be taken up: 1. At village level, stimulate growth by providing electricity through renewables along with more water and sanitation
2. At village level, provide energy and micro-finance services through a community services centre
3. Promote afforestation and control deforestation
4. At urban level, augment electricity through feed-in from privately owned renewable energy sources.

1. At the village level, stimulate growth by providing electricity through renewables along with more water and sanitation
    - **Electricity:** Electricity helps bring education, industry, employment and business. This brings in money for improvement.

☞ An example of electricity at the rural level is the development of portable solar PV lamps (such as those developed by TERI) for lighting up small villages and homes, shops, etc.
☞ Thousands of such lamps have been sold or gifted for use in villages.
☞ With these improvements, the local people will gradually find more small businesses, repair facilities, workshops and industries coming in.
☞ The people will also find more educational facilities available as light will make it possible to study at night.
☞ The family can also benefit from solar lamps if they are capable of recharging mobile phones and supporting TV for family entertainment in the evenings.
☞ The solar lamps will also reduce kerosene usage in the villages.

- **Water:**- Another important requirement for rural upliftment is greater availability of water for various domestic, agricultural and forestry uses by the local people.

  The objective of Rainwater harvesting is to prevent rainwater run-off from gushing down rivers and water courses to the nearest sea, but rather to make it enter the ground and become groundwater which gets naturally filtered (and purified) in passage through the soil and protected from undue loss by evaporation.

  Rainwater harvesting also involves the construction of dykes (often using local materials and labour) to block the passage of surface water flowing along water courses and rivulets, and force it to go underground.

  This helps increase water levels in wells and raises the water table which makes water available for a longer period in the wells.

  It makes it possible to cultivate two or more crops in a year instead of just one crop during the rainy season.

Agricultural income increases and lifestyle changes begin to occur. Education becomes more affordable and employment opportunities increase

- **Sanitation**: In most villages in India, there are no sanitary systems at all. People defecate outdoors in agricultural fields. This is difficult for women folk, especially at night and in rainy weather and can lead to infections.

  The provision of toilets draining into a gobar gas plant (which is based partly on cow dung from their cattle and partly on their own excreta) greatly improves sanitation and consequently their health.

  It also gives the womenfolk more time to attend to their families, and the biogas produced improves their household air pollution situation and smoky cooking conditions.

  Government subsidies are often available for setting up gobar gas installations.

2. At Village Level, Provide Energy and Micro-Finance Services Through a Community Services Centre:-

Most of the villagers cannot afford any capital investment and are dependent on government subsidies.

The cooperative (CSC) could provide the following:

- Electricity (from a renewable source operated by the CSC)

- Biogas and manure (from a community-based gobar gas plant operated by the CSC)
- Oil extraction facility for biofuel cultivated by the villagers and brought to it for oil extraction (operated by the CSC)
- A cold storage facility (if found feasible) for the farmers' perishable produce, so that the variety of agricultural produce available may increase.
- Micro-finance to stimulate women's activities, sewing, etc.
- A solar PV operated bank ATM and a solar PV operated school for children could also be set up.
- Along with portable solar PV lights used in un-electrified villages in India (TERI-lamps and the like) one could make them capable of also operating a radio, a small TV and mobile phone chargers
- A tele-medicine facility to be able to contact doctors of a selected hospital to advise patients through a tele-facility.

MODULE-I

Lecture-11

3. Promote Afforestation and Control Deforestation:-

India being a warm climate country is perfectly well placed to develop new dedicated forests and other plantations to absorb CO2 through photosynthesis. Existing forests are sometimes demolished in order to create new land for agriculture or habitation or for mining. The REDD program (Reduced Emissions from Deforestation and Degradation) under the UN is an international program to cope up with deforestation problem. Where deforestation is the problem rather than forestation, it is hoped that the REDD programme will bring in additional funds for reducing deforestation at the country or local level.

4. At Urban Level, Augment Electricity Through Feed-in from Privately Owned Renewable Energy Sources:- India need a lot more electrical energy at the urban level for development to occur. India wishes to develop rapidly and at the same time reduce carbon emissions, & thus all forms of renewable energy will have to be encouraged as far as possible. The availability of government subsidies for wind, solar and hybrid systems installed in India is highly desired. India is the proud home of one of the largest Indian wind turbine supply companies operating internationally (SUZLON). At urban level it is recommended to augment the feed in of Electricity through a mix of generating sources i.e. traditional and renewables.

c) The support Programme:- The support programs considered essential at the present time are the following:

- Facilitate land and water availability
- Facilitate business interests to come in and lead the way forward through
  (i) Public–private partnerships and media
  (ii) Stable fiscal and other governmental policies
  (iii) Innovation, R&D
- Emphasise sustainability

NATIONAL ACTION PLAN ON CLIMATE CHANGE (NAPCC):-

India, to its credit, is developing a National Action Plan on Climate Change (NAPCC) for which several national 'missions' have been identified to cover the following eight important aspects:

a) Solar energy
b) Enhanced energy efficiency
c) Sustainable habitat
d) Water (soon expected to become crucial)
e) Sustaining the Himalayan ecosystem

f) Green India (afforestation)
g) Sustainable agriculture
h) Strategic knowledge for climate change.

The missions are expected to not only help control emissions but also put India on a low-carbon pathway. The Council first met in 2007. The Council noted that the average world concentration of CO2 in 1820 (pre-industrial era) was 280 ppm while in 2005 it was 379 ppm and by 2050 it was desired to be stabilised at 450 ppm. Below are the details about 8 missions

The MRV Debate

The term MRV originally came from the Bali Action Plan in Bali, Indonesia at the end of 2007.The term 'MRV' stands for 'measurable, reportable, verifiable'. The reductions in carbon emission must be measurable by a national agency and reportable to a common UN authority after which it is important that the results should be verifiable by an agency nominated for the purpose.

The key function of MRV is enhancing transparency through the tracking of national GHG emission levels, the tracking of climate finance flows received or the impact of mitigation actions. MRV seeks to prove that an activity has actually avoided or removed harmful GHG emissions so that actions can be converted into credits with monetary value.

MODULE-II
Lecture-12
OPPORTUNITIES IN CONTROL OF CARBON EMISSION AND ACCUMULATION

ESSENTIAL STEPS FOR CONTROL OF CARBON EMISSIONS AND ACCUMULATION:-

There are several steps which can be taken to control carbon emissions and for their reduced accumulation in the atmosphere. The basic approach is to produce less carbon and absorb more of it.

For any country, the following three guidelines are given

i. Minimise use of fossil fuels

ii. Adopt alternative sources of energy production

iii. Protect existing sinks and develop new ones

Various measures need to be adopted in each country, including India, at different levels as shown below:

- Personal level
- Local authority or city level
- State or central government level
- Commercial, construction and industry level
- Transport level
- Infrastructure level

a. At the individual level, careful and economic use of electricity for domestic purposes and fuel for transport can be expected.

b. At the local authority or city level, the extent of action that may be expected depends on the administration in place. Good housekeeping and good city-keeping, including transport and public advertising, should be practised.

c. At the state and central government level, basic changes in ways of producing energy for different uses can be attempted.

- Alternative sources of energy (wind, solar, hybrid, etc.) can be considered, and use of biofuels can be encouraged.
- Public-private participation and the government's pricing policy can provide better results.

d. At the industry level steps can be taken to reduce electric power consumption through process change, operations change, change of equipment, change of raw material, etc.

e. At the transport level consumption of oil can be reduced to some extent by improved traffic conditions and an increase in mass transport.

f. At the Infrastructure level, green buildings and green area development schemes can be promoted.

PROCEDURE TO DEVELOP OWN PRIORITIES AND BUSINESS OPPORTUNITIES IN INDIA

- Action Plan for each country must be determined by the country itself in order to keep the national expenditure at a minimum affordable level and not to damage its business interests as far as possible.
- Each country must explore how to make the most of its relative advantages and use its natural resources.
- An individual in India normally feels that he/she is too insignificant and too powerless to make any difference in the situation, especially when so many things need improvement.
- Politicians feel that this is too new and uncertain a subject and anyway it may not get them more votes in the next election.
- Businessmen see opportunities but are not sure what government policies will be and whether it will be desirable to invest in its development at this stage or wait just a little while longer.

MODULE-II
Lecture-13

MCKINSEY'S FINDINGS FOR GREENHOUSE GAS REDUCTION, GLOBALLY

McKinsey launched a study in 2006 to estimate costs, globally, of reducing GHGs. The study covered the following areas in six regions of the world i.e. North America, Western Europe, Eastern Europe (including Russia), other developed countries, China other developing nations.

- power generation
- manufacturing industry
- transportation
- residential
- commercial buildings
- forestry
- agriculture and waste

The study covered 2010, 2020 and 2030 and focused on methods of abatement that will cost up to 40 € per tonne or less in 2030. The cost curves developed show estimates of the prospective annual abatement cost in euros per ton of avoided emissions of greenhouse gases, as well as the abatement potential of these approaches in gigatons of emissions.

- The abatement cost for wind power, for example, should be understood as the additional cost of producing electricity with this zero-emission technology instead of the cheaper fossil fuel-based power production it would replace.

It was assumed, for instance, that the cost of carbon capture and storage will fall to 20 to 30 euros per ton of emissions in 2030 and that 85% of all coal-fired power plants built after 2020 will be equipped with this technology.

Abatement potential

Power and manufacturing industry accounts for less than half of the overall potential to reduce emissions at a cost of 40 euros a ton or less.

Developing economies may account for more than half of the total abatement potential at a cost less than or equal to 40 euros a ton.

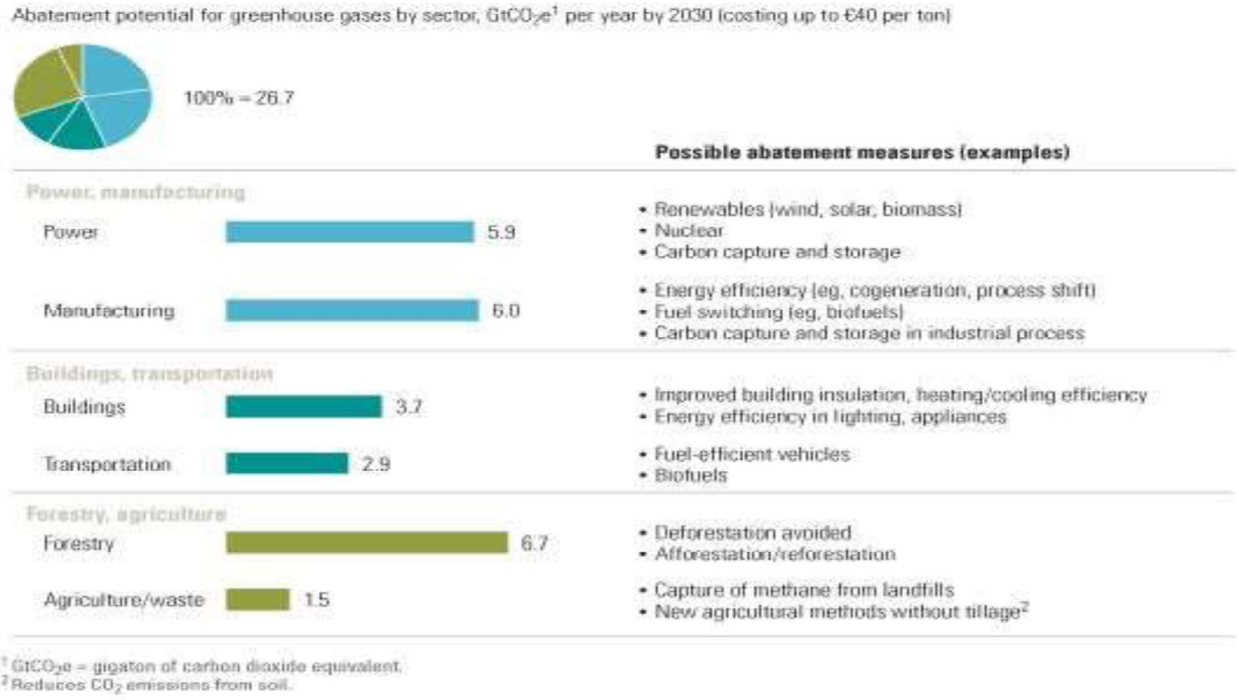
Abatement potential for greenhouse gases by region, $GtCO_2e$[1] per year by 2030 (costing up to €40 per ton)

100% = 26.7

		% of global emissions	
		'Business as usual,'[3] 2030	After abatement
Eastern Europe[2]	1.6	9	11
Western Europe[2]	2.5	8	7
North America	4.4	15	14
Other developed countries	2.5	11	13
China	4.6	18	18
Other developing countries	11.1	39	37

Forestry measures—protecting, planting, and replanting forests—make up 6.7 gigatons of the overall 26.7 gigatons of the potential abatement at a cost up to 40 euros per ton

In agriculture and waste disposal, which produce greenhouse gases such as methane and nitrous oxide, developing economies also represent more than half of the 1.5 gigatons of possible abatements costing no more than 40 euros a ton



The following conclusions are based on the study.

• Power generation and the manufacturing industry, so often the focus of climate change debates, were found to account for only less than half of the potential for reducing emissions at a cost of 40 € or less per tonne. Other sources of carbon besides power generation and the manufacturing industry also needed to be controlled.

• A strong correlation was found between economic growth and the ability to implement low-cost measures to reduce emissions for it is cheaper to apply energy-effi cient technologies when building a new unit than to retrofi t an old one. Almost three-quarters of the potential come from technologies. • In cold weather, almost a quarter of possible emission reduction could result from measures (such as better insulation in buildings) that carry no life-cycle cost, and, in effect, they come free of charge. Insulation is equally important in airconditioned buildings in the tropics.

• In tropical climates, forestry measures (protecting, planting or replanting) have as high as 25% abatement potential considering Asia, Africa and Latin America together. A large potential also exists for reducing emissions by controlling deforestation in developing economies.

• The power generation situation is likely to be as shown below.

Plant	Year 2002	Year 2030
Traditional coal and gas plants	65%	30%
Coal + CCS	–	17
Renewables (including hydro)	18	32
Nuclear	17	21

A major shift is likely to be created globally away from traditional coal-based power generation plants. Much lesser number of new coal-based plants will come up in future years. (In some countries where the geology is favourable, coal plants with carbon capture and storage (CCS) will come up by the year 2030.)

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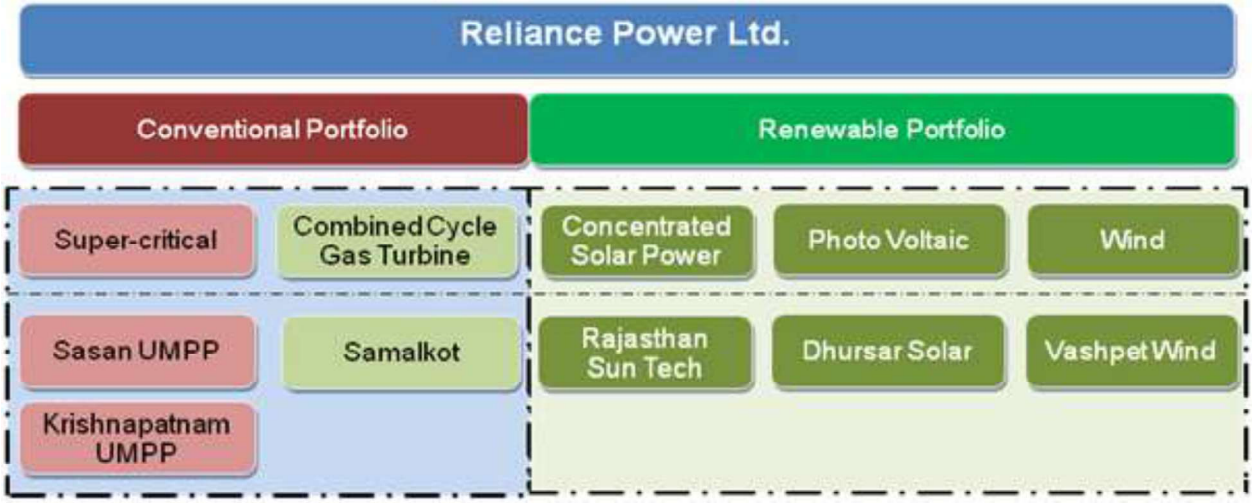
INDIA NEEDS A MIX OF GREEN AND TRADITIONAL POWER SOURCES

The Global Environment Fund (GEF) says that there are opportunities in India for clean energy and environment and natural resource management.

Growth opportunities in the renewable energy field are rapidly shifting from the developed world to South East Asia.

European countries such as Spain are cutting down on subsidies, and since the overall business environment is dull, companies are looking at countries such as India to drive their growth.

In India, Reliance Power has recently commissioned a 40 MW solar power plant in Pokhran near Rajasthan, reducing CO_2 emission by 70,000 metric tonnes per year. Reliance Power handles a portfolio that includes various forms of power generation from coal and gas to solar, wind and hydro.



India needs a mix of green and traditional power sources to meet growth requirements along with the sustainability.

A LOGICAL APPROACH FOR CARBON REDUCTION, WORLDWIDE—MORE FORESTS, LESS DEFORESTATION

Since carbon has been building up in the atmosphere, our ultimate objective has to be to maintain a balance between the 'sources' and the 'sinks' of CO_2, worldwide, so that further build-up stops. This has to be our logical approach to avoid global warming and prevent climate change. The world does not have enough sinks (forests, trees, oceans, fresh water bodies, wetlands, etc.) on an overall worldwide basis to take care of present day emissions. A substantial amount of carbon still remains unabsorbed and goes to the atmosphere, causing global warming even after all our mitigation efforts. To increase sinks:

a. Prevent Deforestation- To stop deforestation, two approaches are recommended:

• Pay for protecting the forests just as we pay for creating new dedicated forests

• Take the help of the 40 million tribals in India to protect the forests since they depend on forests for their livelihood

The UN's REDD program (Reducing Emissions from Deforestation and Degradation) addresses the question of making payments for preventing deforestation at the international level.

b. Tribal Help:- To achieve this, the local villagers, the vanvasis or the adivasis, have to be made the owner of the forest they guard.

