MODULE 1

SUSTAINABILITY – Introduction

Sustainability means capacity to endure (to continue). Sustainability can be defined as a possibility that humans and other forms of life on our planet will flourish forever. Sustainability focuses on balancing the need to move forward technologically and economically and at the same time to protect the environment in which we live. The concept of environmental management formed the basis of sustainability.

NEED FOR SUSTAINABILITY

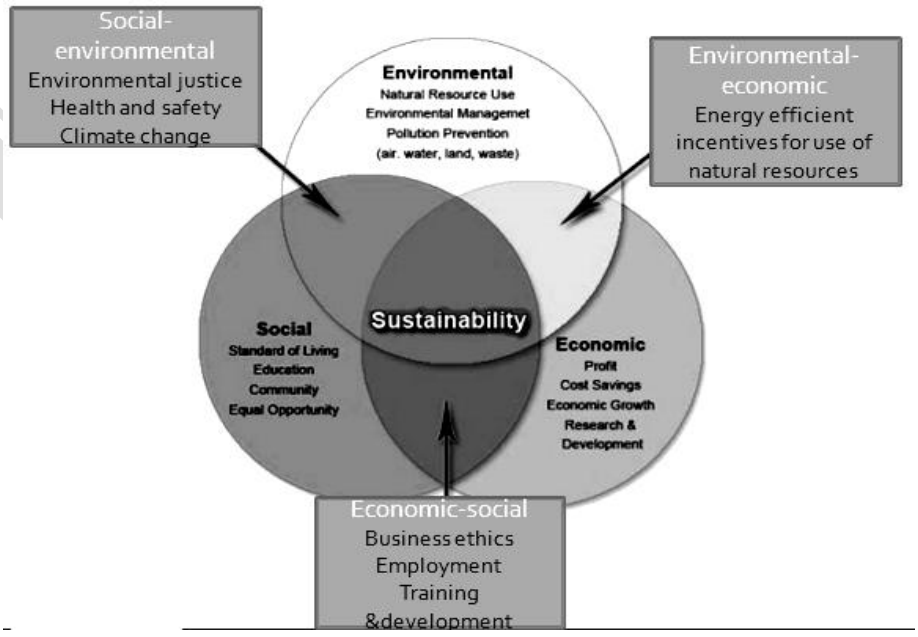
- With a smaller human population in the past the natural self cleansing capacity of the nature appeared infinite.
- With the increase in the human population and with the industrial revolution, the environment impact has grown rapidly and steadily, affecting the regenerative capacities of the earth resulting in degradation of the environment.
- Due to encroachment by human habitation, pollution and over exploitation, more than 12% of birds and 25% mammals of the planet are in danger of extinction.
- One quarter of the developing world's agricultural land is seriously degraded and roughly 30% of the world's remaining forests are fragmented and degraded.
- 50% of world's wetlands also have been lost over the last one hundred years.
- Around 300 to 500 million tons of hazardous waste and toxic chemicals are being produced every year which ultimately ends up in polluting our soil, land, water and air.
- The combination of population explosion in the developing world and the unsustainable consumption levels in the developed world pose a great challenge to sustainability.
- Thus sustainability needs to be the key objective of strategic planning and should be integrated within all decision making processes.

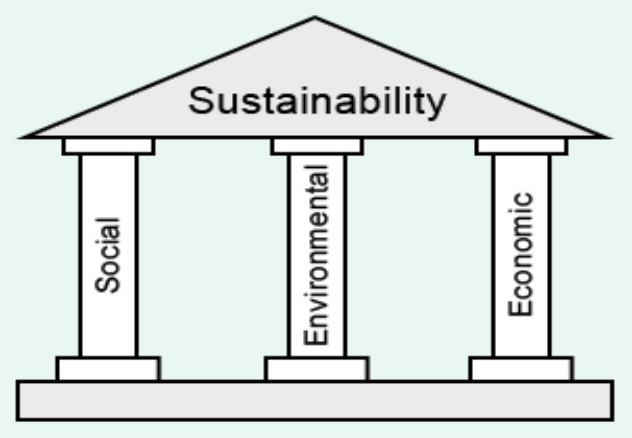
CONCEPT & EVOLUTION OF SUSTAINABILITY

- Sustainable Engineering can be defined as meeting society's present needs without compromising the ability of future generations to meet their own needs.
- Most often quoted definition of sustainability is - "Meeting the needs of current and future generations through integrating **environmental** protection, **social** advancement and **economic** prosperity".
- For the world to be sustainable following **4 principles** are to be followed:
  - Reduce dependence upon fossil fuels
  - Reduce dependence upon synthetic substances
  - Reduce encroachment upon nature
  - Meet human needs fairly & efficiently

Three pillars / spheres of sustainability

- Sustainable development is modelled on three pillars (spheres). This consists of at least the economic, social, and environmental pillars. If any pillar is weak, then the system as a whole is unsustainable.
- Two popular ways to visualize the three pillars are shown.





Concept of Social Sustainability

- Social sustainability points to social well being and harmony that exist in a society.
- All sections (rich & poor) should have **equal access** to basic resources.
- Human values and relationships should be given importance without compromising on their **quality of life**
- Three values that form the **core of social sustainability- quality of life, growth & equality.**
- For ensuring social sustainability the following measures should be implemented:
  - Lessen poverty
  - Provide adequate health care and safety to all
  - Provide necessary basic education to all
  - Protection of human rights in the society
  - Provide adequate sanitation to all
  - Provide adequate food security and drinkable water to all
  - Provide adequate and affordable shelter to all
  - Policies and programs should be planned and implemented for the people to improve the social status by active participation of all stake holders (public, administration, politicians)

Concept of Environmental Sustainability

- Environmental Sustainability means - improving the quality of human life while living within the carrying capacity of our planet.
- Environmental Sustainability demands society to design activities to meet human needs while preserving other life forms too.

- If natural resources are used at a rate at which it can be replenished naturally, then sustainability occurs.

Consumption of resources	**State of environment**	**Sustainability**
< natures ability to replenish	Environmental renewal	Environmentally sustainable
=natures ability to replenish	Environmental equilibrium	Steady state economy
>natures ability to replenish	Environmental degradation	Not sustainable

- For ensuring environmental sustainability following measures should be implemented:
  - Optimum utilization of our natural resources
  - Tapping more renewable resources such as solar power, wind power, tidal power etc
  - Minimizing water pollution, solid waste generated, noise pollution etc
  - Popularizing public transport system to reduce air pollution
  - Maintaining environmental quality and ecological balance in all developmental activities
  - Create awareness about environmental problems among the general public and motivate them to participate in environmental improvement programs
  - Existing laws protecting our environment should be made stricter.

Concept of Economic Sustainability

- The real idea of Economic sustainability to make sure that industry/business is making profit without creating much environmental harm
- In developing world- resource consumption is sustainable but population is exploding which is unsustainable.
- In developed economies, the population is less (sustainable) but resource consumption is very high (unsustainable).

- The challenge for sustainability is to reduce western style of consumption and to increase standard of living of developing world without increasing the resource use and environmental impact.
- For ensuring economic sustainability, the following measures should be implemented:
  - Optimum use of raw materials
  - Maintaining a steady flow of income to the workers to ensure their quality of life
  - Incentives should be given to green business projects causing no/less harm to the environment
  - Proper research and development should be carried out to adopt eco-friendly and cost effective production techniques in industry
  - Awareness should be created among workers about environment friendly practices and motivate them to work more efficiently by providing incentives
  - Value added products should be made along with real products

SUSTAINABLE DEVELOPMENT

- **Sustainable development** is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.
- Sustainable development is based on improving quality of life for all, especially the poor and deprived, which leads to better quality of life while reducing the impact on environment within the carrying capacity of supporting ecosystem.

- The 3 basic pillars of sustainable development are:

1. Social pillar

Community / Societal development that provides food, shelter, clothing, education & health for human beings.

2. Environmental pillar

Environmental protection that provides pollution-free air, water & soil for the present & future generations.

3. Economic pillar

Economic development such as provision of job, industrial development without creating environmental harm.

Measures for achieving sustainable development

- **To promote environmental education and awareness –** develop a feeling of belongingness to our planet by introducing environment as a subject in education from primary level itself.
- **Three 'R' approach –** (Reduce, Reuse & Recycle)
  Reduce the excessive use of natural resources, use them again & again, and also recycle the materials.
- **Use of appropriate technology –** Technology should use local resources, should produce minimum waste and must be eco-friendly.
- **Utilize natural resources as per carrying capacity of environment**
  If the carrying capacity of our planet is exceeded, environmental degradation occurs.
- **Improving quality of life**
  Development should focus on sharing the benefits between rich and poor, and also the cultural heritage of the people should be conserved.

NEXUS BETWEEN TECHNOLOGY AND SUSTAINABLE DEVELOPMENT

- Advancement in science & Technology are considered as the most effective means in resolving the existing economic, social & environmental problems related to sustainable development.
- Technology improves quality of life, eliminate diseases and increase life expectancy.
- On the other hand, technology creates irreparable environmental damage due to resource extraction and pollution of air, water, soil.
- The benefits of technological innovations are mostly enjoyed by the developed countries remains as a dream for underdeveloped countries. Hence it is essential to integrate technology, society into sustainability.

Some of the technological applications towards sustainable development in various sectors are:

1) **Nexus between Agricultural Technology & Sustainable Development**

- Sustainable agriculture with the help of appropriate technology is needed to address the important issues of the 21st century such as food security, depletion of natural resources, climatic changes etc.
- Some of the sustainable agricultural technologies which are practiced are listed below:
  - Good agricultural practices such as organic farming.
  - DRONES help large scale farmers to assess plant health by detecting crop diseases at earlier stage.
  - Terrace cultivation for saving water.
  - Protein rich rice variety has been developed to tackle malnutrition.

2) Nexus between Energy Technology & Sustainable Development

- Sustainable energy is the energy that, in its production or consumption, has minimal negative impacts on human health and environment.
- This can be achieved by using Renewable energy sources such as
  - Solar
  - Biomass
  - Wind
  - Tide

3) Nexus between Communication & Information Technology & Sustainable Development

- Information, education and communication technologies are fundamental in achieving sustainable development.
- Educational programmes will create awareness, develop an attitude of concern for the environment & motivates them to participate in environmental protection activities.
- For eg, videoconferencing is an effective tool in the field of telemedicine.

MILLENIUM DEVELOPMENT GOALS (MDGs)

The United Nations Millennium Development Goals are eight goals that all 191 UN member states have agreed to try to achieve by the year 2015. The United Nations Millennium Declaration, signed in September 2000 commits world leaders to combat poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women.

The Eight Millennium Development Goals are:

- To eradicate extreme poverty and hunger
- To achieve universal primary education
- To promote gender equality and empower women
- To reduce child mortality
- To improve maternal health
- To combat HIV/AIDS, malaria, and other diseases
- To ensure environmental sustainability
- To develop a global partnership for development

SUSTAINABLE DEVELOPMENT GOALS (SDGs)

Recently, the international community decided to adopt a new set of development goals focusing on improving the sustainability of nation-states. The need for a new set of targets was developed at the Rio +20 conference, held in Rio de Janeiro, in June 2012. Sustainable development goals that build on the success of the Millennium Development Goals, and that apply to all countries, can provide a tremendous boost to efforts to implement sustainable development.