   In Shahapur, Thane District, Maharashtra, India, or Mendha in Gadchiroli also in Maharashtra, a 1700 ha tract of forest land, barren over the years, was beautifully re-forested after the local tribal people were given a stake in its development. A joint forest management committee entitled them to benefi t from sale of produce such as gum, dried leaves, fl owers, bamboo and mahua oil.

   The villagers were also entitled to 50% of the income earned by the forest department from the auction of timber.

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PAYMENT RATES FOR SINKS IN WARMER CLIMATES

The reason for concentrating on 'sinks' is that the carbon absorption capacity of sinks in warmer regions is known to be theoretically much higher than that in colder regions.

A tree located in a cold or temperate climate is said to absorb only about 1 tonne of carbon dioxide within its lifetime. In contrast, a tree in a warm country, where photosynthesis occurs faster and for a longer duration in a year, absorbs as much as 2 or 2.5 tonnes within its lifetime. For sustainibility to happen, we should not forget that in future, sinks must increase at the same rate as the sources do.

It should be noted that "Give equal importance to both sources and sinks of carbon, and make sure the people earn something from it all". As the sinks and sources do not have to be adjacent to each other, many countries located in warmer regions must get attracted to protect their forests and cultivate new forests and new sinks dedicated to absorb CO_2 from sources located elsewhere.

The proposed approach has many advantages. The main advantage is

a. Countries are no longer divided into rich and poor.

b. Equal emphasis is given to mitigation and carbon absorption.

c. Countries that are richer in technology and located in colder regions can concentrate on source reduction while those located in warmer regions can concentrate on their forests and other wealth of sinks.

d. Higher rates of payment would act as a welcome incentive for developing newer sinks by using land to grow more trees and forests to absorb carbon dioxide and develop water bodies for the same purpose.

e. It would make people exercise greater vigilance against deforestation.

f. It would also promote conservation of water (and wastewater) as well as promote rainwater harvesting

PROMOTIONAL MECHANISMS NEEDED AT COUNTRY LEVEL

A recent report gives a grim picture of how rapidly deforestation is occurring all over the country.

State	Forest Cover Shrinkage between 2009 and 2011, ha.
Andhra Pradesh	28,100
Manipur	19,000
Nagaland	14,600
Arunachal Pradesh	7,400
Mizoram	6,600
Meghalaya	4,600
Kerala	2,400
Assam	1,900
Tripura	800
Maharashtra	400
Chhattisgarh	400
Uttar Pradesh	300
Gujarat	100
Delhi	100

Deforestation is evidently highest in Andhra Pradesh (for various reasons) and generally high in the seven states of North-East India (due to smuggling). Direct loss could run into several crores of rupees considering wood-stock, vegetation, etc. A further loss in intangible terms could result owing to birds, wildlife and ecosystem damage occurring within the affected areas as well as connecting patches between forests. In case of lakes located within the forests and supplying water to urban areas, a further direct loss could occur. In order to keep it all sustainable, make sure the technology is correct and the people make some money from it. The areas to be covered are:-

1. Development of dedicated forests to earn 'carbon credits' at the country level, similar to those earned from certified emission reductions (CERs) from industries, etc., at the international level
2. Control of deforestation at the country level (similar to the international REDD program)
3. Development of new areas as 'sinks'.

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GREEN TECHNOLOGIES FOR ENERGY PRODUCTION

Various Technologies Available for Energy Production

The world has been using a variety of sources of energy including coal and oil. Some of these sources are polluting, some are renewable, some are free from CO_2 production or produce very little of it, and some are totally unexplored by us at present.

Energy Sources Available at Present

- Fossil fuels (coal, oil, petroleum)
- Hydropower
- Renewable sources (wind, solar, hybrid, wave, geothermal, etc.)
- Gases [coal gas, natural gas, LNG, CNG, liquid petroleum gas (LPG), shale gas]
- Agricultural biomass and community wastes
- Municipal and industrial solid wastes
- Nuclear energy

Cost Comparison of a Few Typical Systems for Power Generation

System Used in India	Gen Capacity %	Capital Cost ₹ Crores/MW	Remarks
Coal-fired, thermal	55	4.00–5.00	India has large coal reserves and is planning to use them in future too. India is also importing coal to meet heavy demand. Coal gives much CO_2
Oil and gas, thermal	10	5.00–5.50	Gas gives less CO_2 than coal. But India has less oil resources and oil prices are ever increasing
Hydro	26	5.00–6.00	Hydro is preferred where sites are available. No CO_2 produced. It adds to water resources also, but capital cost depends on site and pop. displaced
Wind energy	–	5.50–6.50	Low running cost. No CO_2 produced. But possible only at windy sites.
Solar PV	6 (w+s)	8.50–9.00	Costs expected to reduce still further. Solar PV panels manufactured in India, China and other countries
Solar Concentrator (CSP)	–	11.00–13.00	First 400 MW plant coming up in Rajasthan, India
Nuclear	3	7.00–8.00	Much land required. Severe risks attached to its operation
Straight biomass combustion	NA	4.00–5.00	Suited for rural areas and small units

Coal-fired systems are the cheapest in capital cost to install. Hydro systems come next depending on the site. Wind energy is slightly more expensive but its cost depends on the wind speeds at the site. Solar systems appear to be costlier at present, but costs are expected to reach grid parity soon. Moreover, the operating costs of solar systems are normally very low.

SOURCES OF ENERGY PRODUCTION ALREADY IN USE

a)Fossil Fuels (Coal, Oil, Petroleum):- Presently much electrical energy in India is produced from fossil fuels like coal and oil. Transport activities depend on oil and petroleum. Fossil fuels though give energy, but also produce unwanted CO_2 when ignited. India should make efforts to find more efficient ways of using its coal resources, possibly by setting up coal cleaning facilities or plants integrated with carbon capture and storage (CCS) facilities of some sort.

b) Hydropower:- USA, Germany, China and India rank high in the world in hydropower generation.

In hydropower projects, rainwater is harvested in a natural or man-made reservoir located on high terrain and released as desired to drive turbines located in a valley below to generate electricity, thus converting the potential energy of stored water into electrical energy. After use, the water may be released to a river downstream to become a source of fresh water for irrigation or for water supply to towns further downstream or use small flows to just operate a wheel or hydraulic ram or pump to pump up water to an elevated reservoir.

The whole operation is clean and no CO_2 is released in generating electricity there from, and neither does the water go to waste after use in the turbines. Hydropower projects are not possible in fl at terrains with alluvial soils. They are possible where there is mountainous terrain and rocky soil which can hold water.

There are some recent studies that refer to the generation of methane and carbon dioxide from anaerobic activity likely from the mud at the edges of a lake as the water level shrinks.

Double use of land: Mumbai has been served for many years by a large and dependable hydroelectric scheme (Tata Hydro at Bhivpuri and at Lonavla, near Mumbai) with the monsoon filling up its reservoirs. After the lake water operates the turbines, it is released downstream into a river for further use as water supply to several townships and also for irrigation purposes.

The Tatas are now working with the idea of placing floating solar PV panels on the lake water surface (24,000 acres) so as to make double use of the lake land. The waters will continue to give hydropower while the solar PV panels will help generate additional electric power from solar sources. If the full water surface is used, a potential of 4,000 MW exists. No new land will have to be purchased for the solar panels.

c) Gases:-

i. Coal Gas:- Coal gas is also referred to as town gas and in the past was the principal fuel for domestic heating and cooking. Coal burning was also used in the past to generate 'producer gas' to drive vehicles (especially during the war time when imported petrol was scarce but coal was locally available). However, it has tended to lose favour as it is based on a polluting, fossil fuellike coal.

ii. Liquid Natural Gas(LNG): Natural gas deposits have been found in abundance in the Qatar region of the Middle East, as well as in Russia and in the North Sea above Britain. The gas is composed mainly (>90%) of methane. It is odourless, non-toxic and non- corrosive. It liquefi es at atmospheric pressure when cooled to -160^0 C.

Qatar has invested heavily in refrigerated ships to be able to transport liquid natural gas (LNG) in bulk to other countries, whereas Europe receives its supplies in the form of gas through pipes laid from Russia.

India has enormous gas resources which will no doubt be used extensively in the years to come. The gas deposits found in the Krishna–Godavari basin will last for many years to come.

iii. Compressed Natural Gas (CNG): Natural gas may also be supplied in the form of compressed natural gas (CNG), generally supplied at high pressure (200–250 kg/cm^2) in small cylinders (50 L water capacity) and is used both in households as well as in transport vehicles. The properties of CNG make it a safe fuel. It is lighter than air, and hence in case of leakage it disperses into the atmosphere rapidly. Its high auto-ignition temperature of 540 degrees centigrade as against petrol's 360 degrees centigrade makes it even more safe fuel. The use of CNG is has increased and the people use it increasingly for car and bus transport purposes.

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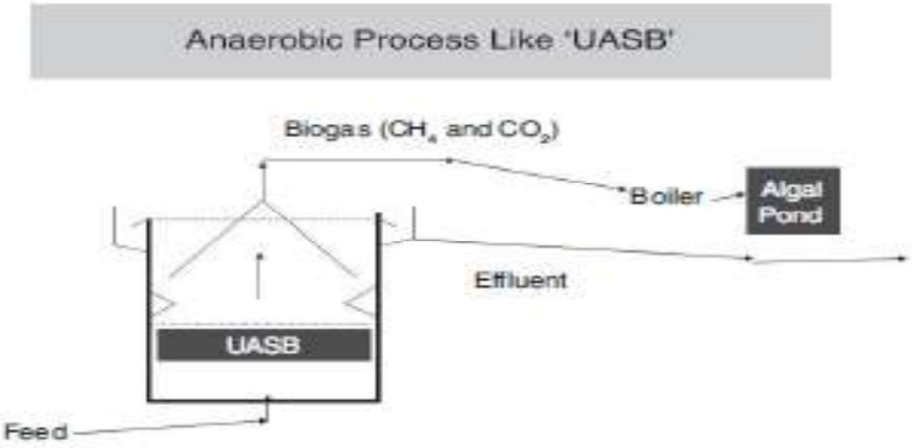
d) Agricultural Biomass and Community Wastes: Agricultural biomass (crop residues, sugarcane bagasse, leaves, twigs, grass, etc.) and community wastes (sewage) and wastewaters from the food and beverage industry, etc., can all be a good source of biogas.

Wastewaters like sewage are sent to municipal wastewater treatment plants, while wastes from market places and food and such industries which are high in organic content may be treated separately in industry-owned plants such as 'upflow anaerobic sludge blanket' (UASB) plants or other 'waste-to-energy' plants, for anaerobic decomposition. In breaking down organic matter through the action of anaerobic decomposers, CO_2 is released along with CH_4 (methane), both of which are greenhouse gases responsible for global warming. The methane can be used as fuel while the carbon dioxide can be bubbled through an algal pond where it can be absorbed in photosynthesis forming more algae which can be harvested



Municipal Solid Waste Collection and Disposal

In India, the conventional system of handling solid wastes has been to use petrol- or diesel-driven vehicles for collection of the waste from roadside bins or from houses, followed by transport to a low-lying dump-site for disposal by dumping.

- All collection trucks and other vehicles engaged in solid waste collection must operate on renewable sources of energy.
- Vehicles should either run on biogas or CNG or be converted to EV (with electricity generated by solar panels or UASB-type anaerobic systems with dual-fuel engines in tow).

Waste Segregation:- Waste segregation in Indian cities must be implemented as it recycles and conserves resources and improves the working condition of the rag-pickers. The wet fraction of the segregated wastes being organic in nature needs to be composted. Incineration of the solid waste instead of dumping or landfill is done mostly in Western countries. Across Europe, there are over 400 plants of the 'waste-to-heat' type. Such plants use the city's solid wastes as fuel instead of oil or other fossil fuels and have efficient waste gas cleaning devices incorporated in

them so as to remove mercury, dioxine, CO_2, etc., besides smoke, soot and dust. Their excess heat is piped for use in adjoining homes or for producing electricity.

e) Nuclear Energy:- Nuclear fuel's efficiency of conversion to power is high, upwards of 70%, which makes it the cheapest fuel after fossil fuel (coal and oil) and it can reduce India's power shortage without producing any CO2 .

1. Besides safety aspects, the large land requirement of nuclear energy plants is a severe deterent. A large chunk of land has to be left vacant surrounding a nuclear plant for safety considerations. An additional chunk of land around this area has to be left vacant for controlled activities and controlled habitation. And yet another chunk of land has to be provided nearby for holding the nuclear waste for long periods.
2. Besides safety and land, another constraint is water. Large volumes of water are needed as cooling waters in the reactors. Their location is, therefore, often limited to coastal areas with easily accessible sea water. A danger which comes with seaside location is the danger of Tsunami wave action. Similarly, when located inland near large and perennial rivers, earthquake zones have to be avoided.
3. Another problem is the long time period required for getting international permits for nuclear plants and their construction (about 8–10 years altogether).

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ALTERNATIVE METHODS READY FOR USE

i) Wind Energy - Use of wind turbines for generating electric power is a ready-to-use alternative method of power generation. A wind energy plant on an average needs an investment of Rs 5.5 crore to Rs 6.50 crore per MW, compared to Rs 4 crore for a thermal and Rs 5 crore for a hydropower plant. Wind power costs Rs 3.50 to Rs4.00 per kWh against Rs 2.50 for coal-fired plants. Wind power is made affordable by pooling it with normal supplies.

Centre for Wind Energy Technology (CWET) for R&D work under the Ministry of New and Renewable Energy (MNRE, New Delhi) & according to CWET, Tamil Nadu has the most number of sites where wind power density is greater than 200 watts per sq metre.

Certain geographic areas in India (e.g., coastal areas, hilly areas and other specific locations) are located where wind farms can be set up.

Anaemometres are generally used to determine wind speeds. Currently, the ideal average wind speeds are reported to be between 7 and 9 metres per second (15–20 miles per hour) for utility-scale wind turbines suitable for commercial applications. Wind speeds less than 2 m/sec are not workable whereas wind speeds in excess of 14 m/sec are considered cyclonic.

Good wind speeds are best achieved by going above trees and buildings, preferably on building terraces.

- The greater the power to be generated, the larger the diametre of the turbine fan has to be provided.

Reverse Selling:- it is necessary to enable reverse selling of surplus electric power to national power grids so that those who generate power can also earn some money from it. Reverse selling is in a way encouraging private capital to be employed and public–private partnership to occur.

SOME DISCOURAGING PRE-REQUIREMENTS:- Before wind turbines can be installed in certain places, one may need permits from appropriate authorities involving one to submit

(i) A noise study

(ii) An avian study to determine potential impacts on birds and bats

(iii) An aviation administration study to determine if the wind turbine might interfere with aviation radar.

SOME INDIAN INSTALLATIONS:-

Wind power generation capacity in India has significantly increased in recent years. As of 30 September 2022, the total installed wind power capacity was 41.666 GW, the fourth largest installed wind power capacity in the world. Wind power capacity is mainly spread across the Southern, Western, and Northwestern states.

Muppandal Wind farm

Installed Wind Power Capacity	
Fiscal year,	**Cumulative capacity (MW)**
2005	6,270
2010	16,084
2011	18,421
2012	20,149
2013	21,264
2014	23,354
2015	26,769
2016	32,280
2017	34,046
2018	35,626
2019	37,669
2020	38,785
2021	40,355

The Indian government has installed over 800 wind-monitoring stations all over the country through the National Institute of Wind Energy (NIWE) and issued wind potential maps at 50m, 80m, 100m, and 120m above ground level.

State	Total Capacity (MW)
Tamil Nadu	9608.04
Gujarat	8561.82
Maharashtra	5000.33
Karnataka	4938.60
Rajasthan	4326.82
Andhra Pradesh	4096.65
Madhya Pradesh	2519.89
Telangana	128.10
Kerala	62.50
Others	4.30

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ii) Solar Energy- Solar energy is another ready-to-use technology whose prices are equalizing with existing grid prices. India has a lot of potential for developing solar energy systems as it is a tropical country which receives much sunlight for 250 to 300 days a year.

To meet this enormous demand of electricity, India has to consider renewable sources of energy (wind, solar, etc.)

- Solar power is reported to have the potential to meet 7% of India's electricity needs by 2022. It would reduce its carbon emissions by 2.6% and save India some US $5.5 billion by way of imports. For this reason, the Jawaharlal Nehru National Solar Mission was launched in 2009.
- Development of solar energy would give India added energy security, save it some foreign exchange, create new jobs and mitigate some carbon.

Some Typical Solar Energy Systems

Small solar thermal units

- solar cookers
- solar heaters
- solar coolers

They are based on direct absorption of heat from solar radiation to heat up water. No electricity is generated.

- Solar Cookers have very useful applications in schools, hostels, etc., where meals have to be prepared usually in large quantities. They are also useful for religious centres where large crowds visit on certain days and meals have to be prepared for them. Their use makes cooking cheaper and also saves production of CO_2 from use of other cooking media like LPG, wood, charcoal, etc

- Solar water heaters are popular for bathrooms and kitchens where hot water is required in relatively large volumes for hostels, hotels, hospitals, guest houses, industry canteens and such purposes, generally up to 60–70°C. Many industries (textile, dairy, pulp and paper, Pharma, leather, etc.) also often require hot water up to 100o C or more and may use solar heaters as pre-heaters
- Solar coolers capture solar radiation through solar collectors in the form of troughs. This generates hot water whose heat generates chilled water elsewhere of temperature 7° C. The chilled water is circulated to the rooms through a fan coil unit. No energy is consumed from the city grid.