The 17 sustainable development goals to transform our world are:

1) No Poverty
2) Zero Hunger
3) Good Health and Well-being
4) Quality Education
5) Gender Equality
6) Clean Water and Sanitation
7) Affordable and Clean Energy
8) Decent Work and Economic Growth

9) Climate Action
10) Industry, Innovation and Infrastructure
11) Reduced Inequality
12) Sustainable Cities and Communities
13) Responsible Consumption and Production
14) Life Below Water
15) Life on Land
16) Peace and Justice Strong Institutions
17) Partnerships to achieve the Goal

KYOTO PROTOCOL

To tackle the challenges posed by global warming and climate change, the **U**nited **N**ations **F**ramework **C**onvention on **C**limate **C**hange (UNFCCC) initiated the framing of a protocol during the climate change meeting held at Kyoto, Japan in 1997. This was the first international step towards global greenhouse gas emission reduction & later came to be known as the **Kyoto Protocol.**

- A **greenhouse gas** is any gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere.
- By increasing the heat in the atmosphere, **greenhouse gases** are responsible for the **greenhouse** effect, which ultimately leads to global warming.

CLEAN DEVELOPMENT MECHANISM (CDM)

- Under Kyoto Protocol- countries are classified into 2
  -Annex 1 countries (developed countries)
  - Non-Annex 1 countries (developing countries)
- The greenhouse gas reduction responsibility was put on Annex 1 countries because these countries have emitted the greatest quantity of greenhouse gases in the past (due to industrial revolution).
- As per Kyoto protocol, the Non-Annex 1 countries had no greenhouse gas reduction targets, but they are expected to reduce greenhouse gas emissions.

- **Clean development Mechanism (CDM)** is one flexible mechanism under which the developed countries are allowed to invest in emission reduction projects in developing countries.
- The main purpose of CDMs are
  - to help developing nations achieve sustainable development
  - to assist developed nations in complying their emission reduction commitments.
- The measures for reduction of greenhouse gas in developing countries often cost more, since they may have many difficulties pertaining to availability and adoption of new technology.
- It will be more economical for the developing countries to simply pay a developed country to reduce emissions on their behalf. The payment will be done by the private companies.
- Thus **CDM** project generates **Certified Emission Reduction (CER)** unit or **Carbon Credit** for the developed country. (one CER is the unit related to the reduction of one tonne of CO_2 or its equivalent greenhouse gas).
- The CDM Executive Board (CDMEB) controls and monitors the implementation of CDM.
- They assess, approve and take steps to register the CDM projects.

MODULE 2

POLLUTION

- The word pollution is derived from the Latin word “Polluere” which means to defile or make dirty.
- Pollution can be defined as the undesirable changes in the environment/surroundings which not only adversely affect humans and other living things, but also our developmental activities and socio-cultural life.
- Materials in any form that causes pollution are called pollutants.

AIR POLLUTION

- It is the introduction of particles, biological molecules, or other harmful materials into earth's atmosphere, causing diseases, allergies, death to humans, damage to other living organisms such as animals and food crops, or the natural or built environment.
- Industries & vehicles are the main sources of air pollution.
- Air pollution means different to different people. To the house holder it may be an eye irritation, to the farmer it may be damaged vegetation, to the pilot it may be dangerously reduced visibility etc.
- The problems of air pollution get aggravated during the winter season.

i) SOURCES OF AIR POLLUTION

- The sources of air pollution may be broadly classified as **natural** & **anthropogenic.**

➢ **Natural sources of air pollution include:**

- Volcanoes: Volcanic activity produces smoke, ash, carbon dioxide, sulphur dioxide etc.
- Dust: Wind blown dust from areas with little or no vegetation such as desert areas.
- Forest fires: Forest fires created by natural causes , result in the formation and release of smoke, ash, dust, carbon dioxide, nitrogen oxides and other air pollutants.

- **Anthropogenic (Man-made) sources of air pollution:**
  - **Stationary point sources:** It is a single, identifiable source of air pollutant emission & can be controlled at the origin. (factories & power plants)
  - **Mobile sources:** It includes the exhaust emissions from vehicles.
  - **Evaporative sources:** Volatile liquids that, when not completely enclosed in a tank or other container, evaporate and release vapours over time.(paints, solvents, pesticides , perfumes , hair spray etc.)

ii) TYPES OF AIR POLLUTANTS

- Based on how they reach the atmosphere, pollutants are classified as **Primary & Secondary** pollutants.
  - Primary pollutants directly enter the air from their respective sources.
  - Secondary pollutants are produced by chemical or photochemical reactions of primary pollutants.

Major Outdoor air pollutants

a) Carbon Monoxide

- colorless, odorless
- produced when carbon does not burn in fossil fuels
- present in car exhaust
- deprives body of O_2 causing headaches, fatigue, and impaired vision

b) Sulphur Dioxide

- produced when coal and fuel oil are burned
- present in power plant exhaust
- narrows the airway, causing wheezing and shortness of breath, especially in those with asthma

c) Nitrogen Dioxide

- reddish, brown gas
- produced when nitric oxide combines with oxygen in the atmosphere
- present in car exhaust and power plants
- affects lungs and causes wheezing; increases chance of respiratory infection

d) Particulate Matter (PM)

- Particles of different sizes and structures that are released into the atmosphere
- Present in many sources including fossil fuels, dust, smoke, fog, etc.
- Can build up in respiratory system
- Aggravates heart and lung disease; increases risk of respiratory infection

e) Ground Level Ozone

- at upper level, ozone shields Earth from sun's harmful UV rays
- at ground level, ozone is harmful pollutants
- formed from car, power and chemical plant exhaust
- irritate respiratory system and asthma; reduces lung function by inflaming and damaging lining of lungs

EFFECTS OF AIR POLLUTION

- **Effects of air pollution on human health**
  - Generally occur as a result of contact between pollutants and the body
  - Eye irritation
  - Nose and throat irritation
  - Increase in mortality rate
  - Chronic pulmonary diseases
  - Carbon monoxide readily combines with haemoglobin in blood replacing oxygen from blood
  - Causes cancer
- **Effects of air pollution on plants**
  - Suppressed growth and premature ageing in plants
  - Causes leaf bleaching which results in Chlorosis (photosynthesis is affected due to loss of Chlorophyll)
  - Premature falling of leaves(abscission)
  - Causes necrosis (dead spots on leaves)
- **Effects of air pollution on animals & birds**
  - Affects the mucous lining of respiratory tract

- Causes bronchitis and asthma
- Lack of appetite in pet animals
- Acid deposition cause aquatic life damage
- Migration of seasonal birds are hampered due to severe air pollution

- **Effects of air pollution on material and property**
  - Acid deposition can corrode metals, eat away stone on statues and monuments
  - Discolour buildings, cloth fabrics
- **Effects of air pollution on environment**
  - Reduce visibility
  - Pollutants can travel long distance – results in global (transboundary) pollution
  - Climate change , acid rain, global warming etc

WATER POLLUTION

- Water pollution can be defined as any chemical, biological, or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for use.
- Water contained in water bodies like lakes, rivers and oceans are called surface water.
- Water stored in aquifers (underground rock structures) is called underground water (subsurface water). Both these sources are prone to pollution.

SOURCES OF WATER POLLUTION

Water pollution occurs mainly due to presence of domestic as well as industrial wastes in fresh water.

1. Point Source: Sources which can be readily identified at a single location. This type of discharges can be controlled easily.

Examples: Waste water discharge from industries, domestic sector etc..

- **Non-point sources:** Source of origin cannot be traced to a single discharge point.

Examples: runoff from agricultural land, mining areas etc...

3. Natural sources of water pollution

Rain water, atmosphere, Underground rocks and volcanoes

4. Anthropogenic (man made) sources of water pollution

These sources include oil spills, industrial waste water discharges runoff from agricultural fields, waste water from automobile garages etc.

- Generally water gets polluted from the following sources.

a) Domestic Waste water:

- Waste water generated from residential areas, commercial places, institution and other public places. Generally domestic sewage consists of 99.9% water and 0.1% solids.

b) Agricultural waste water:

- This is the runoff from the agricultural fields and animal farms and this waste water is rich in Nitrogen, Phosphate, Organic matter and Pesticides.
- This induces rapid growth of microscopic plants in surface waters thereby reducing oxygen content in aquatic environment, known as Eutrophication.

c) Industrial waste water:

- They are the one which results from industrial operations.
- It may have pollutants of almost all kinds ranging from simple nutrients and organic matter to complex toxic substances.

d) Groundwater pollution:

- Various kinds of harmful materials like fertilizers, pesticides, metals etc present in the solid waste gets dissolved into water.
- During rain these pollutants drain down into the soil & contaminate the groundwater.

ZERO WASTE CONCEPT

- Zero waste concept focuses on minimizing waste and maximizing recycling, thus resulting in reduced resource consumption.
- Zero waste focuses on
  - Maximizing recycling
  - Minimizing waste
  - Reducing resource consumption
  - Ensuring products can be re-used, repaired or recycled back to nature.

Principle of zero waste concept

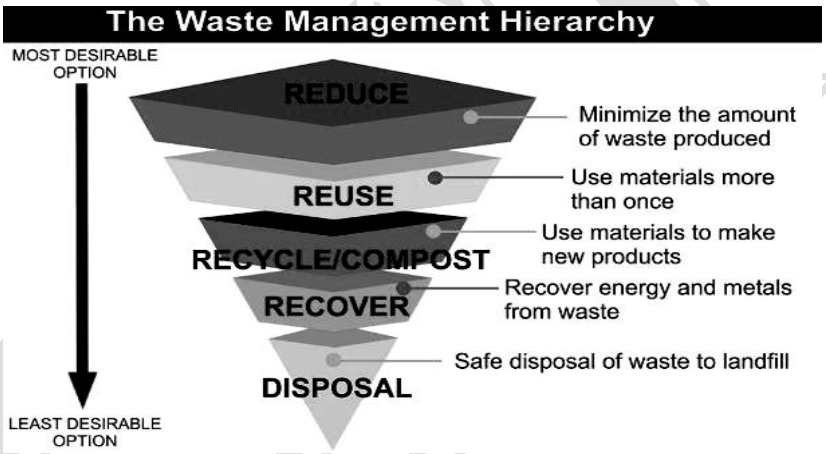
- Living organisms consume resources and produce waste.
- What is waste for one species is food for another, so that within the ecosystem all waste are continually recycled.

Benefits of zero waste concept

- Saves money
- Supports Sustainability
- Improves material flows

Waste Management Hierarchy

- The waste management hierarchy is a nationally and internationally accepted guide for prioritizing waste management practices.



3R CONCEPT OF SOLID WASTE MANAGEMENT

- Waste management consists of all those activities required to reduce the adverse effects of waste on our health and environment.
- The waste hierarchy generally refers to "3 Rs" – **Reduce, Reuse & Recycle.**

1. REDUCE

- This means reducing the waste generation at the source.
- Select only those products that you need, prefer high quality items which are durable for longer period.
- The minimum packaging is also an important aspect of reduction.
- This saves not only money and resources, but also reduces the waste generated.

2. REUSE

- Reuse means using something again rather than throwing it out.
- Reusing prevents new resources from being used and old resources from entering the waste stream.
- Long lasting goods should be reused over & over.

  For eg; bottles, cans and cartons can be used as multipurpose container. Also a number of electronic gadgets can be reused again and again after minor repairs.

- **RECYCLE**

- In recycling, the discarded material that cannot be used in its original form should be sent back to the industry.
- There, the waste material is broken down and can be used for remanufacturing the product.