Solar photovoltaic panels

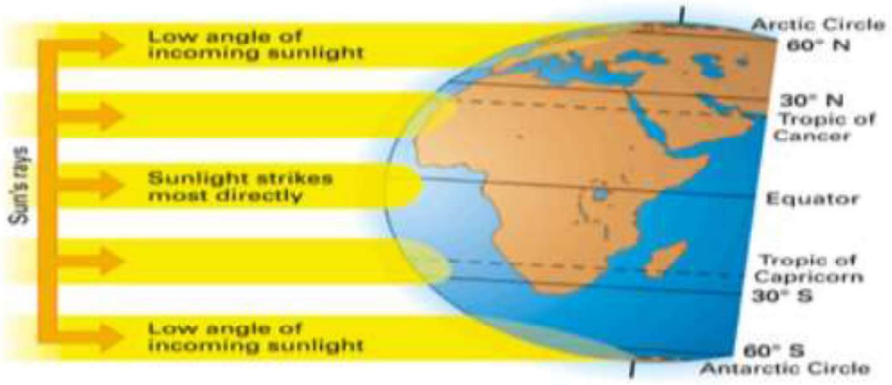
Solar PV cells directly convert sunlight energy into electrical energy by the use of silicon diodes. They can be used either for stand-alone systems or as grid-connected systems. It was Becquerel, the French scientist, who first discovered this phenomenon in 1839. Conversion efficiency is low, being only 10–13% at present for thin film type and 17–18% for crystalline silicon.

Solar energy business is reducing costs by 5 to 7% per year while coal-fired thermal plants are becoming costlier at 4 to 5% per year.

- The 'cells' are connected together either in series or in parallel to form what are called 'modules' or panels. These modules are encapsulated properly in glass or other material to be able to perform in field conditions for many years (upward of 25 years).
- The maximum area of a single, solar cell at present is about 225 cm2 (15 cms × 15 cms) and each cell can give about 3.4–4.0 Wp at 15% efficiency (where Wp stands for. watts at peak radiation).
- Several cells can be connected together to give a module or panel capable of giving 230 to 240 Wp or more. Panels capable of giving lesser wattage (like 44 or 75 or other) are also made mainly for smaller stand-alone installations.

Note: A series connection is done to increase output voltage while a parallel connection is done to increase the current output.

Different parts of the earth receive different amounts of solar radiation. This is because the Sun's rays strike the Earth's surface most directly at the equator. As you move away from the Equator, you will notice areas also receive different amounts of sunlight in different seasons.



The power that is generated with PV systems depends on the latitude and the duration of the peak. As one goes northwards, the available power reduces. At all latitudes, the power is maximum at

Large solar concentrators (for larger installations to serve cities and towns) which also work on the thermal principle of producing steam to operate turbines

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Solar PV Panel Installations

PV installations are made for various purposes. With larger panels, two types of installations are normally done: stand-alone systems and grid-connected systems. The main thing to remember is that solar power is ideal to use on a short time-per-day basis, for only a few hours in a day, so that the electricity need not be stored.

Use of solar energy in villages and rural areas are often restricted to a few hours in the evening. Solar PV lanterns (TERI-type) are the simplest and smallest type of devices which use solar energy. They require the use of small handy photovoltaic panels and have relatively short payback periods. Solar radiation generates the electric power for free. But the power may need to be stored in a battery for a few hours. The running cost then consists of replacement of the battery every 2–3 years. TERI-type lanterns make excellent items for donation to NGOs and others for installation in villages without electricity.

Solar PV Stand-alone Systems

a. Street-lights or telephones along roadways: - Street light poles provided along some roads in India, each carrying its own solar PV panel is very good example of stand-alone systems.

b. Operating intermediate stations for mobile phones in unelectrified areas: Presently, India has about 7 lakhs mobile telephone stations. The mobile phone industry used an enormous quantity of 2 billion litres of diesel oil in the year 2010 for operating these stations, and generated 5.3 million tonnes of CO_2 .The National Telecom Policy 2011 recommends the use of solar PV panels instead of gensets.

c. Operating small water treatment units in out of way places: In order to save on electricity storage batteries while operating the water treatment units locally, so as to remove hardness, arsenic or fluoride or any impurity in drinking water, the solar PV panels may be used.

d. Operating small wastewater treatment units in out of way places: Small wastewater treatment plants like lagoons may need renewable sources of power for operating aerators.

e. As a standby source of electric power in industry: Instead of a diesel-generating set for operating a machine or process in an industry, one could use a solar PV panel set up.

Problem:- A 5 HP pump is required to be operated only 4 hours per day to pump up enough water for a village water supply scheme. Solar PV panels are proposed as the area is not served by the local electricity board. The water is stored in a tank and supplied as needed. Estimate the number of panels required for operating the tube well pump.

Solution:-

Rating of Pump= 5 HP = 746 Watts/HP × 5 HP = 3730 Watts = 3.73 kW

Provide 50% more capacity to allow for losses, mismatch, etc.,

= 3.73 × 1.5 = 5.6 kW capacity.

Total power required for 4 hour operation = 5.6 kW × 4.0 hrs = 22.4 kWh.

If a panel can give 230 Wp, it will generate about 1 kWh in 4.35 hours. Hence, to generate 22.4 kWh, we will need, say, **23 panels** **Ans.**

Advantages of PV systems:

a. Long transmission lines are not necessary. Hence, transmission and distribution (T&D) losses are minimal.

b. Much land is not required to install them.

Solar PV Systems for Feedback of Excess Power to City Grids

Payment for 'feedback' of electricity from private installations into the public grid is an attractive inducement for new solar installations.

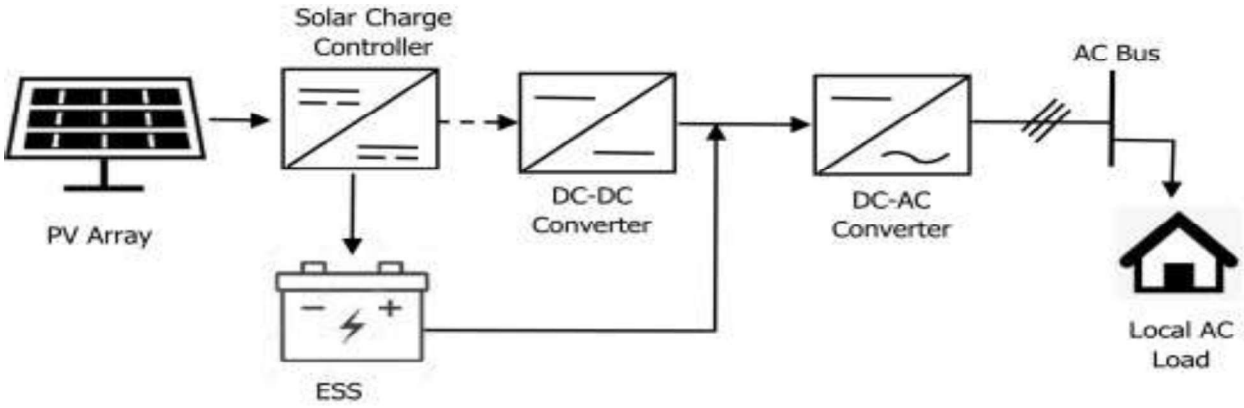
- It improves the electricity situation in the city as most cities suffer from a shortage of electricity, and governments are unable to meet this shortage for want of capital.
- It encourages private capital to come in and improve the shortage situation since payment is made at a rate that would make such feedback profitable for the investor.

It should be remembered that electricity must first be transformed into an alternating current of the correct voltage for the area using an inverter and also synchronised to 50 cycles per minute of the electricity network at the cost of the seller.

- In Gujarat, private parties are willing to install solar energy systems at their own cost and risk in cities provided the building terrace is leased out to them at a mutually agreed rent for a long enough period. The party gets paid at the official rate by the electric company for feeding-in the electricity into the town grid, and the party in turn, pays the building owner ` 3 per kWh fed as per metre.
- Maharashtra, India, has started to build a 150 MW solar power project in Dhule District. It is reported that the plant will produce electricity at ` 12 per unit and sell it at ` 17.90 to the grid.

When solar PV panels are provided and supply is either to the public grid or to the building tenants, there is a further cost of providing the necessary so-called 'balance of system' (BoS) to meet the needs of the installation. These may consist of all or some of the following items:

• Batteries (lead-acid or Ni-Cd batteries are preferred over lithium-ion)
• Inverter (needed because solar power is DC whereas AC is required for feed-in)
• Charge controller
• Metering of power produced by the PV system and power fed into the grid is necessary
• Cables to connect all items
• Supporting structures for mounting of PV panels, batteries, etc.



MODULE-II
Lecture-21

RENEWABLE ENERGY CERTIFICATES (RECs)

Objective:- Renewable Energy Certificates (RECs) is a market-based instrument to promote renewable sources of energy and development of the market in electricity.

- One REC is created when one megawatt hour of electricity is generated from an eligible renewable energy source.
- REC acts as a tracking mechanism for solar, wind, and other green energies as they flow into the power grid.

In India, RECs are traded on two power exchanges — Indian Energy Exchange (IEX) and Power Exchange of India (PXIL).

Types:-

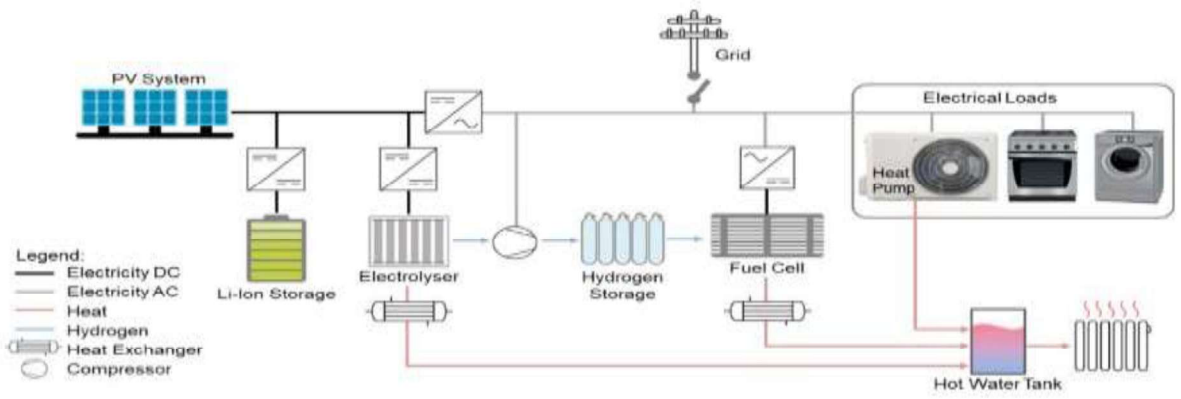
There are two categories of RECs, viz., solar RECs and non-solar RECs. Solar RECs are issued to eligible entities for generation of electricity based on solar as renewable energy source, and non-solar RECs are issued to eligible entities for generation of electricity based on renewable energy sources other than solar.

The solar certificate shall be sold to the obligated entities to enable them to meet their renewable purchase obligation for solar, and non-solar certificate shall be sold to the obligated entities to enable them to meet their obligation for purchase from renewable energy sources other than solar.

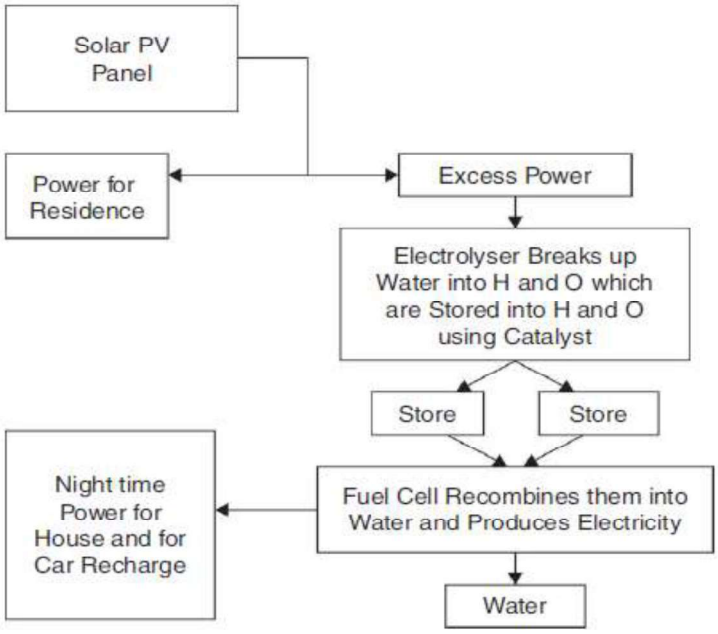
PV Solar Panels + Electrolyser + Fuel Cell: A unique arrangement has become possible to generate electricity from solar energy for domestic purposes and to recharge the batteries of an electric vehicle at night.

An MIT researcher who has developed a cheap self-generating catalyst recently, using which it is possible to run an electrolyser which is hooked up with a PV solar panel system.

- The PV solar panel produces electricity during the daytime to meet domestic needs. Surplus electricity is taken to an electrolyser which uses Electrolysis process to generate H and O from water and stores it for recombining later in the night hours in a fuel cell to generate electricity once again and give water as a by-product.



Below is the block diagram of the Solar PV panels using Fuel cells



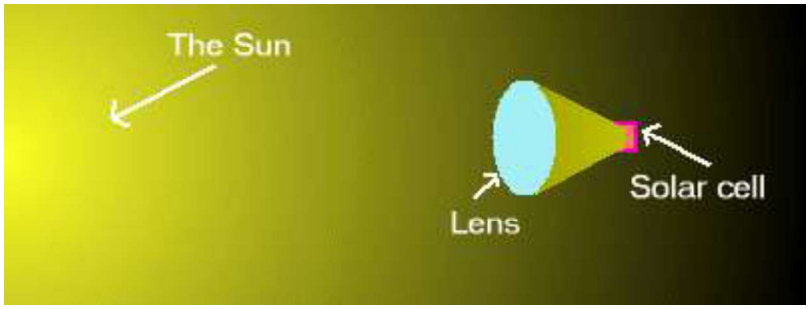
CONCENTRATED SOLAR POWER (CSP) SYSTEMS:

Concentrated solar power (CSP, also known as concentrating solar power, concentrated solar thermal) systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight into a receiver.

Electricity is generated when the concentrated light is converted to heat (solar thermal energy), which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermochemical reaction.

The efficiency of PV panels is only about 15%, which is relatively higher at 24% for Concentrated Solar systems using parabolic mirrors.

Solar concentrators are the devices that collect solar radiation and concentrate at a single focal point. The devices are mainly comprised of series of lens or mirror assembly, heat receiver, and the tracking system.



A solar concentrator uses lenses, called Fresnel lenses, which take a large area of sunlight and direct it towards a specific spot by bending the rays of light and focusing them. Fresnel lenses are shaped like a dart board, with concentric rings of prisms around a lens that's a magnifying glass.

The solar concentrators have the advantage that the solar cells can be spaced farther apart since light can be focused on each cell. This means fewer solar cells need to be made and the panels cost less to construct.

Concentrating technologies exist in four optical types, namely parabolic trough, dish, concentrating linear Fresnel reflector, and solar power tower.

A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned at the longitudinal focal line of the parabolic mirror and filled with a working fluid. The reflector follows the sun during the daylight hours by tracking along a single axis

In a CSP plant that includes storage, the solar energy is first used to heat the molten salt or synthetic oil which is stored providing thermal/heat energy at high temperature in insulated tanks. Later the hot molten salt (or oil) is used in a steam generator to produce steam to generate electricity by steam turbo generator as per requirement.

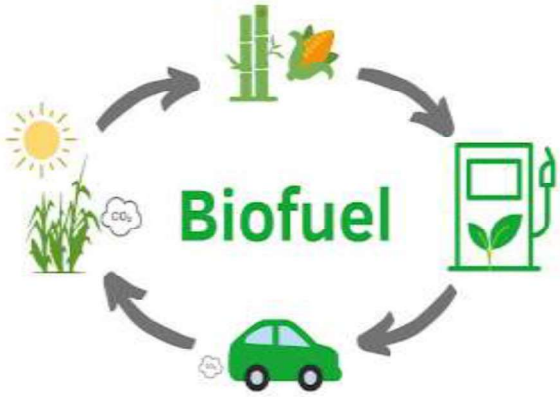
HYBRID SYSTEMS: WIND–SOLAR INTEGRATED SYSTEMS

- Hybrid systems are used where solar and wind-operated systems are both required to complement one another.
- We know solar systems are not available at night or in cloudy weather, while wind-driven systems do not work at no-wind times.
- Thus, the two could be made to complement one another to keep power supply available for longer time of day and night without much use of storage batteries

MODULE-II
Lecture-22

BIOFUELS

Biofuel is a fuel that is produced over a short time span from biomass, rather than by the very slow natural processes involved in the formation of fossil fuels, such as oil.



There are several biofuels obtained from natural sources such as agricultural plants, algae, corn, sugarcane, etc.

a. Ethanol (CH_3CH_2OH) is a renewable fuel that can be made from various plant materials, collectively known as "biomass." Ethanol is an alcohol used as a blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions.

The most common blend of ethanol is E10 (10% ethanol, 90% gasoline) and is approved for use in most conventional gasoline-powered vehicles up to E15 (15% ethanol, 85% gasoline). Ethanol can be obtained through chemical conversion of agricultural products such as corn or sugarcane and can be used as an additive or as an alternate fuel.

Corn is used in colder countries and sugarcane in warmer countries such as India and Brazil.

Brazil and USA are also making flexi-fuel cars and cars capable of running on 85% blend of ethanol and gasoline giving proportionately less mileage

b. 'Jetropha' an oil-bearing plant that can be readily cultivated in India and whose oil can be used as additive with petrol or diesel.