  For eg; Aluminium battery, glass, metal scrap, paper electronic waste etc.
- Recycling produces new industries, job opportunities and reduction in waste.
- It also reduces consumption of many valuable resources.

GREEN HOUSE EFFECT

- It is a natural phenomenon which refers to the rise in temperature of the earth due to the presence of certain green house gases (GHG) in the atmosphere.
- GHG are watervapors, carbondioxide, methane, nitrous oxide etc.
- These gases are transparent to the incoming ultraviolet solar radiations but trap the outgoing infrared radiations, reflected back from the earth's surface.
- If these gases were not present, the annual average temperature of the earth would be much lower (-18^0c) than they are now (15^0c).Excess amount of green house gases will create excess hot conditions all over the earth.

GLOBAL WARMING

- It is the increase of earth's average surface temperature due to the presence of too much greenhouse gases such as carbon dioxide, methane etc. The atmosphere holds on to too much heat, instead of letting it escape into space. This results in Global Warming.

Causes of Global Warming

- Burning of fossil fuels
- Refrigerants and air conditioners release CFC
- Deforestation - carbon dioxide intake is reduced when forests are cut down.
- Methane emission occurs due to anaerobic decomposition at huge landfills.
- Methane emission from livestock (animal farm)

Effects of Global Warming

- Rising Seas
- Changes in rainfall patterns
- Increased global temperature
- Melting of the ice
- Melting glaciers
- Widespread vanishing of animal populations
- Spread of disease
- Acidification of oceans

Measures to control Global Warming

- Promote renewable energy usage (solar energy, wind energy etc.)
- Depend more on public transport system to reduce the use of fossil fuels.
- Afforestation and reforestation
- Adopt 3R concept whenever possible.
- Reduce energy consumption at home, office etc.

CLIMATE CHANGE

- Climate change refers to changes caused by global warming in weather (temperature, untimely rain etc) and exists for an extended period of time.

Causes of climate change

- Natural causes of climate change are
    1. Continental Drift
    2. Variations in solar output
    3. Volcanoes

4. Earth's tilt
5. Ocean Currents

- Anthropogenic causes of climate change are
    1. Increase in usage of fossil fuels
    2. Deforestation
    3. Population growth
    4. Urbanization
    5. Industrial revolution

Effects of climate change

- Rising Seas
- Changes in rainfall patterns
- Increased global temperature
- Melting of the ice
- Melting glaciers
- Widespread vanishing of animal populations
- Spread of disease
- Acidification of oceans

OZONE LAYER DEPLETION

- Ozone layer is a deep layer in earth's atmosphere
- Ozone is a naturally occurring molecule containing three oxygen atoms.
- These ozone molecules form a gaseous layer in the Earth's upper atmosphere called stratosphere.
- This lower region of stratosphere containing relatively higher concentration of ozone is called Ozonosphere.
- The ozonosphere is found 15-35 km (9 to 22 miles) above the surface of the earth and it protects our planet from the harmful UV radiations.
- The ozone layer has the capability to absorb almost 97-99% of the harmful ultraviolet radiations that sun emits.
- UV rays produce long term devastating effects on human beings as well as plants and animals.

- **Ozone depletion refers to the phenomenon of reductions in the amount of ozone in the stratosphere.**

Man-made causes for Ozone layer depletion

- Main reason for the depletion of ozone layer is the excessive release of chlorine and bromine from man-made compounds like CFCS (chlorofluorocarbons), halons, methylbromide etc
- These man–made compounds are classified as Ozone-Depleting Substances (ODS).
- Ozone- Depleting Substances (ODS) are not washed back in the form of rain on the earth and remains in the atmosphere for quite a long time. With so much stability, they are transported into the stratosphere. These gases are carried to the stratosphere layer of atmosphere.
- Ultraviolet radiations from the sun break them to release chlorine (from CFCs) and bromine (from methylbromide and halons).

Effects of Ozone layer depletion

- Skin cancer
- Eye damage such as cataracts
- Immune system damage
- Reduction in phytoplankton (microscopic marine organisms that are food small fish, as well as whales
- Damage to the DNA in various life-forms

CARBON CREDITS

- It is a credit for greenhouse emissions reduced or removed from the atmosphere from an emission reduction project which can be used, by governments, industry or private individuals to compensate for the emissions they are generating.
- One carbon credit corresponds to one ton of CO_2.
- It is also defined as the amount of GHGs removed or reduced from the atmosphere from an emission reduction project.
- Carbon credits are used as a permit to emit certain amount of CO2 into the atmosphere

- Carbon credits can be created through
    - Construction of a wind farm rather than coal fired power station
    - Afforestation & reforestation which reduce the amount of carbon in atmosphere
    - Solar schemes
- Once approved, these credits are known as **"certified emission reduction" or CER.**
- If one carbon credit is issued to an industry, it means that they can emit one ton of carbon dioxide or equivalent.

CARBON TRADING

- It refers to buying and selling of carbon credits that have been either distributed by a regulatory authority or generated by GHG emissions reduction projects.
- If organizations have a short fall or surplus in GHG allowances, they can engage in trade with each other.

	Company A	Company B
Alloted :	10 carbon credits	12 Carbon credits
Used :	8 carbon credits	14 carbon credits
	2 carbon credits not used	2 carbon credits overused

- Here company A can sell 2 carbon credits to company B for financial benefit. Thus a carbon market is created.

How Does Carbon Credits Work?

- Carbon credits are typically measured in tonnes of CO_2-equivalents.
- They are bought and sold through number of international brokers, online retailers and trading platforms.
- Businesses that find it hard to comply with the carbon emissions, purchase carbon credits to offset their emissions by making finance readily available to renewable energy projects, forest protection and reforestation projects around the world.
- The buyers of the credits benefit as they can use these credits to overcome their green house gas emissions.

- Projects which acquire carbon credits include
  - Wind, solar projects
  - Biomass projects which replace fossil fuel powered plants
  - Different afforestation projects
  - Destruction of heat trapping green house gases from the atmosphere etc…

CARBON FOOTPRINT

- It is a measure of the total amount of carbon dioxide emissions that is directly and indirectly caused by an activity, individual, organization etc.
- Carbon foot print is the sum of all emissions of CO_2 which were induced by your activities in a given time frame.
- Every individual, organization, business unit etc should focus to reduce their carbon footprints.

- Carbon footprint is the sum of two parts
  - **Primary footprint** - It is a measure of direct emission of carbon dioxide as in the case of burning of fossil fuels.
  - **Secondary footprint** – It is the measure of indirect green house gas emissions associated with manufacture of a product

Carbon footprint – classification

- **Personal carbon footprint:** CO_2 emissions caused by each person's clothing, food etc.
- **Product carbon footprint:** It measures the greenhouse gas emissions over the entire life of a product
- **Organizational carbon footprint:** It measures the greenhouse gas emissions from all activities across the organization.
- **Country carbon footprint:** It focuses on CO_2 emissions in the entire country generated by the direct and indirect emissions.

- Main Contributors to Carbon Footprint are
  - Population
  - Energy
  - Industrialization
  - Agriculture
  - Human action (and inaction)

MODULE 3

ENVIRONMENTAL MANAGEMENT STANDARDS (EMS)

- The essence of environmental management is the harmony between man and environment. Along with economic development natural resources needs to be protected. The industries recognized that proper planning right from the start can prevent a number of environmental problems. For this, every organization requires an " **Environment Management System"**
- Protection of environment in a sustainable way is the main intention behind Environment Management System (EMS).
- EMS is defined as a tool with a set of management procedures that allow an organization /industry to identify, evaluate and control the impact of its activities, products and services on the natural environment

EMS mainly serves the following purposes

- Restricts over exploitation of natural resources
- Improves environmental performance by the industry
- Meet regulatory and legislative requirements
- Focuses on continuous improvement of the system
- Enhanced employee morale
- Enhanced image of organization among the public

Basic EMS Framework

This follows a **Plan-Do-Check-Act (PDCA)** cycle. PDCA cycle is a four step management method used to identify a problem and solving the same later.

The four phases are:

- **Plan:** identify and analyze the problem or opportunity, develop hypothesis about what the issues may be, and decide which one to test.
- **Do:** test the potential solution, ideally on a small scale, and measure the results.
- **Check/Study:** study the result, measure effectiveness, and decide whether the hypothesis is supported or not.
- **Act:** if the solution was successful, implement it.

ISO 14000 SERIES

- The International Organization for Standardization (ISO) developed a series of International recognized standards known as ISO 14000 series to help organizations for implementing and evaluating Environmental Management Systems.
- ISO 14000 series is a voluntary standard system which specifies only the procedure "how to achieve the goal". ISO 14000 is not a set of rules and regulations. ISO 14000 is the standard and ISO 14001 is the document containing the requirements.
- The most important of the various Environmental Management Standards is the **ISO 14001** standard. ISO 14001 is the document containing the Environmental Management System specification with guidelines. ISO 14001 standard is voluntary in nature and is the only standard that is auditable.

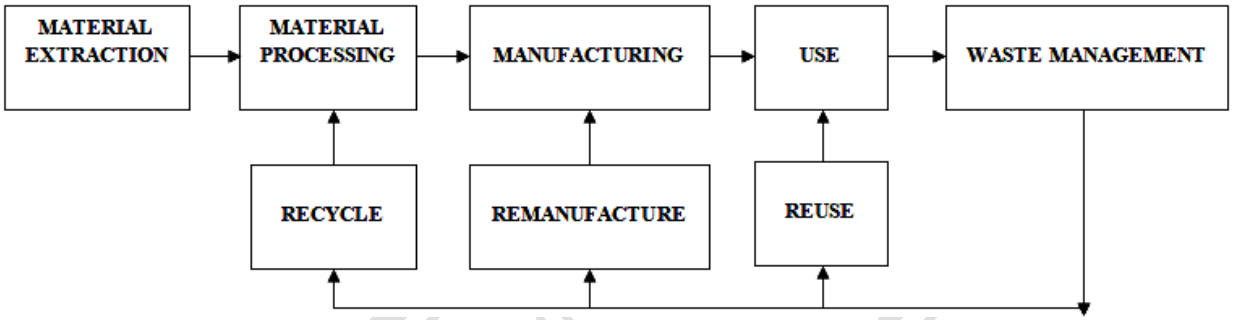
BENEFITS OF ISO 14001:2015

- ***Identify cost savings*** with greater emphasis on resource, waste and energy management
- Develop ***corporate image and credibility***
- Ensure ***legislative awareness and compliance***
- Improve ***environmental performance of supply chain***
- ***Protect the company***, assets, shareholders and directors
- Potentially ***decrease public liability insurance costs*** for your organization
- Grow your ***access to business partners*** and potential customers

LIFE CYCLE ANALYSIS or LIFE CYCLE ASSESSMENT (LCA)

Life cycle analysis or life cycle assessment is an environmental management tool which helps us to determine the environmental impacts of a product throughout its entire lifecycle. The life cycle of a product starts with the raw material extraction from the nature and ends when the product is disposed off finally after use, repair and reuse. It is also known as cradle to grave analysis (cradle- raw material extraction from nature & grave- final disposal).

A schematic representation of a product's lifecycle is as shown.



BASIC COMPONENTS /STAGES IN LCA

1. Goal and scope definition
2. Life cycle inventory (LCI) Analysis
3. Life cycle impact assessment(LCIA)
4. Data interpretation

1. Goal and scope definition

- Here the goal and scope along with assumptions are clearly defined.
- The system boundary is fixed, that is, what is to be included in the study and what not to be.
- It includes technical details that guide subsequent work. It also explains how and to whom the results of the study are to be communicated.