Jetropha is regarded as a better alternative to sugarcane as it needs much less water (even wastewater will do) and can be grown on land considered 'wasteland' for other purposes. With diesel engines, Jetropha can be used unblended on 100% basis also. Jetropha has performed well even on High Mountain and sub-zero temperatures.

c. Methanol' is another biofuel. It is methyl alcohol (CH_3OH). Commonly known as non-drinking alcohol since it is toxic. Methanol has only 1 carbon ion and four H ions which makes it a good fuel for mixing in petrol, or if slightly modified, it can be used alone in modern petrol engines. Methanol can also be easily transformed into bio-diesel and used. It can also be used in fuel cells and be burnt in power generation plants. Methanol can be used to produce many other things, e.g., plastics, paints and plastics, furniture and carpeting, car parts and windshield wash fluid.

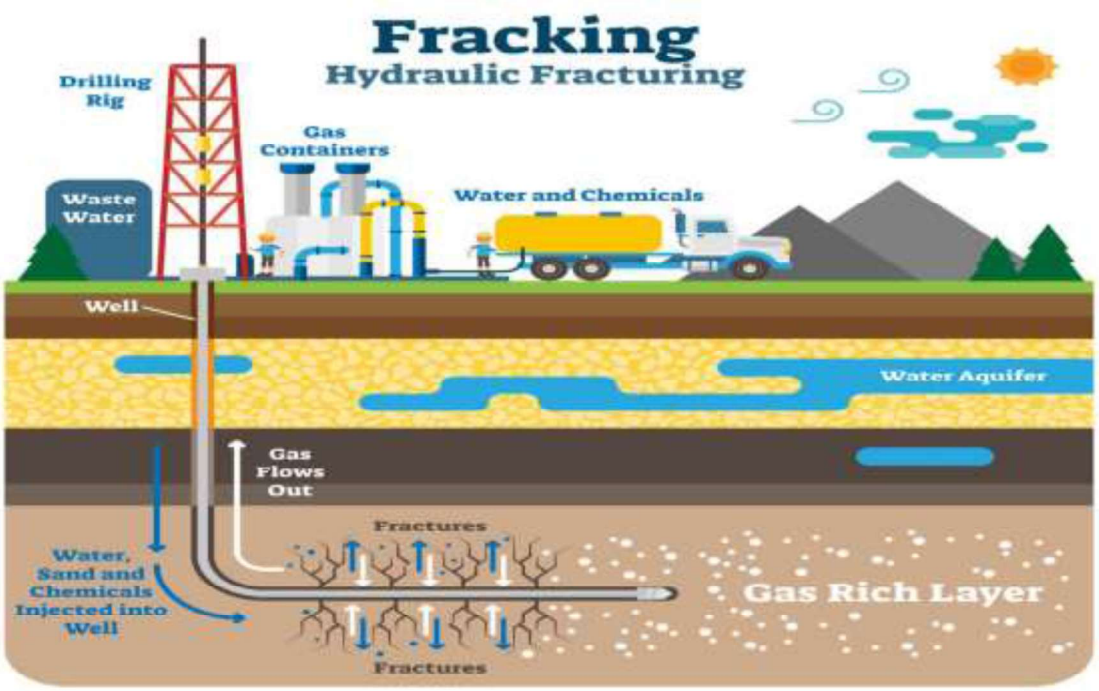
d. Microalgae:- The production of various biofuels from microalgae has the potential of providing a sustainable technology for addressing the growing global energy need while partially mitigating global warming by capturing carbon dioxide from the atmosphere through photosynthesis.
The use of wastewater for growth of microalgae may be preferred to satisfy the need of microalgae for nitrogen, phosphorus and trace metals and simultaneously provide treatment of wastewaters. The organisms are then subjected to ultrasound and hydraulic cavitation for harvesting and for extraction of lipids from the cells. The extracted lipids are then subjected to esterification for production of biodiesel.
Currently, the major drawback for wide-use application of microalgae as fuel source is high economic cost of the conventional processes used for growth and harvesting of microalgae, and the extraction of lipids from the cells for biodiesel production.

Advantages of using Biofuels:
1. It would start a new industry and give employment to many people
2. it would save the country the foreign exchange it spends at present to import oil from the world market.

GREEN TECHNOLOGIES NEEDING SOME PRIOR R&D WORK

i) Shale Gas:

Shale gas is a natural gas found in rock formations and requires specialised production techniques. No gas is exactly a green technology because some carbon is produced in its combustion. However, much lesser carbon is produced than with oil or coal.
Shale gas exploration is called 'fracking' or vertical drilling followed by horizontal drilling using chemicals, explosives and millions of gallons of water to create tiny fractures in the shale formations underground.



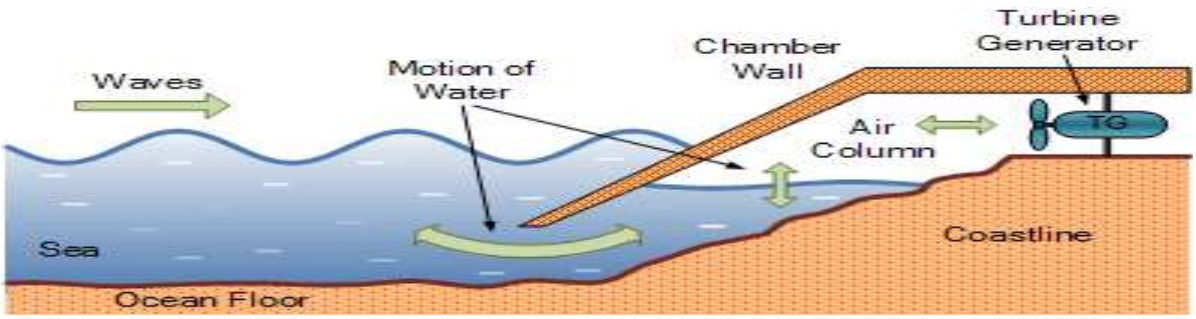
Shale gas is found in tight reservoirs that have poor permeability. Shale gas requires large number of wells as the volume per well is small.

Hydraulic fracturing ('fracking') requires enormous water and causes water pollution problems. The wastewater contains hydrocarbons, heavy metals, scalants, salts and microbes in the flow-back water from shale gas wells.

India also has massive shale deposits and, thus, there is good scope for use of this gas. Gas from shale deposits will become available all over the Gangetic plain, Gujarat, Rajasthan, NE Assam, and some coastal regions.

ii) **Wave Energy**: Wave energy appear to be most promising for use in India. The wave potential is said to be around 1,000 times more than the wind potential. Waves are a stable and predictable source of power.

Wave energy is a form of renewable energy that can be harnessed from the motion of the waves. Depending on the lunar cycles, tides, winds, and weather, waves can vary in size and strength. As waves roll through the ocean, they create kinetic energy, or movement. This movement can be used to power turbines, which, in turn, create energy that can be converted into electricity and power.



Waves Make Water Rise and Fall in Chamber This Forces the Air Back and Forth Through Turbine and Generates Power

iii) **Geothermal Energy**:- Geothermal energy is available in certain parts of the world e.g., Iceland and around southern Russia and can be used in the form of hot or lukewarm water in homes or public baths. Naturally available hot water from a groundwater source can be, for example, piped and supplied city-wide through a network of pipes laid in tunnels, built to facilitate their maintenance.

India is supposed to have a large scope for setting up geothermal energy projects (10,000 MW) but not much progress has been done yet.

MODULE-III
Lecture-23
GREEN TECHNOLOGIES FOR PERSONAL AND CITYWIDE APPLICATION

In the present situation of increasing global warming, we have to think 'green' at every level. Precisely because we are a poor country, we should think 'green' without waiting for any other country. Thinking 'green' saves us money, and may help us earn some money too.

Thinking 'green' helps us to:

a. Conserve our precious resources such as fossil fuels, water, forests, etc.
b. Reduce our expenditure on use of costly electricity by using it more efficiently
c. Generate less pollution (including less greenhouse gas emissions) from various activities.

MEASURES TO BE TAKEN FOR GREEN CITY:-

Indian government wants to develop a 'green city' in every state of the country, powered by renewable energy. The 'green city' will mainstream environment-friendly power through solar rooftop systems on all its houses, solar parks on the city's outskirts, waste-to-energy plants and electric mobility-enabled public transport systems. Of the 100 GW of solar power that the Indian government aims to have by 2022, 40 GW is targeted through solar rooftops by 2022. Some of the measures to be taken for Green City are:-

a) Plentiful Parks: - Public green space improve the quality of life of urban dwellers and serve as a buffer against flooding.
b) Efficient Public Transportation: Transit solutions that allow people to get around quickly and easily without a car are a key element to a green city. The most sustainable transit systems utilize clean technologies and reduce CO_2 emissions.
c) Quality Public Space: - Good green city has places that are built (or renovated) to human scale, places where people can safely walk and happily gather.
d) Bike Lanes:- Heavy traffic (and angry drivers) can make cycling unpleasant and even dangerous without designated lanes. The most bike-friendly cities create separated bike paths, provide safe parking, offer charging stations for e-bikes, institute bike-sharing programs, and allow cyclists to bring their bikes on buses and trains for longer trips.
e) Green Buildings:-Green building refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.
f) Comprehensive Recycling and Composting Programs:- The green city initiatives are going further than gathering cans and bottles, by adding electronics and food waste to the list

of items recycled and composted, and by instituting larger-scale programs to recycle water for park and agriculture irrigation.

g) Smart Energy Policies:-Government should encourage by making policies towards development of green cities.Over 100 U.S. cities and counties have partnered with the LEED (Leadership in Energy and Environmental Design) for Cities certification program to institute actionable plans to reduce carbon emissions and create sustainable waste, transportation, energy.

CARBON EMISSION REDUCTION AT PERSONAL LEVEL

There are many possible ways in which carbon reduction can be achieved at the personal level, such as in travel, in the use of electricity at home, in avoiding imports and in dietary habits.

i. **Travel:** Remember "Walk if walkable, share transport otherwise". Use public transport. Emissions vary per passenger per km travelled with the mode of travel, being maximum for air travel, lesser for cars, still less for buses, least for trains and zero if you walk. Hence, one is always advised to walk to a nearby (walkable distance) destination. Send children to school either by school bus or public bus. Car-pooling is always a good idea as it reduces the fuel consumed per person. The larger the car, the greater the emissions.
The advice for car owners is to use small or medium-sized cars, drive fewer kilometres per year and use low emission fuels, blended with biofuels if available.
Use LPG or CNG as fuel. In India, CNG gas is preferred as a clean and cheaper fuel. 55,000 taxis in Bombay have switched over to CNG in recent times. Avoid high speeds and start-and-stop driving. Go for electric cars. They can be used as needed during the day and charged from the building's solar energy system when the car is parked for the night.

ii. **Video Conferencing**: For a single person, avoid long distance business visits by air. Use 'video conferencing' instead of air travel. It is immensely cheaper and often just as effective.

iii. **Holiday Travel by Air**: Avoid Travelling to long distances or other countries as Air travel consumes lot of fuel and are the reason for carbon emission.

iv. **Food and Flower Travel**:- People seek exotic items from distant countries forgetting the damage they cause to local trade and the general environment. Large amount of CO2 is produced because food and flower items go by air from one country to another daily. Air travel is generally required to keep them fresh. The world buys pineapples, fruits and flowers from tropical countries. It is also applicable to various building materials, fittings and fixtures and a whole lot of commercially traded items.

v. **Change from Fossil Fuel to Biofuel**: The use of biofuels instead of diesel oil in tractors, cars and water pumps and as additives to petrol for other vehicles is possible.

vi. **Avoid Stand-by Mode of Appliances**:- Shut off all TVs, electronic devices at the wall plug instead of keeping on stand-by mode with a red light on, as the latter consumes some electricity.

vii. **Dietary Aspects**: Buy organic and local, avoid processed and packaged items and become a vegan if possible.

MODULE-III
Lecture-24

CARBON EMISSION REDUCTION AT LOCAL AUTHORITY AND CITYWIDE LEVEL

Electric consumption in a community is much affected by:

1) **Presence of Industries**: The extent of electricity consumed by a community depends on the level of industrialization within that community. Industry and commerce are often the biggest consumers of electricity. Infosys in Bangalore reduced electric consumption by nearly $7 million.
2) **Residential Consumption**: The extent of electricity consumed by residencies in a community depends on the lifestyle of the people and the efficiency of its fittings and fixtures used.

   The average electric consumption of a family of average size 2.3 persons in different countries varies from 4,000 kWh/year in the USA to as little as 426 kWh/year in Denmark.

   It would be a clever idea in India to replace an electric heater by a solar thermal heater to let nature do the job especially if it is a large family or a hotel or hospital or a student hostel.

   Use LED as they consume even lesser power (one-third less than CFL).
3) **General Lighting**: General lighting covers various uses such as:

   (i) Traffic Lights,

   (Ii) Street Lights,

   (Iii) Advertisement Hoardings,

   (iv) Lighting for open air marriages and other functions

   (v) Public purpose TV's, etc.

   In Indian cities, one sees very bright lighting at open air functions/weddings and for illuminating all advertisement hoardings. LED lighting could be made mandatory for such purposes. In some countries, the manufacture of 100W or higher incandescent bulbs is now forbidden.

4) **Timer Switches**: Fix timer switches on electric lights in common usage areas such as staircases and passages.
5) **Use Certified Fittings/Fixtures**: Use fixtures and fittings certified by the Bureau of Energy Efficiency (BEE). Avoid cheap and uncertified products which consume more electricity for the same service given.
6) **Provide Solar Water Heaters**: Adopt solar water heaters for hot water in all hotels, hostels, guesthouses, clubs, industrial kitchens, etc., where water consumption is high enough.

7) **Cooking Fuel**: It is always recommended that cooking be done using gas rather than electricity. Pressure cookers are recommended for use. Solar cookers are especially recommended where mass cooking has to be done for many persons at a time. Microwaves are best for heating pre-cooked food. Industrial kitchens need much hot water for washing of utensils, etc., and solar heaters are generally recommended for use.
8) **Economic Air Conditioning**: Just as heating is essential in colder countries, air-conditioning is needed in warmer countries. Air conditioning is not considered a luxury anymore in warm climates. Most important buildings and offices have air conditioning provided in them. However, air conditioning is one of the highest consumers of electricity.

   The design of the building to be air-conditioned should take into account the use of cavity walls (hollow blocks for walls of rooms) and the provision of sun breakers and double-glazed window panes as far as possible.

   Effort has to be made to reduce sunlight penetration into the interiors while allowing daylight to come in.

   Prepare the rooms to be air-conditioned. Use thermostats/ sensors on A/C areas, if possible, to save on electricity. Just as insulation is important in case of home heating, the same way insulation is important for air-conditioned spaces.

   Set A/Cs to kick-in at 26^{o}C rather than at usual 22 or 23^{o}C. It will make the area comfortable and save on electricity.
9) **Computers**: The manufacture of a single desktop computer is reported to produce nearly ½ tonne of CO_2 per unit.

   The 2-gram microchip contained in each computer produces 4,000 g of CO_2 in its manufacture.

   A liquid crystal display (LCD) monitor consumes much less power than one with a cathode ray tube (CRT).

   A desktop computer uses 60–120 W of power when active. A laptop uses only 15 W.
10) **Mobile Phones**: A mobile phone contains copper, gold, silver and a small amount of platinum. As these are precious metals consuming much power in their refining, they should be recycled.
11) **Cattle and Other Animals**: In India, 70% of the rural population owns livestock. Livestock includes cattle, buffaloes, horses, sheep, goats, donkeys, camels, poultry and many more. It also includes their dung. Belching (enteric emissions) gives 600 L of methane gas per day per cow.

MODULE-III
Lecture-25
GREEN TECHNOLOGIES FOR SPECIFIC APPLICATIONS

Promotion of 'Green' Buildings: Urbanisation is so rapid that 60% of the world population is expected to be living in cities in the next 15 years. So, green buildings and green infrastructure seem a must.

- Green buildings focus on health, environment and resources.
- Green buildings can save a community some good money and a lot of carbon emissions.
- Green buildings reduce exposure to toxic material that may have health impacts.
- Green buildings help conserve resources such as fossil fuels, water, etc.

Promotion of 'green' buildings and area planning begins with sensitising professionals such as architects, engineers and builders through the medium of seminars/talks, etc. held along with professional organisations such as The Indian Institute of Architects, The Institution of Engineers, etc.

Benefits of Green Buildings:

Environmental Benefits:-

- Enhance and protect ecosystems and biodiversity
- Improve air and water quality
- Reduce solid waste
- Conserve natural resources

Economic Benefits:-

- Reduce operating costs
- Enhance asset value and profits
- Improve employee productivity and satisfaction
- Optimize life-cycle economic performance

Health and community benefits:-

- Improve air, thermal and acoustic environments
- Enhance occupant comfort and health
- Minimize strain on local infrastructure
- Contribute to overall quality of life

First and Second Generation Green Buildings:-

First generation green buildings are those which use various architectural and engineering devices in planning and constructing the building so as to minimise electric power and other resources consumed, but do not generate any power of their own, whereas second generation

green buildings not only minimise use of power and resources needed to operate the building but also generate some or all of their power requirements at the building site itself.

- **When the entire power needs of the building are met from local generation, the building is often referred to as 'zero-energy building'.**

Green Buildings in India:- 'Green' buildings might cost 5–10% more in capital cost, but it is certainly less expensive in operating cost. The country already has over 1.2 billion sq feet (from over 500 buildings) under LEEDS certification and another 105 million sq feet under GRIHA. Urbanisation is rapid all over the world. In India, certification is likely to reach 80 billion, making green buildings 20% of the total by 2030 says the Indian Green Building Council (IGBC).