2. Life cycle inventory(LCI) Analysis

- This is the heart of LCA method. It consists of data collection and the main objective is to develop a flow diagram that can **map inputs** (raw materials and energy consumed) **and outputs** (products and environmental emissions).

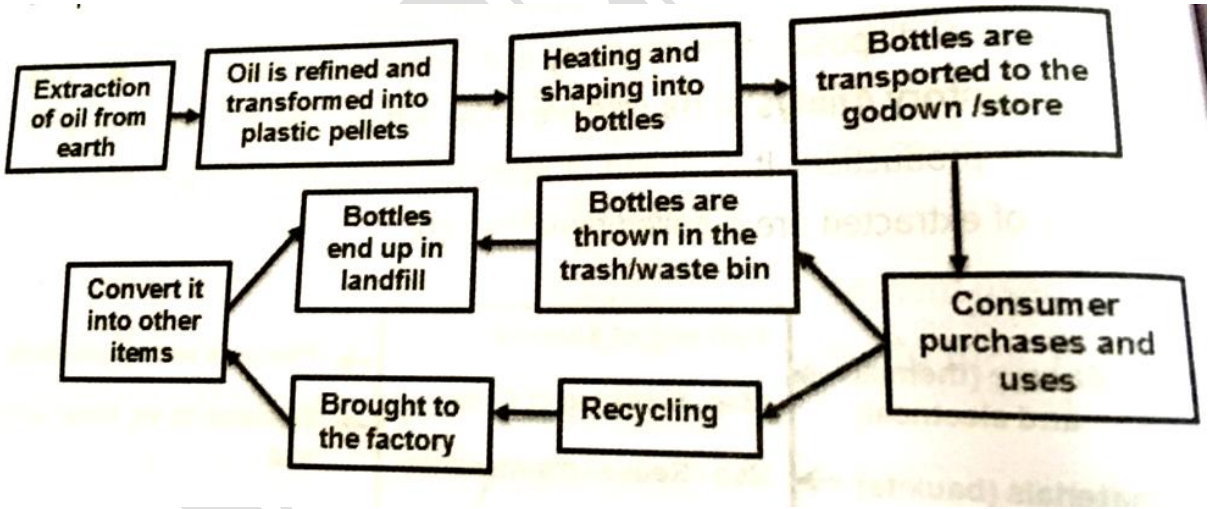
3. Life Cycle Impact Assessment(LCIA)

- In this step, the significance of potential impacts are evaluated with the help of LCI flow results. It focus on human health, ecological health, resource depletion.
- The mandatory steps for accessing the impacts are:
    a) Selection of impact categories
    b) Classification of impacts
    c) Impact characterization

4. Data interpretation

- It is a systematic process to identify, quantify, check and evaluate the results from LCI & LCIA studies.
- The results from the above studies are summarized and presented as a set of conclusions and recommendations.

Case Study: LCA of plastic bottles



1. Goal and Scope

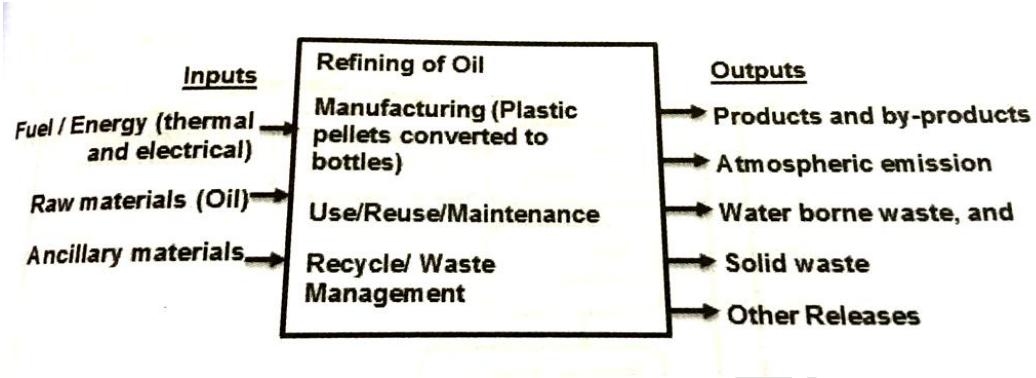
Goal

- The goal of this study is to carry out the LCA of plastic bottles.

Scope

- It comprises a cradle to grave analysis, starting with extraction of the oil from the earth, including oil refining and manufacture of bottles and final disposal.

2. Life Cycle Inventory Analysis (LCIA)



3. Life Cycle Impact Assessment

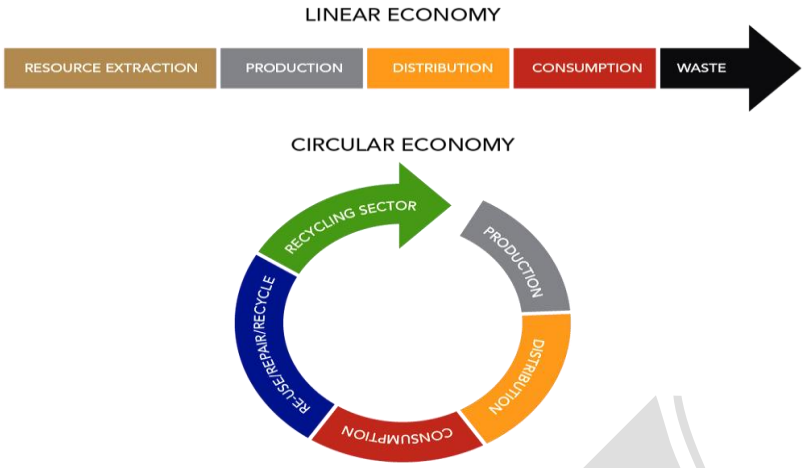
- The various environmental effects includes:
  - **Air emission** – occurs mainly from heating process
  - **Wastewater** – samples of wastewater taken from discharge pipes- analyzed to find physical , chemical and biological impurities
  - **Solid waste-** waste sample collected and proper characterization is carried out.