** LEEDS (Leadership in Energy and Environmental Development Systems)
***GRIHA (Green Rating for Integrated Habitat Assessment)

The government has also mandated that SEZ areas conform to green requirements. Today, there are at least 265 registered SEZs in India. A 100 new airports are coming up. The new Hyderabad airport has secured silver rating under LEEDS.

Benefits:

- Excellent business opportunities exist for architects, builders, engineers, plumbers and other professionals conversant with green building guidelines and practices and ECBC codes.
- It makes people conscious of the need of the resources such as fossil fuels, water etc.
- People get exposed to the need for a low-carbon lifestyle.

Comparison between LEEDS and GRIHA

LEEDS RATING SYSTEMS	GRIHA RATING SYSTEMS
It is a measurement tool which is used to verify that a building or neighbourhood was designed and built using strategies aimed at improving performance.	It is a tool used for building's environmental performance in context to Indian Atmospheric Condition
It was created by U.S Green Building Council in 2000	It was developed jointly by TERI (The Energy Research Institute) New Delhi, and the Government of India from 2006
LEEDS is for all building types and all building phases including new construction, interior fit outs, operations and maintenance and core and shell.	It applies to new buildings-commercial, residential & institutional

LEEDS primarily allocates points for achieving a certain performance level.	GRIHA awards points for implementing strategies, as well as for outcomes
LEEDS allocates comparatively more points to materials.	GRIHA emphasizes energy use above all other categories
In LEEDS no negative marking is given for an environment-unfriendly act committed by a developer.	GRIHA gives negative marks for an environment-unfriendly act committed by a developer.

MODULE-III
Lecture-26

The Leeds Rating System Guidelines:-

The LEEDS guideline can be used to cover various aspects of a project design starting with the building construction site itself and proceeding up to the various planning modules. All new 'green' buildings are required to comply with the guidelines suggested for each of the following aspects of a project:

1. The building construction site
2. Environmental concerns in architectural planning
3. Energy conservation and its better management
4. Water conservation
5. Waste management
6. Social relevance

1. The building construction site

- Design with minimum disruption to the site; minimise soil displacement indiscriminate leveling. At the same time, minimise soil erosion, if necessary
- Preserve and reuse nutrient-rich top soil for landscaping
- Reduce micro-climate temperature rise by planting shady trees, etc.
- Minimise pumping; let drainage follow existing slopes/contours; facilitate easy maintenance.
- Preserve biodiversity, compensate by reforestation and replanting if necessary
- Facilitate groundwater recharge; restrict rainwater run-off by constructing small bunds as necessary to promote groundwater recharge. Avoid local flooding problems

2. Environmental concern through choice of materials and architectural planning:

The following measures are recommended to keep a building more cool and comfortable and reduce power costs in air-conditioning:

- Achieve thermal comfort (e.g., use hollow blocks for walls to keep house cool and cut down on use of A/Cs in tropical climates)
- Avoid use of glass facades especially on sunny sides as they greatly increase the load on electricity for air-conditioning
- Achieve visual comfort (through choice of colors, materials, etc. as necessary)
- Prevent heat gain (through use of larger roof overhangs to extend shade for longer hours)
- Use of concrete or stone 'jalli'
- Where a sloping roof is provided, use double-roofing for heat insulation
- Where roofing is in the form of a terrace, a roof garden may be provided to keep heat away from the floor below. Special treatment of the terrace floor before laying the earthwork is necessary to prevent later leakages.
- Scientifically designed vertical and horizontal fins (sun breakers) could be provided in some cases. Double-glazed window panes would reduce heat transfer.

- Ensure entry of adequate daylight inside the house to avoid use of electric lights during day time (important to use skylights, transparent sheets, etc., which would admit natural daylight and save electric power).

3. **Energy conservation and better management**: Heating, ventilation and air-conditioning (HVAC) are usually the three heaviest users of electricity. Normally, air-cooled window air conditioners are said to use more electricity per tonne of refrigeration capacity than equally large units with re-circulating waters.
    - Use LED-type bulbs
    - Also shut off all electrical fixtures from wall plugs. Some energy is consumed when kept on 'stand-by' position.
    - Use timers and other control devices on staircases and other common areas to turn off lights when not needed.
    - Use solar water heaters (not electric devices) to meet hot water requirements.
    - Use 'heat pumps' to recover heat which would otherwise be lost in wastewater or waste air.
    - Use renewable sources of energy such as wind energy and/or solar energy for power generation wherever possible.
4. **Water conservation**:
    - Minimise use of public water supplies. Conserve water. Reuse wherever possible.
    - Provide for rainwater harvesting and groundwater recharge to minimise use of water from public water supplies.
    - Provide low-flow fixtures, orifices in pipes and dual-flushing tanks to minimise use of water.
    - Provide waterless urinals where power supply is dependable.
    - Reuse grey/black waters after suitable treatment either for flushing in toilets or for gardening.
    - In garden, plant species which inherently require less water.
5. **Waste management**:
    - Use a 'natural' method of treatment such as a lagoon, pond or constructed wetland or land irrigation which avoids use of electric power for aeration in wastewater treatment, pumping, etc.
    - Reuse wastewater as far as possible for gardening, crop irrigation, groundwater recharge and other uses at site, after minimal treatment
    - Reuse solid wastes after segregation (i) to recover re-usable materials and (ii) use the wet waste to prepare compost from the organic wastes and recover biogas and manure for use.
6. **Social relevance**: We must use affordable, durable and low-maintenance building materials which are locally available, need locally available skills and management systems to maintain and avoid use of fuel for transport of men and materials from distant countries. It should also reduce consumption of all resources, promote reuse of water and avoid wastage of materials and production of wastes. Use green plants to keep up air quality.

MODULE-III
Lecture-27

GRIHA Rating System Guidelines:

GRIHA- the National Rating System evaluate the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'.

- Keeping in view of the Indian agro-climatic conditions and in particular, the huge number of non-AC buildings, a National Rating System - GRIHA has been developed which is suitable for all kinds of building in different climatic zones of the country.
- The system was initially conceived and developed by TERI (The Energy & Resource Institute) as TERI-GRIHA which has been modified to GRIHA as National Rating System after incorporating various modifications.
- It takes into account the provisions of the National Building Code 2005, the Energy Conservation Building Code 2007 announced by BEE and other IS codes, local bye-laws, other local standards and laws.

The criteria have been categorised as follows:

The criteria have been categorised as follows:

A. Site planning

Conservation and efficient utilization of resources

Objective: To maximize the conservation and utilisation of resources (land, water, natural habitat, avi fauna, and energy) conservation and enhance efficiency of the systems and operations.
Criteria 1 Site Selection:

Commitment: Site plan should be in conformity to the Development Plan/Master Plan/UDPFI guidelines (mandatory). Site should be located within ½ km radius of an existing or planned and funded bus stops, commuter rail, light rail or metro station or the proposed site is a brownfield site (to rehabilitate damaged sites where development is complicated by environmental contamination, reducing pressure on undeveloped land).
Criteria 2 Preserve and protect the landscape during construction/compensatory depository forestation.

*Commitment P*roper timing of construction, preserve top soil and existing vegetation, staging and spill prevention, and erosion and sedimentation control. Replant, on- site, trees in the ratio 1:3 to those removed during construction.

Criteria 3 Soil conservation (till post-construction).

Commitment Proper top soil laying and stabilization of the soil and maintenance of adequate fertility of the soil to support vegetative growth.

Criteria 4 Design to include existing site features.

Commitment Minimize the disruption of natural ecosystem and design to harness maximum benefits of the prevailing micro-climate.

Criteria 5 Reduce hard paving on-site and /or provide shaded hard- paved surfaces.

Commitment Minimize storm water run-off from site by reducing hard paving on site.
Criteria 6 Enhance outdoor lighting system efficiency.

Commitment Meet minimum allowable luminous efficacy (as per lamp type) and make progressive use of a renewable energy -based lighting system.
Criteria 7 Plan utilities efficiently and optimize on-site circulation efficiency.

Commitment Minimize road and pedestrian walkway length by appropriate planning and provide aggregate corridors for utility lines.

Health and well being

Objectives To protect the health of construction workers and prevent pollution.
Criterion 8 Provide at least, the minimum level of sanitation/safety facilities for construction workers.

Commitment Ensure cleanliness of workplace with regard to the disposal of waste and effluent, provide clean drinking water and latrines and urinals as per applicable standard.

Criterion 9 Reduce air pollution during construction.

Commitment Ensure proper screening, covering stockpiles, covering brick and loads of dusty materials, wheel-washing facility, water spraying.

B. Building planning and construction stage Conservation and efficient utilization of resources

Objective To maximize resource (water, energy, and materials) conservation and enhance efficiency of the system and operations.

Water

Criterion 10 Reduce landscape water requirement.

Commitment Landscape using native species and reduce lawn areas while enhancing the irrigation efficiency, reduction in water requirement for landscaping purposes.

Criterion 11 Reduce building water use.

Commitment Reduce building water use by applying low-flow fixtures, etc.

Criterion 12 Efficient water use during construction.

Commitment Use materials such as pre-mixed concrete for preventing loss during mixing. Use recycled treated water and control the waste of curing water.

Energy: end use

Criterion 13 Optimise building design to reduce the conventional energy demand.
Commitment Plan appropriately to reflect climate responsiveness, adopt an adequate comfort range, less air-conditioned areas, day lighting, avoid over-design of the lighting and air-conditioning systems.

Criterion 14 Optimise the energy performance of the building within specified comfort limits.
Commitment Ensure that energy consumption in building under a specified category is 10%–40% less than that benchmarked through a simulation exercise. Ensure that thermal comfort in non air conditioned spaces are within specified limits.

Energy: embodied and construction

Criterion 15 Utilization of fly ash in the building structure.
Commitment Use of fly ash for RCC (reinforced cement concrete) structures with in-fill walls and load bearing structures, mortar, and binders.

Criterion 16 Reduce volume, weight, and time of construction by adopting an efficient technology (e.g. pre-cast systems, ready-mix concrete, etc.).

Commitment Replace a part of the energy-intensive materials with less energy-intensive materials and/or utilize regionally available materials, which use low-energy/energy-efficient technologies.

Criterion 17 Use low-energy material in the interiors.

Commitment Minimum 70% in each of the three categories of interiors (internal partitions, panelling/false ceiling/interior wood finishes/ in-built furniture door/window frames, flooring) from low-energy materials/finishes to minimize the usage of wood.

Energy: renewable

Criterion 18 Renewable energy utilization.

Commitment Mandatory provide renewable energy system with capacity equivalent to 1% of connected load for lighting and space conditioning. Meet energy requirements for a minimum of 5% of the internal lighting load (for general lighting) or its equivalent from renewable energy sources (solar, wind, biomass, fuel cells, etc). Energy requirements will be calculated based on realistic assumptions which will be subject to verification during appraisal.

Criterion 19 Renewable energy - based hot- water system.

Commitment Meet 20% or more of the annual energy required for heating water through renewable energy based water-heating systems.

Recycle, recharge, and reuse of water

Objective: To promote the recycle and reuse of water.

Criterion 20 Waste- water treatment

Commitment Provide necessary treatment of water for achieving the desired concentration of effluents.

Criterion 21 Water recycle and reuse (including rainwater).

Commitment Provide wastewater treatment on-site for achieving prescribed concentration, rainwater harvesting, reuse of treated waste water and rainwater for meeting the building's water and irrigation demand.

Waste management

Criterion 22

Commitment: To minimize waste generation, streamline waste segregation, storage, and disposal, and promote resource recovery from waste.

Criterion 23 Reduction in waste during construction.

Commitment Ensure maximum resource recovery and safe disposal of wastes generated during construction and reduce the burden on landfill.

Criterion 24 Efficient waste segregation.

*Commitmen*t Use different coloured bins for collecting different categories of waste from the building.

Criterion 25 Storage and disposal of waste.
Commitment Allocate separate space for the collected waste before transferring it to the recycling/disposal stations.

Criterion 26 Resource recovery from waste.

Commitment Employ resource recovery systems for biodegradable waste as per the *Solid Waste Management and handling Rules, 2000 of the MoEF*. Make arrangements for recycling of waste through local dealers.

Health and well-being

Objective To ensure healthy indoor air quality, water quality, and noise levels, and reduce the global warming potential.

Use of low-VOC (volatile organic compounds) paints/ adhesives / sealants.
Commitment Use only low VOC paints in the interior of the building. Use water – based rather than solvent based sealants and adhesives.

Criterion 27 Minimize ozone depleting substances.

Commitment Employ 100% zero ODP (ozone depletion potential) insulation; HCFC (hydrochlorofluorocarbon)/ and CFC (chlorofluorocarbon) free HVAC and refrigeration equipments and/halon-free fire suppression and fire extinguishing systems.

Criterion 28 Ensure water quality.

Commitment Ensure groundwater and municipal water meet the water quality norms as prescribed in the Indian Standards for various applications (*Indian Standards for drinking [IS 10500-1991], irrigation applications [IS 11624-1986].* In case the water quality cannot be ensured, provide necessary treatment of raw water for achieving the desired concentration for various applications.

Criterion 29 Acceptable outdoor and indoor noise levels.
Commitment Ensure outdoor noise level conforms to the Central Pollution Control Board–Environmental Standards–Noise (ambient standards) and indoor noise level conforms to the *National Building Code of India, 2005, Bureau of Indian Standards, Part 8–Building Services; Section 4–Acoustics, sound insulation, and noise control.*

Criterion 30 Tobacco and smoke control.

Zero exposure to tobacco smoke for non-smokers, and exclusive ventilation for smoking rooms.

Criterion 31 Universal accessibility

Commitment: To ensure accessibility and usability of the building and its facilities by employees, visitors and clients with disabilities

C. Building operation and maintenance

Objective Validate and maintain 'green' performance levels/adopt and propagate green practices and concepts.

Criterion 32 Energy audit and validation.

Commitment Energy audit report to be prepared by approved auditors of the Bureau of Energy Efficiency, Government of India.

Criterion 33 Operation and maintenance protocol for electrical and mechanical equipment.

Commitment Ensure the inclusion of a specific clause in the contract document for the commissioning of all electrical and mechanical systems to be maintained by the owner, supplier, or operator. Provide a core facility/service management group, if applicable, which will be responsible for the operation and maintenance of the building and the electrical and mechanical systems after the commissioning.

☞ GRIHA is a guiding and performance-oriented system where points are earned for meeting the design and performance intent of the criteria. Each criterion has a number of points assigned to it. It means that a project intending to meet the criterion would qualify for the points. GRIHA has a 100 point system consisting of some core points, which are mandatory to be met while the rest are optional points, which can be earned by complying with the commitment of the criterion for which the point is allocated.

Points Scored	Rating
51-60	1 star
61-70	2 star
71-80	3 star
81-90	4 star
91-100	5 star

MODULE-III
Lecture-28

Energy Conservation Building Code (ECBC):-

The purpose of Energy Conservation Building Code (ECBC) is to provide minimum requirements for energy-efficient design and construction of buildings and their systems.

- ☞ The ECBC was developed as a first step towards promoting energy efficiency in the building sector.
- ☞ The Code is applicable to buildings or building complexes that have a connected load of 100 kW or greater or a contract demand of 120 kVA or greater.
- ☞ Generally, buildings or complexes having conditioned area of 1,000 m^2 or more will fall under this category

The provisions of the Code apply to:

- Building envelopes, except for unconditioned storage spaces or warehouses(walls, roofs, windows)
- Mechanical systems and equipment, including heating, ventilating, and air conditioning
- Solar hot water heating
- Interior and exterior lighting
- Electrical power and motors

The provisions of this Code do not apply to:

- Buildings that do not use either electricity or fossil fuel
- Equipment and portions of building systems that use energy primarily for manufacturing processes

To comply with the Code, buildings shall:

(a) Have an Energy Performance Index Ratio (EPI Ratio) as defined, that is less than or equal to 1
The Energy Performance Index (EPI) of a building is its annual energy consumption in kilowatt-hours per square meter of the building. While calculating the EPI of a building, the area of unconditioned basements shall not be included.

Under ECBC, the Bureau of Energy Efficiency (BEE), India, has a rating system for green buildings ranging from one star to five-star The rating system recognises that there are two major climatic conditions prevalent in India, the hot-humid and hot-dry
The Bureau (BEE) recommends the following range of electric power consumption for a building which is more than 50% air-conditioned and is located under a given climatic condition, as follows

Rating Hot and Humid Hot and Dry	(kWh/sq m/year)	
1-star	200 – 175	180 – 155
2-star	175 – 150	155 – 130
3-star	150 – 125	130 – 105
4-star	125 – 100	105 – 80
5-star	Below 100	

For buildings that are less than 50% air-conditioned, the rating is as follows:

Rating Power Consumption	(kWh/sq m/year)	Hot and Humid Hot and Dry
5-star	below 45	below 35

GREEN HOTELS: - A green hotel, is an environmentally sustainable hotel or accommodation that has made important environmental improvements to its structure in order to minimize its impact on the natural environment.

Green hotels are invariably designed as 'green' buildings first, along with green services to their guests.

- Hotels try to become 'water positive', i.e., they try to generate more fresh water than they use which is done by rainwater harvesting and reuse of wastewater after treatment for gardening and non-potable uses.
- Hotels try to become 'Carbon positive' (through afforestation and minimum use of fossil fuels)
- Hotels try to have 'zero solid wastes' (through salvaging, recycling and composting).
- Hotels use several energy saving devices (LED bulbs, efficient pumps, timer switches, etc.).
- Their door keys are smart cards which are also used to operate room lights and air-conditioners by the customers
- They save water by using dual flushing tanks, pressure reducing devices, dual-plumbing, etc.
- They save power through solar water heating equipment for rooms as well as hotel kitchens and laundry, etc.

- The hotels also make extensive use of wastewater after treatment to meet cooling, gardening and other needs and ensure solid waste segregation and reuse, composting, use of recycled paper, use of less water consuming plants in their gardens, etc.

Characteristics of a green hotel:-

- Housekeeping uses non-toxic cleaning agents and laundry detergent
- 100% organic cotton sheets, towels and mattresses
- Non-smoking environment
- Renewable energy sources like solar or wind energy
- Bulk organic soap and amenities instead of individual packages to reduce waste
- Guest room and hotel lobby recycling bins
- Towel and sheet re-use (guests can tell housekeeping to leave these slightly used items to reduce water consumption)
- Energy-efficient lighting
- On-site transportation with green vehicles
- Serve organic and local-grown food
- Non-disposable dishes
- Offers a fresh-air exchange system
- Grey water recycling, which is the reuse of kitchen, bath and laundry water for garden and landscaping
- Newspaper recycling program.

Criteria of a Green Hotel:-

An eco-hotel must usually meet the following criteria:

- Dependence on the natural environment
- Ecological sustainability
- Proven contribution to conservation
- Provision of environmental training programs
- Incorporation of cultural considerations
- Provision of an economic return to the local community

GREEN HOSPITALS

According to the Indian Green Building Council, a green hospital building can be defined as one which enhances patient wellbeing, aids the curative process, while utilising natural resources in an efficient, environment friendly manner.

Benefits of Green Hospitals:

a. Can reduce patient recovery time
b. Eliminates Sick building Syndrome for both patients & staffs
c. Reduces stress level in hospital workers, thus improving quality of care
d. Lower energy and water consumption

- ☞ Green Hospitals incorporate all the devices which a green hotel would. They also incorporate all the devices which different municipal services would incorporate.
- ☞ Hospitals must also ensure that used needles and sharps do not find their way back to the market. They must be broken before disposal to make reuse impossible.
- ☞ Radioactive wastes and cytotoxic drugs need separate removal as per their own guidelines.
- ☞ Body parts are generally sent to local crematoria for incineration.

MODULE-III

LECTURE-29

GREEN TECHNOLOGIES FOR TRANSPORT

There are many different forms of transport to serve a city and they all have varying forms of greenness among them. For example,

a) In inland cities, there are the usual motor cycles, motor cars, SUVs, rickshaws, buses, trucks and tempos, using different fuels.

b) In Coastal Cities there are more different transport medium which include motorboats, launches, ferries, catamarans, and ships

The many varieties of transport can all be placed under two broad groups:

i. **Private Mode**

ii. **Public Mode**

i. **Private Mode:-** In greening modes of transport, effort has mainly been directed towards greater use of the following:

- Biofuels
- Use of smaller cars, (eventually hybrid cars, electric vehicles)
- Switch over to CNG or LPG gas
- Facilitation of traffic by providing flyovers, tunnels, wider roads, etc.
- Discouraging of traffic in certain areas by various means
- Mass transport (buses, trains, metros, monorails, etc.)
- Better planning and layout of new towns with walkways, cycle paths, etc., connecting residential and working areas

ii. **Public Mode:-** Mass transport is often provided for ensuring better traffic conditions so that business is not affected. mass transport facilities will always be ultimately needed in every city (not because of their lower per capita emission) but mainly because there is a limit to the build-up of vehicular traffic that can be handled by any city's roadway system, and every city would like to attract more and more people to come and live in it, and shop in it, for commercial reasons.

GREEN ROADS:- India is planning to invest enormous sums of money in infrastructure, starting with roads, railways, bridges, ports, airports, water, sanitation, power, gas, irrigation and telecom. Green roadways have to deal with many items listed under at least the following:-

- Environment
- Water
- Access, congestion
- Safety
- Construction activity

- Materials
- Technology

The designers/town-planners have to be encouraged to improve sustainability of the roadways and to lessen their environmental impact.

The construction process may itself generate large quantity of debris, produce run-off that chokes the sewer system and pollutes the receiving water bodies. The massive traffic may cause its own problems.

Government has taken various initiatives to cut pollution by promoting bio-fuel and e-rickshaws, and now the Green Highways Policy has been launched for roadside plantation in this respect

Key features of Green Highways Policy 2015

- Promote greening and development eco-friendly National Highway corridors across the country with participation of farmers, private sector and government institutions including Forest Department.
- It will address the issues that lie in the road of development and pave the way towards sustainable development.

At present, the National Highways in the Country cover about one lakh Km. Most of this length is available in varying widths.

PORTS AND HARBOURS:-

Ports and harbours become key points in transport for any city, more so if the city has an international reputation. Therefore, the design of ports and harbours is intimately tied up with design concerning other infrastructure such as roads, railways, bridges, tunnels, waterways, airfields, buildings and their drainage systems.

GREEN TECHNOLOGIES FOR INDUSTRIES:

From cradle to the grave:- Industries often constitute a big part of our so-called 'carbon footprint'. Industries generate carbon emissions right from the start of mining operations for their raw materials to the chemicals and processes used in their manufacture, and continue to emit during transport and use of their products and even during their disposal after their useful life is over. Industries, therefore, produce emissions *from cradle to the grave*

Manufacturing Emissions and Secondary Emissions

- ☞ Emissions occurring from manufacturing operations at the factory site may be called 'manufacturing' emissions.
- ☞ Emissions occurring elsewhere (e.g., on the road during transport, etc.) may be termed 'secondary' emissions.

CARBON EMISSIONS FROM INDUSTRIES IN GENERAL AND CARBON TAX

Carbon emissions from industries depend on several factors such as

- ❖ Requirement of electric power for operating its various machinery and manufacturing processes
- ❖ Type of fuel used for generating additional power locally
- ❖ Type of devices which require pumping, compression, pressure build-up, etc.
- ❖ Type of solvents and other chemicals used in manufacture.

Indian companies are gradually picking up the idea of measuring their carbon emissions. It is true that "*what you measure, you can control; what you do not measure, you do not know*".
The following are among the top 10 Indian companies which have started measuring and controlling emissions:
The Tata Companies (TCS, Tata Global Beverages, Tata Chemicals, and Tata Power) Wipro, Yes Bank, ACC, Sesa Goa, GVK Power and Infra, ABB and some more

ACC has a carbon dioxide reduction target of 27 kg per tonne of cement by 2013. Tata Chemicals is targeting a 20% reduction by 2020 with 2008 as the baseline. Titan industries are targeting a 50% reduction by 2015 with 2010 as the baseline. Infosys, Wipro, Yes Bank, all have Carbon reduction targets of 50% and over.

MODULE-III

LECTURE-30

CARBON EMISSIONS FROM A FEW SELECTED INDUSTRIES IN INDIA

a) **Cement Industry:-** Cement is an important construction ingredient produced in virtually all countries. Carbon dioxide (CO_2) is a byproduct of a chemical conversion process used in the production of clinker, a component of cement, in which limestone ($CaCO_3$) is converted to lime (CaO). CO_2 is also emitted during cement production by fossil fuel combustion and is accounted for elsewhere. However, the CO_2 from fossil fuels is accounted for elsewhere in emission estimates for fossil fuels. The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines) provide a general approach to estimate CO_2 emissions from clinker production, in which the amount of clinker produced is multiplied by the clinker emission factor.

Cement is produced in large, capital intensive production plants generally located near limestone quarries or other raw carbonate mineral sources as these sources are the principal raw materials used in the cement production process. Because the production plants are expensive, the number of plants in a country is generally limited (less than 100). Carbon dioxide is released during the production of clinker, a component of cement, in which calcium carbonate ($CaCO_3$) is heated in a rotary kiln to induce a series of complex chemical reactions (IPCC Guidelines). Specifically, CO_2 is released as a by-product during calcination, which occurs in the upper, cooler end of the kiln, or a pre calciner, at temperatures of 600-900°C, and results in the conversion of carbonates to oxides. At higher temperatures in the lower end of the kiln, the lime (CaO) reacts with silica, aluminum and iron containing materials to produce minerals in the clinker, an intermediate product of cement manufacture. The clinker is then removed from the kiln to cool, ground to a fine powder, and mixed with a small fraction (about five percent) of gypsum to create the most common form of cement known as Portland cement.

A possible reduction in CO_2 emissions through various measures for improving the energy efficiency of the whole process can be achieved by

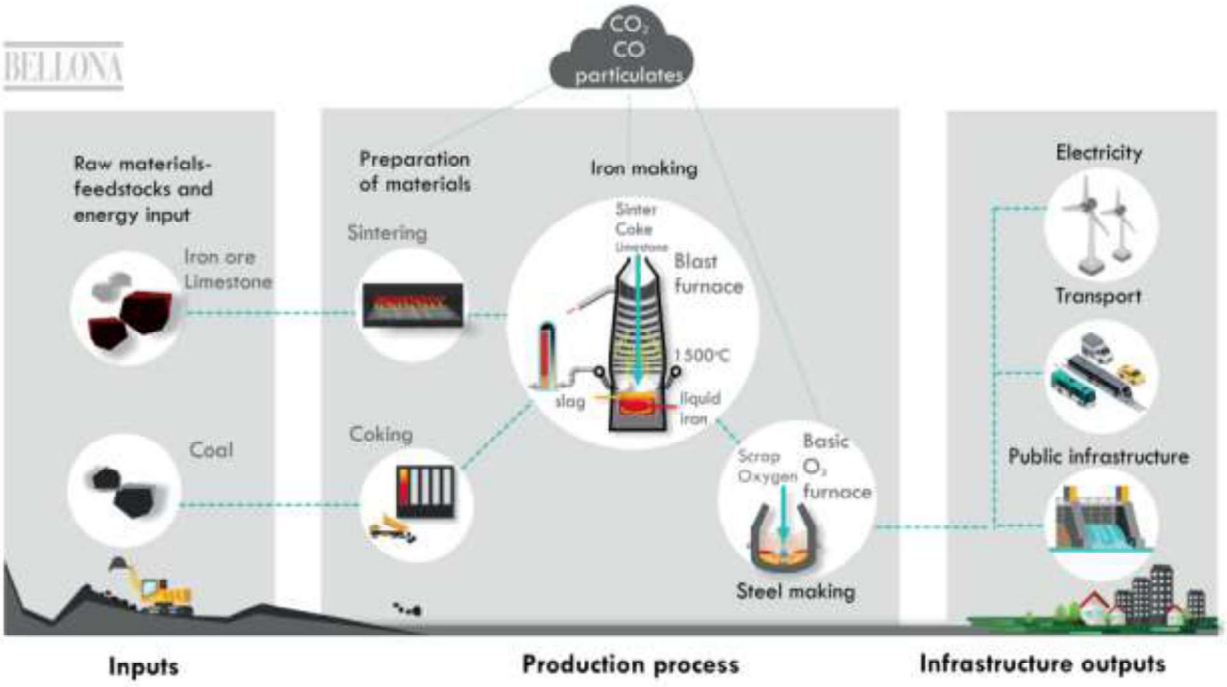
- Shifting from semi-wet to semi-dry process
- By replacing high-carbon fuels by low-carbon fuels
- By applying a lower cement/clinker ratio
- By increasing the additives in proportion to the cement
- By use of blended cements and application of alternative cements (mineral polymers).

b) **Steel Industry:-** In steel plants, the coke ovens help convert raw coal into coke of required quality, while producing by-products which become raw materials for other operations. This coke along with limestone and iron ore brought from the mines are fed into blast

furnaces (along with air) to make pig iron. The resulting pig iron from the blast furnaces is treated further in open hearth or electric furnaces for conversion into steel.

All the fumes and polluted air are passed through dry and wet scrubbers and electrostatic precipitators for cleaning before disposal to the open atmosphere. No attempt is made to remove or treat CO_2 and other GHGs before release.

Cleaning up one of the largest industrial sources of CO2 pollution is therefore key to tackling climate change. Emissions from steel must be reduced by 50% by 2050 and then continue to fall, to meet the world's climate goals, according to the International Energy Agency (IEA).



Green steel is the manufacturing of steel without the use of fossil fuels such as use of green hydrogen and Electric Arc Furnaces

c) **<u>Brick-making:-</u>** Brick-making is a widely dispersed industry since bricks are made all over India. Brick-making industry is widely associated with the construction industry in India. Bricks are used not only in housing but also in infrastructure construction in the country. Hence, it is fabricated in several parts of the country wherever the soil permits its fabrication and in most cases, extremely simple, rural type of set-up are used, such as brick-kilns fired by locally available fuels including agricultural residues. The emissions are, therefore, entirely dependent on the fuels used for fi ring the brick kilns, and must be estimated accordingly.

d) **Fertilisers:-** Manufacture of fertilisers is a complex matter as it involves several different types of fertilisers (ammonia, urea, ammonium nitrate, etc.). For ammonia production, naptha or natural gas is reformed with air and steam resulting in CO_2 , N_2 and H_2 which are taken to a methanator for further treatment. Ammonia is used in producing urea. Reaction between ammonia and sulphuric acid gives ammonium sulphate. Phosphate rock or fluorapatite when reacted with sulphuric acid gives phosphoric acid. Gaseous wastes such as CO_2 and methane are produced in manufacture and some fugitive releases also take place. The fuel used in manufacture also leads to co-production of CO_2.

e) **Food, Beverage and Allied Industries:-** A large number of industries fall in this group such as the following:

- milk and milk products
- meat and poultry
- cane sugar
- tanneries
- beer breweries
- wineries
- whiskey
- rum distilleries
- edible oils

Their liquid effluents have been subjected to treatment (often anaerobic) before discharge either into water courses or on land for irrigation of food and fodder crops. Treatment has often been in the form of non-mechanised systems such as lagoons, ponds, ditches, wetlands and the like, all of which require relatively large tracts of land.

Industrial wastes high in organic content have been treated in up flow anaerobic sludge blanket (UASB)-type plants to undergo anaerobic digestion and produce biogas containing CO_2 and methane (CH_4) without use of external power.

The methane can be used in the industry's boilers as fuel instead of oil or coal and the CO_2 removed by bubbling it through an algal pond. If biogas is available in large enough quantities, it can be supplied to a near-by industry or fed to a dual fuel engine and electricity produced.

f) Shops, Offices and Commercial Establishments

Some scope lies in

- Economic use of paper and other materials, Xerox and such machines.
- Another important source of GHGs depending on company's policies is regarding travel, both daily travel to and fro office and long distance travel by air or car or public transport to meet clients, etc.
- Economy with A/Cs, use of more efficient equipment and appliances, office and shop lighting (CFL or LED lights), etc.

MODULE-III

LECTURE-31

Need for Wider Application to Town Planning and Area Re-Development Projects

Green concepts should become immediately applicable to the planning of all new large buildings in both the public and private sectors, with immediate effect. Besides this:-

- ❖ All new SEZs.
- ❖ All new regional development schemes planned for areas within large metropolitan cities.
- ❖ Intra-city roadways

'GREEN' INFRASTRUCTURE FOR MUNICIPAL SERVICES

Green infrastructure covering various municipal services refers to a city's entire infrastructure mainly consisting of its

- ➢ Water supply distribution network,
- ➢ Storm water collection and disposal network
- ➢ Wastewater collection, treatment and disposal system
- ➢ Solid waste collection and disposal system
- ➢ Industrial and hazardous waste collection and disposal system.

a) Water Supply and Distribution:-

- ✓ Electricity usage must be minimized in water treatment and in water distribution, since the production of 1 kWh of electricity to operate a pump releases 0.44 kg CO_2 at the power generating station
- ✓ A gravity scheme must invariably be preferred
- ✓ Where pumping is involved, pressures in the system must be optimized so as to meet desired pressure criteria without unduly heavy pumping.
- ✓ Various typical water conservation measures such as avoiding unduly high pressures in distribution systems, installing dual-flushing tanks, pressure reducing devices, promoting reuse, etc. have to be taken by the local body.
- ✓ Corrosion has to be avoided as it leads to leakages and excessive wastage of water.
- ✓ Metering is another possibility but is often limited to small areas of a city's network and penalties for non-payment are not imposed strictly.
- ✓ Augmentation of fresh water supply can be done through
  - rainwater harvesting
  - reuse of wastewater after treatment
  - desalination of sea water

b) Storm Water Run-off:- All storm water drainage systems will need to be reviewed in the light of local rainfall and runoff data every few years and suitable measures taken to provide flap gates, dykes, holding ponds, large volume pumping stations, large canals,

locks, etc. Mumbai is already setting up its first storm water pumping station at Haji Ali. This will place a demand on the power supply grid when the pumps are operated since a separate renewable source of energy has not been provided. Under changing climatic conditions, the people will need more accurate data on rainfall intensities and corresponding run-off patterns. Better and timely statistical data will be needed all round.

c) **Wastewater Collection, Treatment and Disposal:-** Much work remains to be done in terms of wastewater collection, treatment and disposal, and it gives us an opportunity to decide whether we need a centralised or a decentralised sewerage system.

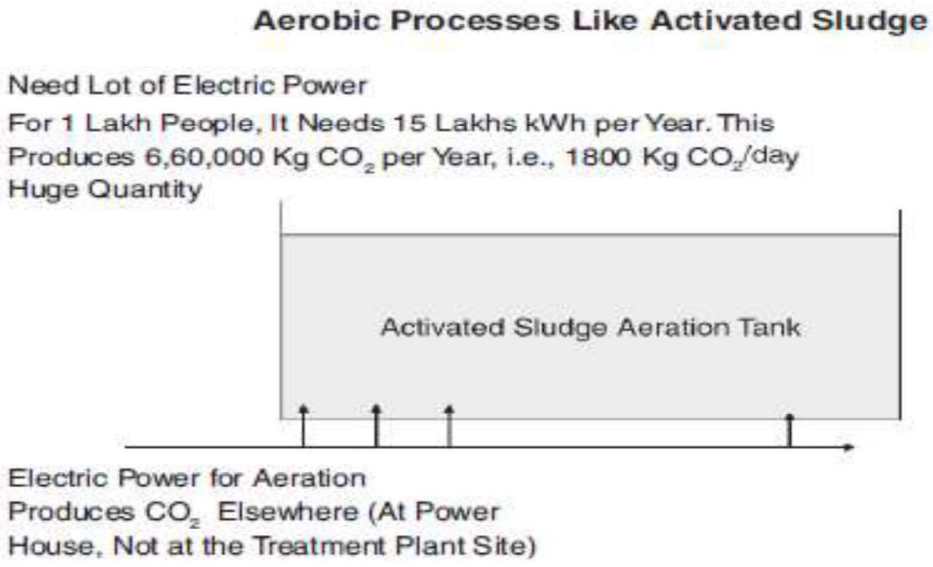
In a centralised system, a network of laterals, sub-mains and mains are provided with a long outfall leading to a river or water course where the wastewater is finally discharged

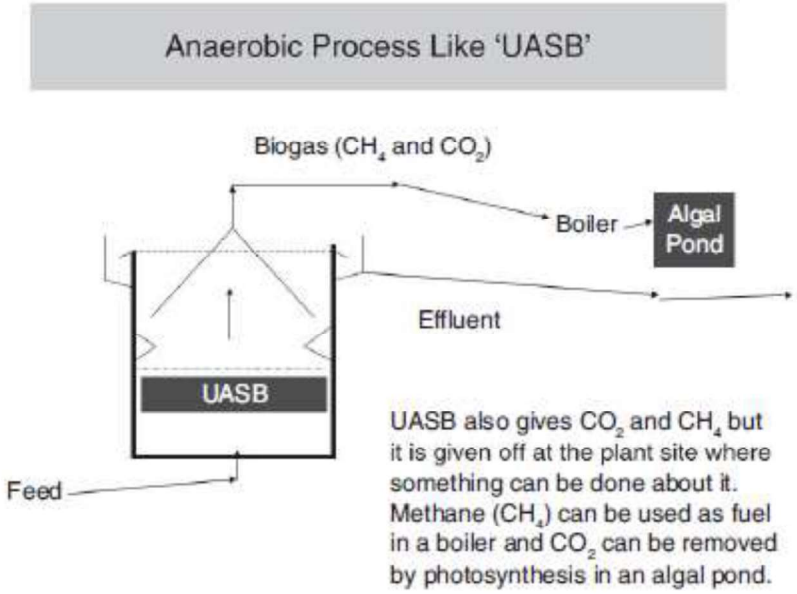
In decentralised collection network consisting of several smaller outfalls discharging smaller quantity at each outfall which can be either used for irrigation or soaked underground to conserve water.

With the old-style long outfall, we have to treat a large volume of wastewater at the outfall and hence conventional treatment methods (activated sludge and such) needing electric power for aeration are generally used. They also produce carbon along with power generation.

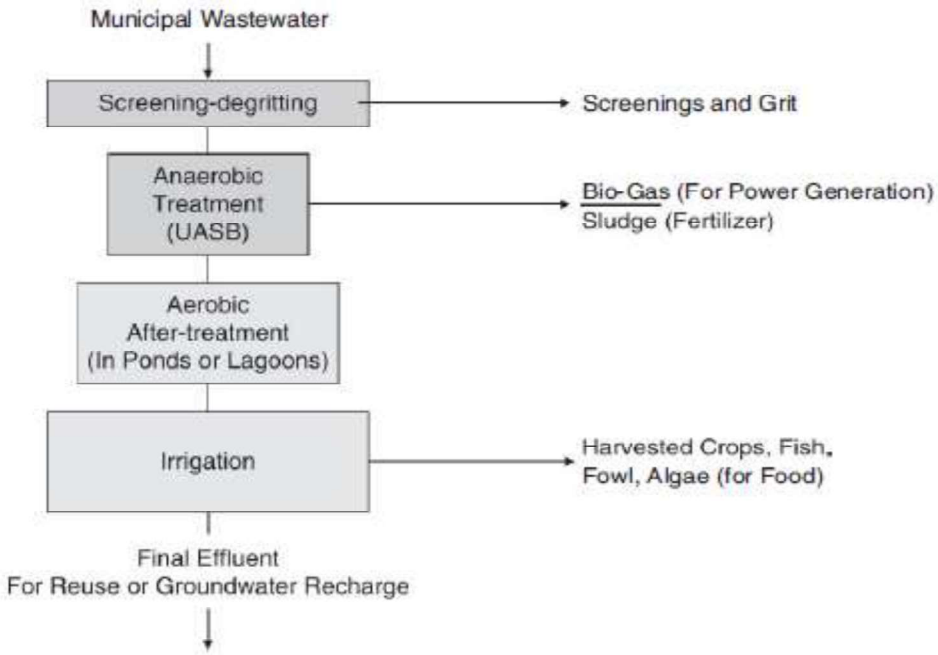
With decentralised collection systems, the volumes to be handled at each outfall are smaller and hence, 'natural' systems of treatment (such as ponds, lagoons, constructed wetlands, irrigation, etc.) become feasible to use. Natural methods do not need electric power which means they become affordable in a warm country like India, and additionally, they do not generate CO_2

Decentralised systems deal with a number of smaller areas. This requires less pumping. Natural systems also require minimum of building materials and earthwork and conserve water and nutrients through final ground water recharge.





(UASB) process does not need power. Hence, its use is considered desirable and economic for wastewater treatment. However, because of anaerobic activity, it directly produces CO_2 and CH_4 which are both GHGs. However, carbon dioxide can be removed by bubbling the effluent through an algal pond before discharge. The methane can be used for its fuel value. Hence, both these problems can be sorted out, and the UASB made a very useful process to consider especially as a pre-treatment unit before a pond or lagoon for high BOD wastes.



d) Solid Waste Collection and Disposal

In India, the conventional system of handling solid wastes has been to use petrol- or diesel-driven vehicles for collection of the waste from roadside bins or from houses, followed by transport to a low-lying dump-site for disposal by dumping.

- All collection trucks and other vehicles engaged in solid waste collection must operate on renewable sources of energy.
- Vehicles should either run on biogas or CNG or be converted to EV (with electricity generated by solar panels or UASB-type anaerobic systems with dual-fuel engines in tow).

Waste Segregation:- Waste segregation in Indian cities must be implemented as it recycles and conserves resources and improves the working condition of the rag-pickers. The wet fraction of the segregated wastes being organic in nature needs to be composted. Incineration of the solid waste instead of dumping or landfill is done mostly in Western countries. Across Europe, there are over 400 plants of the 'waste-to-heat' type. Such plants use the city's solid wastes as fuel instead of oil or other fossil fuels and have efficient waste gas cleaning devices incorporated in them so as to remove mercury, dioxine, CO_2, etc., besides smoke, soot and dust. Their excess heat is piped for use in adjoining homes or for producing electricity.

Biogas emissions from municipal solid waste (MSW) disposal sites occur continually for up to 20–25 years or more after waste is freshly deposited. Biogas can be economically pumped out for at least 23 years. The biogas can be collected by a network of pipes buried in the deposited material and connected to a suction pump. Indian solid waste dumpsites give a biogas production of 0.263 m^3 /kg or 263 m^3 /tonne of waste deposited. The fraction of methane gas contained in landfill biogas varies from 0.35 to 0.65 of methane

Methane (tonnes/year) = Total MSW (tonnes/year) × MCF × (DOC) × 0.77 × F

where,

MSW = Municipal solid wastes, tonnes/year

MCF = Methane correction factor = 0.4 for open dumps less in-depth

DOC = Degradable organic carbon (determined for each city) = say 0.10 –0.40

Degradable fraction = 0.77 conversions to methane assumed as 0.077 (default basis)

F = Fraction of methane in landfill biogas = 0.35 to 0.65 (taken as 0.5 on default)

MODULE-III

LECTURE-32

BRINGING UP INDIAN VILLAGES

It is necessary to discuss about the villages of India where there is no scope for green buildings, nor major hotels or hospitals coming up nor any infrastructure. New techniques can be brought in to bring the village people out of their difficult situation by providing:

- Water
- Electricity
- Sanitation

a. More Water in Villages: Today, 60% of India depends on rain and reaps only one crop a year. With rainwater harvesting and groundwater recharge using locally erected check dams and shallow bunds their lives would change.

The objective of Rainwater harvesting is to prevent rainwater run-off from gushing down rivers and water courses to the nearest sea, but rather to make it enter the ground and become groundwater which gets naturally filtered (and purified) in passage through the soil and protected from undue loss by evaporation.

Rainwater harvesting also involves the construction of dykes (often using local materials and labour) to block the passage of surface water flowing along water courses and rivulets, and force it to go underground.

This helps increase water levels in wells and raises the water table which makes water available for a longer period in the wells.

It makes it possible to cultivate two or more crops in a year instead of just one crop during the rainy season.

Agricultural income increases and lifestyle changes begin to occur. Education becomes more affordable and employment opportunities increase.

b. **Electricity:** Electricity helps bring education, industry, employment and business. This brings in money for improvement.

- ☞ An example of electricity at the rural level is the development of portable solar PV lamps (such as those developed by TERI) for lighting up small villages and homes, shops, etc.
- ☞ Thousands of such lamps have been sold or gifted for use in villages.
- ☞ With these improvements, the local people will gradually find more small businesses, repair facilities, workshops and industries coming in.
- ☞ The people will also find more educational facilities available as light will make it possible to study at night.
- ☞ The family can also benefit from solar lamps if they are capable of recharging mobile phones and supporting TV for family entertainment in the evenings.
- ☞ The solar lamps will also reduce kerosene usage in the villages.

c. **Sanitation**: In most villages in India, there are no sanitary systems at all. People defecate outdoors in agricultural fields. This is difficult for women folk, especially at night and in rainy weather and can lead to infections.

The provision of toilets draining into a gobar gas plant (which is based partly on cow dung from their cattle and partly on their own excreta) greatly improves sanitation and consequently their health.

It also gives the womenfolk more time to attend to their families, and the biogas produced improves their household air pollution situation and smoky cooking conditions.

Government subsidies are often available for setting up gobar gas installations.

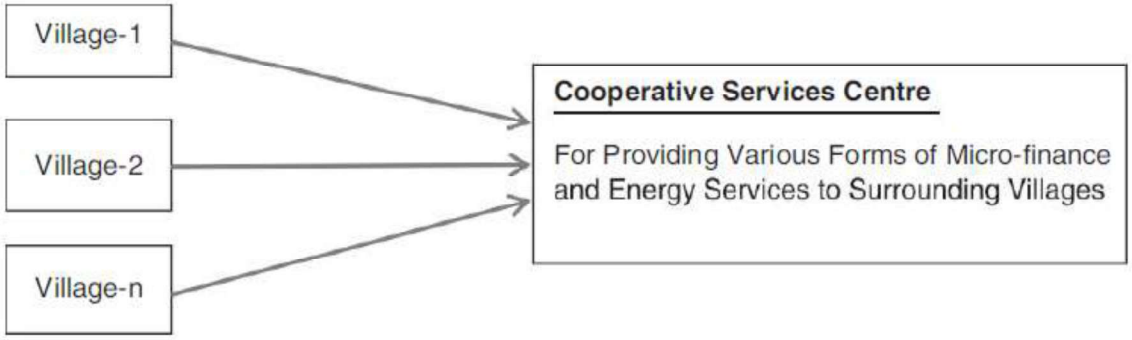
Business Model:- At Village Level, Provide Energy and Micro-Finance Services Through a Community Services Centre:-

Most of the villagers cannot afford any capital investment and are dependent on government subsidies.

The cooperative (CSC) could provide the following:

- Electricity (from a renewable source operated by the CSC)
- Biogas and manure (from a community-based gobar gas plant operated by the CSC)
- Oil extraction facility for biofuel cultivated by the villagers and brought to it for oil extraction (operated by the CSC)
- A cold storage facility (if found feasible) for the farmers' perishable produce, so that the variety of agricultural produce available may increase.
- Micro-finance to stimulate women's activities, sewing, etc.

- A solar PV operated bank ATM and a solar PV operated school for children could also be set up.
- Along with portable solar PV lights used in un-electrified villages in India (TERI-lamps and the like) one could make them capable of also operating a radio, a small TV and mobile phone chargers
- A tele-medicine facility to be able to contact doctors of a selected hospital to advise patients through a tele-facility.



GREEN SERVICES FOR CREMATORIA

Green cremation is a gentle, eco-friendly alternative to flame-based cremation or casket burials. It is a quiet process that uses water and potassium hydroxide to reduce the body to its basic element of bone ash.

Cremation in India is done either with wood or gas. When wood is burnt (as is often done), a considerable amount of deforestation occurs. It has been estimated that for this purpose worldwide, the wood comes from 50 to 60 million trees per year. Burning this much wood is estimated to release 8 million tonnes of CO2 per year. Cremation of a human body, however, is estimated to give 50 kg of CO2 whether wood or gas is used

During the Green Cremation process the body is reduced to its basic element of bone ash.

Green Cremation process It uses the natural process of water and alkalinity (potassium hydroxide) to reduce the body, like flame based cremation, to a basic element of bone ash in the same amount of time as traditional cremation. This process is also known as alkaline hydrolysis or bio cremation. Alkaline hydrolysis is the natural process a body undergoes after burial, which can take up to 25 years. Green Cremation essentially accelerates this natural process to 2-3 hours in a very quiet, controlled environment.

Green Cremation is a much more eco-friendly process as compared to flame-based cremation. Here are just a few environmental benefits this flameless alternative offers:

- More than 75% reduction of carbon footprint
- Eliminates concerns over mercury emissions
- Uses 1/8 the amount of energy of flame-based cremation

SPREADING MESSAGE TO ALL STAKEHOLDERS:-

For Spreading Message to all Stakeholders about various initiatives; it is suggested to hold meetings, seminars, workshops, conferences, etc. as listed below

Stakeholders	Typical Topics
General public, community organisations, public bodies	Lifestyle changes at personal and community levels
• Architects, engineers, builders consultants, plumbers, etc.	Green buildings and new area development projects
• Manufacturers, dealers, electric supply authority offi cials, public	Use of effi cient appliances, timer switches, power-saving devices, BEE recommendations, etc
• General	Renewable sources of energy
• General	Transport, biofuels and other alternate fuels, electric and hybrid cars, mass transport
Municipal and government staff, town engineers, consultants, etc	Green infrastructure
Industry associations, engineers, cultivation of biofuels and oil	Green industries, consultants, etc
Extraction and use at local level	Concerned villagers

Carbon Emissions Caused by Conferences

A conference also has a carbon footprint of its own. Emission is due to:

- Consumption of electricity for lighting and air-conditioning of the auditorium.
- Paper and other materials handed out to the participants.
- Food and drinks prepared for the occasion.
- Transporting to and fro for the venue.

MODULE-IV
LECTURE-33

SOME HIGH-TECH MEASURES FOR REDUCING CARBON EMISSIONS

Use of Solar Concentrators:- Concentrated solar power (CSP, also known as concentrating solar power, concentrated solar thermal) systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight into a receiver.

Electricity is generated when the concentrated light is converted to heat (solar thermal energy), which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermochemical reaction.

The efficiency of PV panels is only about 15%, which is relatively higher at 24% for Concentrated Solar systems using parabolic mirrors.

Large parabolic mirrors shaped as ultra-long troughs are needed to concentrate sunlight on to a long tube of molten salts that store heat. The heat energy is stored in molten salt (actually a mixture of two fertilisers, sodium nitrate and potassium nitrate). This heat is then used in a conventional thermal power plant to give electricity. A solar concentrator uses lenses, called Fresnel lenses, which take a large area of sunlight and direct it towards a specific spot by bending the rays of light and focusing them. Fresnel lenses are shaped like a dart board, with concentric rings of prisms around a lens that's a magnifying glass.

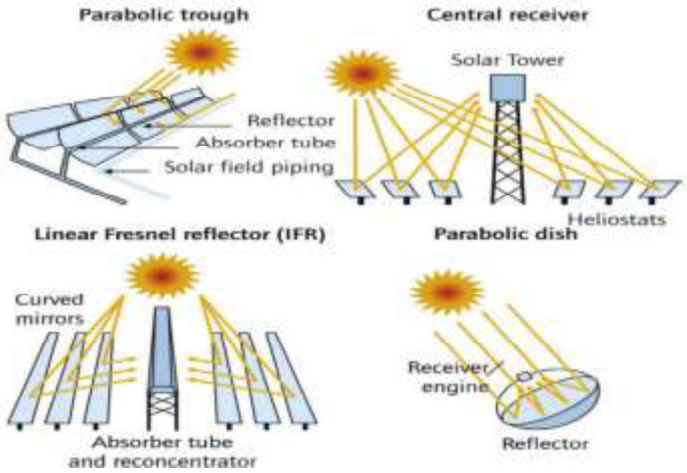
The solar concentrators have the advantage that the solar cells can be spaced farther apart since light can be focused on each cell. This means fewer solar cells need to be made and the panels cost less to construct. Concentrating technologies exist in four optical types, namely parabolic trough, dish, concentrating linear Fresnel reflector, and solar power tower.

A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned at the longitudinal focal line of the parabolic mirror and filled with a working fluid. The reflector follows the sun during the daylight hours by tracking along a single axis

In a CSP plant that includes storage, the solar energy is first used to heat the molten salt or synthetic oil which is stored providing thermal/heat energy at high temperature in insulated tanks. Later the hot molten salt (or oil) is used in a steam generator to produce steam to generate electricity by steam turbo generator as per requirement.

Benefits of using the solar concentrators.

1. It comes with the ability to increase the intensity of solar energy by concentrating the available energy over a large area on a smaller surface
2. It assists in reducing the cost in a solar power generation system as it replaces an extensive and costly receiver with a less expensive reflecting area.
3. The heat loss is drastically reduced.
4. The temperature on the receiving area is quite high, a thermodynamic match can be achieved which augurs well for the overall efficiency of the solar power system



Issues with Solar Concentrator projects:

- Land Problem:- It is estimated that about 10,000 acres for 1,000 MW plant is needed, the land alone costing around ` 100–200 crores. Cheaper land would be available in a place like the Rajasthan desert. Land can become a serious problem in India as even what is classified as wasteland by the government, is considered valuable by villagers who use the land for grazing, collecting minor timber and as transport corridors.
- Need of Water:- water is needed to wash off dust from the solar mirrors. This water may be scarce in wasteland areas and need expensive reuse techniques to make it possible.

Satellite-based Solar Power Systems:- It is the concept of collecting solar power in outer space by solar power satellites (SPS) and distributing it to Earth. Its advantages include a higher collection of energy due to the lack of reflection and absorption by the atmosphere, the possibility of no (or very little) night, and a better ability to orient to face the sun. Space-based solar power systems convert sunlight to some other form of energy (such as microwaves) which can be transmitted through the atmosphere to receivers on the Earth's surface. SBSP designs generally include the wireless power transmission. The collecting satellite would convert solar energy into electrical energy, powering a microwave transmitter or laser emitter, and transmit this energy to a collector (or microwave rectenna) on Earth's surface. As of 2020, SBSP is being actively pursued by Japan, China, Russia, India, the United Kingdom and the US

Advantages

The SBSP concept is attractive because space has several major advantages over the Earth's surface for the collection of solar power:

- It is always solar noon in space and full sun.
- Collecting surfaces could receive much more intense sunlight, owing to the lack of obstructions such as atmospheric gasses, clouds, dust and other weather events. Consequently, the intensity in orbit is approximately 144% of the maximum attainable intensity on Earth's surface
- A satellite could be illuminated over 99% of the time, and be in Earth's shadow a maximum of only 72 minutes per night at the spring and fall equinoxes at local midnight. Orbiting satellites can be exposed to a consistently high degree of solar

radiation, generally for 24 hours per day, whereas earth surface solar panels currently collect power for an average of 29% of the day.
- Power could be relatively quickly redirected directly to areas that need it most.
- Reduced plant and wildlife interference.

Disadvantages

The SBSP concept also has a number of problems:

- The large cost of launching a satellite into space. For 6.5 kg/kW, the cost to place a power satellite in GEO cannot exceed $200/kg if the power cost is to be competitive.
- Microwave optic requires GW scale due to Airy disk beam spreading. Typically a 1 km transmitting disk at 2.45 GHz spreads out to 10 km at Earth distance.
- The space environment is hostile; PV panels (if used) suffer about eight times the degradation they would on Earth (except at orbits that are protected by the magnetosphere).
- Space debris is a major hazard to large objects in space, particularly for large structures such as SBSP systems in transit through the debris below 2000 km. Collision risk is much reduced in GEO since all the satellites are moving in the same direction at very close to the same speed.

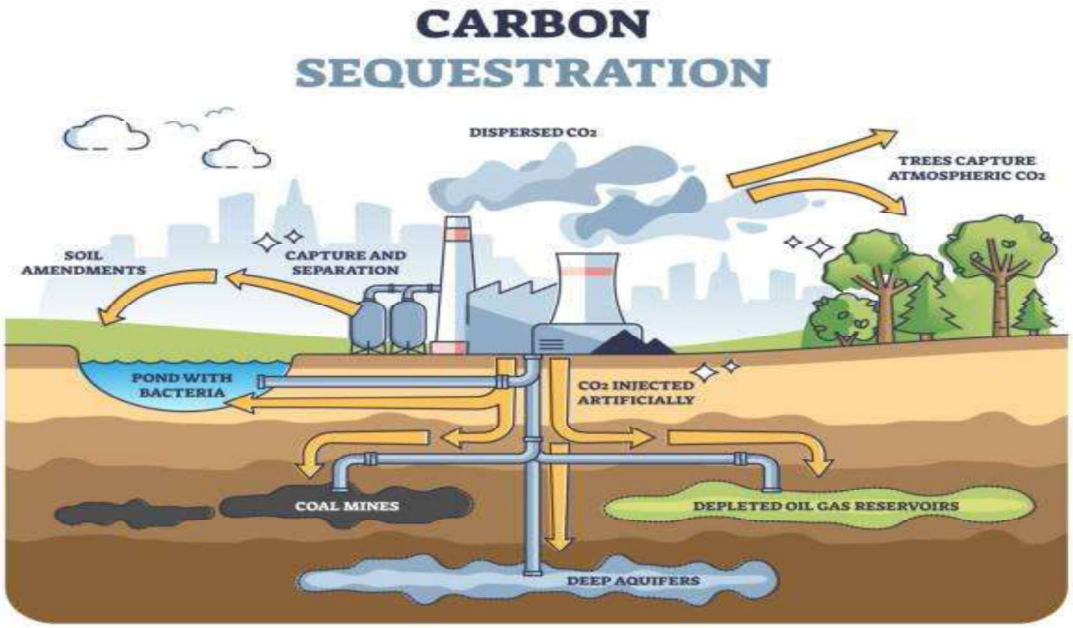
Sahara CSP Project:- The Sahara Forest Project is an agriculture initiative that uses abundant desert resources—sunlight, sand and carbon dioxide (CO_2)—to produce what deserts desperately need: a self-sufficient food production system, water, and energy. The saltwater-cooled greenhouses work similarly to a typical greenhouse, except the seawater that is pumped in is evaporated by wind instead of by fan. The seawater cools and humidifies the greenhouses. CSP harvests the abundance of sunlight in the desert to produce electricity and heat. Solar panels contain tiny mirrors that produce heat to indirectly produce electricity via steam turbine-controlled generators.

MODULE-IV

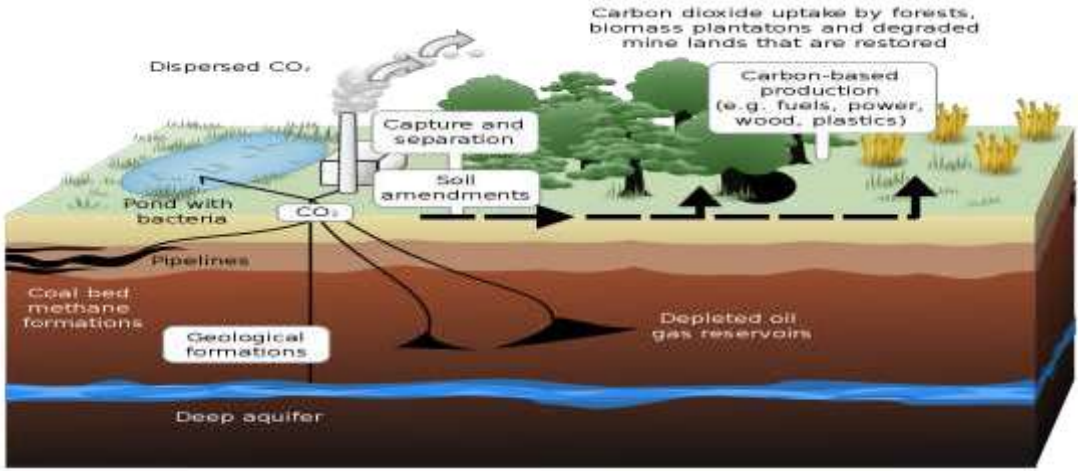
LECTURE-34

Use of Carbon Capture and Storage (Sequestration)

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change.



The term "Carbon Sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations. Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes.



Geologic carbon sequestration is the process of storing carbon dioxide (CO_2) in underground geologic formations. The CO_2 is usually pressurized until it becomes a liquid, and then it is injected into porous rock formations in geologic basins.

Worldwide storage capacity in oil and gas reservoirs is estimated to be 675–900 Gt CO_2, and in un-minable coal seams is estimated to be 15–200 Gt CO_2. Deep saline formations have the largest capacity, which is estimated to be 1,000–10,000 Gt CO_2

Forests, kelp beds, and other forms of plant life absorb carbon dioxide from the air as they grow, and bind it into biomass. However, these biological stores are considered volatile carbon sinks as the long-term sequestration cannot be guaranteed. For example, natural events, such as wildfires or disease, economic pressures and changing political priorities can result in the sequestered carbon being released back into the atmosphere.

Carbon dioxide that has been removed from the atmosphere can also be stored in the Earth's crust by injecting it into the subsurface, or in the form of insoluble carbonate salts (mineral sequestration). These methods are considered non-volatile because they remove carbon from the atmosphere and sequestering it indefinitely and presumably for a considerable duration (thousands to millions of years).

Elements of a Carbon Capture and Sequestration Scheme (CCS)

A stepwise approach to the planning of a CCS scheme in any country would include the following elements:

- Capturing the CO2 gas at source
- Compressing it to the required temperature, density and low volume
- Transporting it by pipe to the holding site
- Injecting it underground to the required depth and stratum
- Monitoring its performance with regard to regulatory requirements (leakage risks, etc.)

Storage basins in the form of deep, sedimentary basins have been found suitable for CO_2 storage.

Options in geological storage generally include the following:

- Use of space released by depleted oil and gas reserves underground
- Use of CO_2 to increase oil and gas outputs from deposits
- Use of deep saline formations (offshore and onshore) for storage
- Use of CO_2 to improve coal-bed methane recovery

CO_2 is generally injected over 0.8–1.0 km depth at which the volume of gas and its density are both suitable for injection.

Issues Involved in Planning CCS Projects

- Limited fundamental knowledge of storage and leakage mechanisms
- Limited experience in site characterisation and selection
- Storage engineering
- Safe operation of project
- Monitoring
- Remediation
- Regulatory oversight
- Financial responsibility

Genetic Modification of Microorganisms: Another relatively high-tech method is 'genetic modification' of microorganisms as suggested by Dr Craig Venter.CO_2 in the atmosphere is converted back to oil through use of genetically modified microbes. We will not suffer any global warming at all because a new equilibrium would be achieved between carbon sources and carbon sinks. CO_2 in the atmosphere is in a dilute form. Its capture and concentration is the first problem to be solved. Genetic alteration of microbes is another problem.

Electric Vehicles: Electric vehicle (EV) has transformed transportation technologies. Many countries are already doing much research in this field.

Biodegradable Plastics: Biodegradable plastics have now been made from plants using organic catalysts instead of petroleum-based plastics made with metal oxide catalysts. They could solve the plastics waste problem.

Planes Powered by Renewables:

A single-seater plane has been successfully test flown in Zurich, Switzerland, for a 24-hour, day and night flight, after it received its charge of solar energy during the day. A round the world trip is now being planned. Planes working on biofuels are also being developed and have been test-flown successfully.

A Quick SWOT Analysis:-

- Strengths: Many good, young and educated people capable of doing a variety of things ranging from R&D to manufacturing, marketing, etc.
- Weaknesses: Local prejudices (caste, creed, colour)
- Opportunities: Plenty
- Threats: Slow starters. Poor funding and facilities

RECOMMENDED PLAN OF ACTION

The Missions Help Develop Awareness and Political Will:- Developing attitudes and approaches is a continuous effort, not a one time job. Some methods which are followed:

a. Organise seminars and conferences along with relevant professional organisations to include all the stakeholders, and take the help of media to discuss the pros and cons.

b. Use 'demonstration projects. These projects are more expensive but they are tried out on real people to get honest reactions for future planning

c. Use outside expertise (Indian and expatriate) to help develop suitable measures.

India's demographic status tells us that there is a very good chance of adopting new methods because we have a high proportion of young people in our population mix. Our youth may find sense in our desire to reduce carbon emissions. They will permanently reshape our economy in the low-carbon direction. The advantage of reshaping the Indian economy is that even if global warming does not reduce, our country's economy and resource position will improve and our business opportunities will increase.

Some Demonstration Projects of Various Countries

a. Bio-solar home Thailand:- In Thailand, a beautiful residential house, a so-called 'bio-solar home' (Soontorn 2005) that is designed to be self-sufficient in all respects has been built by an architect. The important difference is that it needs no municipal services such as water supply or electric supply or wastewater disposal or garbage disposal, etc. The electricity is secured from solar panels mounted on the sloping roofs of the house. The drinking water supply is obtained by capturing the natural dew. Wastewater treatment is achieved by using 'natural' processes which need no electric power, while garbage disposal is done by composting.

b. Green Town, Masdar, Abu Dhabi:-Abu Dhabi fears it will run out of oil in the next 50–60 years. Dependent on oil for too long, Abu Dhabi has invested US$15 billion in building Masdar City, a sustainable, low carbon eco-city in the desert.

The aim of Masdar City were to:

- Specialise in greenhouse gas emission reduction projects and develop large-scale renewable energy projects.
- Rely entirely on solar energy and other renewable energy sources.
- Become a hub for cleantech companies.
- Provide homes for about 50,000 people.
- Provide facilities for 1,500 businesses, primarily commercial and manufacturing firms specialising in environmentally friendly products, and create 10,000 new jobs, with more than 60,000 workers expected to commute to the city daily.
- Create a new tertiary education institution, the Masdar Institute of Science and Technology (MIST), modelled on MIT, which was founded in 2007, a year after the Masdar initiative began, and admitted its first students in 2009.

c. Marco Polo Tower, Hamburg, Germany:- This sustainable building was first built in 2009, and has won architectural awards and prizes such as the Mipim Award for best residential

project. The tower is residential accommodation that is split up into apartments. Each floor of the building is turned on an axis by a few degrees. This means every floor overhangs the one above so the apartments are protected from direct sunlight. Vacuum collectors on the roof, along with a heat exchanger are used to turn heat into a cooling system which is used within the apartments.

d. SEAT's Martorell plant, Barcelona:-Seat's car factory in Barcelona has a lot of sustainable building features. The factory has around 4000 square meters of photo catalytic pavement which reduces air pollution by 40% because of the way the materials react in contact with pollution and light. The building also features the largest solar power plant in automotive companies. There are 53,000 panels in total, this generates around 17 million kWh every year.

e. Sun-Moon Mansion, China:-This building is one of the largest solar structures in the world. The building features a fan shaped roof with over 5000 solar panels. The building itself is used as a hotel, research facilities, meeting rooms as well as an exhibition centre.

f. Suzlon one earth, India:- This corporate campus is one of the greenest in the world. Due to this company's sustainable measures it has cut its costs by 35%. Some of the building's most sustainable features include rain water harvesting, onsite waste recycling and conversion, as well as a design that puts the office within the garden to utilize daylight usage.

g. A Town in Japan:- Japan is reported to be setting up a hybrid town near Fukuoka where every house will have a hybrid car and the house itself will run on electricity generated by using hydrogen which works out cheaper than using usual fossil fuels.

Adaptive Measures Essential for Indian People to Cope with Climate Change

Adaptive Measures in India depend upon the actual location i.e.

- Coastal
- Inland
- Himalayan

a. Adaptive Measures in Coastal Region:-

- **Flooding of low-lying lands** is expected to occur in coastal areas. These areas have to be identified now and people living in such areas have to be warned and moved in course of time.
- **Flooding due to rain (storm runoff)** also occurs in some parts of urban areas of coastal cities. To clear this runoff, more pumping stations (and, therefore, more electric power) will be needed.
- **Wells in coastal areas will turn brackish**. Agriculture and mangroves in these areas will be affected by saline intrusion.
- **More storage of grain** will be needed to tide over difficult food periods.
- **Foundations of buildings will need special protection** against seawater ingress and resultant corrosion.
- **Increased control measures** against accumulated pools of water and easier availability of medical facilities be needed as Malaria, dengue, etc., will increase with flood and cause health problems.

- **Political and security problems** will have to be expected and some steps need to be taken as migration of people will occur from low-lying coastal areas to higher areas to avoid rising sea levels.

b. Adaptive Measures in the Inland Region:-

- **Flooding of low-lying lands**: Rapid snow melting will cause flooding of low-lying lands adjacent to the river banks. These areas have to be identified now and people living in such areas will have to be warned and moved in course of time
- **Flooding due to rain** also occurs in some parts of urban areas of cities on river banks. To clear this runoff, more pumping stations (and, therefore, more electric power) will be needed. For example in Bihar, the Kosi River (known as the river of sorrow) leads to flooding and much damage. People have turned to grow 'makhana' or fox nut which grows well in water-logged farms/ponds. It has become a flourishing business today.
- In Assam's flood-prone districts, people have learnt to survive floods by building their houses on stilts, planting more flood-tolerant crops, and innovating more flood-holding systems,
- **Wells in Inland areas will have too much or too little water in them**. Agriculture in these areas will demand a renewed need for irrigation to tide over difficult periods of snow and manage the new water situation.
- Agricultural practices will have to change in drier areas (such as Rajasthan). Crops requiring less water will have to be cultivated.
- **More storage of grain** will be needed to tide over difficult food periods.
- **Water conservation and recycling will be needed**
- **Increased control measures** against accumulated pools of water and easier availability of medical facilities be needed as Malaria, dengue, etc., will increase with flood and cause health problems.
- **Political and security problems** will have to be expected and some steps need to be taken as migration of people will occur from low-lying coastal areas to higher areas to avoid rising sea levels.

c. Adaptive Measures in the Himalayan Region:-

- The Himalayan area is important for India as it provides sustenance to the main land mass by feeding its three major rivers, the Ganges, Indus and Brahmaputra, with waters that help to provide drinking water to millions of people, and waters for various industrial, hydropower and irrigation purposes.
- The Himalayan area also has its unique ecosystem and biodiversity, its agriculture and spectacular tourism.
- Climate change may affect snow melt, endanger river flows and bring drought.
- Himalayas may need integration with forest preservation programs and need better monitoring and understanding of various phenomena.