4. Data Interpretation

- Pollutants are analyzed & various impact parameters are found. If the values are within the limit then product is ecofriendly. If value exceeds limit, then proper remedial measures should be adopted in waste management.
- Recycling has to be ensured to reduce impacts

CIRCULAR ECONOMY

- A circular economy is an economic system of closed loops in which raw materials, components and products lose their value as little as possible and renewable energy sources are used.
- The circular economy refers to an economic model whose objective is to produce goods and services in a sustainable way, by limiting the consumption and waste of resources (raw materials, water, energy) as well as the production of waste.
- It is based on three principles:
  - Design out waste and pollution
  - Keep products and materials in use
  - Regenerate natural systems



Circular economy Benefits

The benefits of circular economy includes

Environmental

- Protection of the environment, reducing waste and the emissions of greenhouse gases
- Allows to decrease the dependence on importation of resources (raw materials, water, energy).

Economic

- It stimulates innovation and boost economic growth, and could in the long run Enhance The Competitiveness Of National Companies

Social

- In addition, the circular economy creates jobs and enables people to save money, cutting unemployment and poverty as well as reducing the social impacts of pollution and climate change.

BIO-MIMICKING

- The word is derived from
  - bios, meaning “life” + mimesis, meaning “to imitate”

  Biomimicry = to imitate life
- **Biomimicry is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology.**

- Biomimicking involves viewing nature as role model/teacher. The nature has already solved many of the technological and sustainability problems that we face today - learning *from nature, not about nature.*

The steps involved in Biomimicking are:

- Identify the human need
- Observe and study the nature carefully
- Get inspired from the nature
- Copy the natural process
- Develop the solution for solving problems of mankind
- Evaluate and refine the developed solutions.

BIOMIMICRY EXAMPLES

1. Kingfisher-Inspired Bullet Train

- The fastest train in the world with speed up to 200 miles per hour, Japan's Shinkansen Bullet Train, after adopting the kingfishers beak design (aerodynamic design), became more silent and consumed 15% less electricity and goes 10% faster than before**.**

2. Termite den = Office building.

- Termites maintain an almost perfectly uniform temperature inside their den. Inspired from this, a commercial office and shopping complex is set up in Zimbabwe with natural ventilation by specially designed windows, variable thickness walls and light colored paints to reduce heat absorption.

3. Swimsuits mimicking shark skin

- Sharkskin is covered with dermal denticles which create a low-pressure zone and pulls the shark forward. 98 percent of the medals at the 2008 Olympics were won by swimmers wearing this sharkskin swimwear.

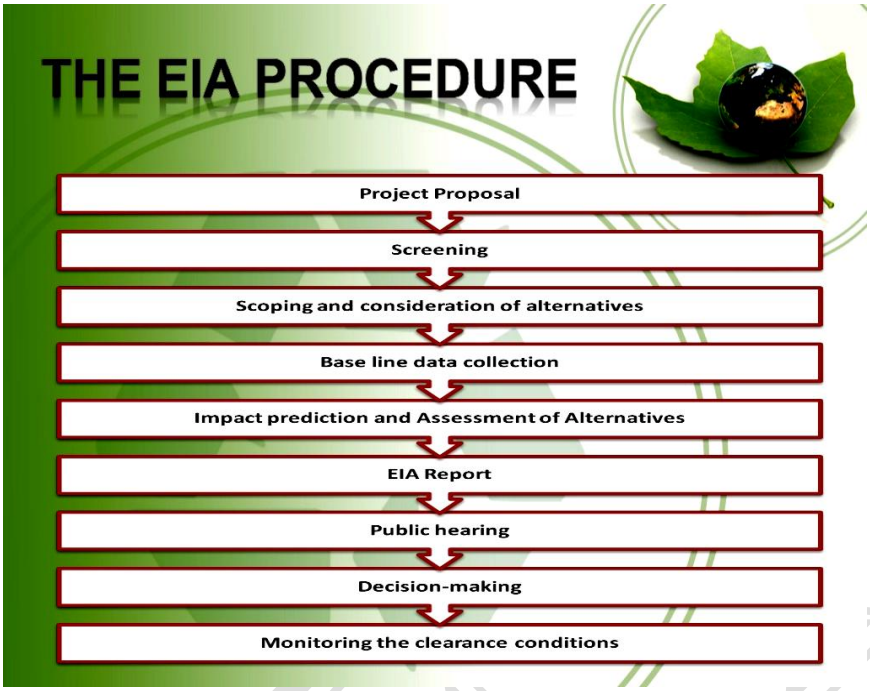
ENVIRONMENT IMPACT ASSESSMENT (EIA)

- It is defined as an activity designed to identify and predict the impact of a proposed project or development on the environment and on the health and wellbeing of human beings and to interpret and communicate information about the impact.
- It also examines implications of a project that might harm people, their homeland or their livelihoods, or other nearby developments. After predicting the problems, EIA identifies measures to minimize the problems and outlines ways to improve the project's suitability for its proposed environment.

Main objectives of EIA

- Predict environmental impacts of projects
- Find ways and means to reduce adverse impacts
- Refine / shape the proposed project to suit the local environment
- Present the predictions and options before the decision makers

EIA PROCEDURE



1. **Project Proposal** – Its is a condensed description of all aspects of the project.
2. **Screening -** Screening basically screen outs the projects that don't require EIA process.
3. **Scoping & Alternate considerations –** Scoping identifies the important environmental impacts that need to be further investigated. Then all the available alternatives should be considered with respect to project site.
4. **Baseline data collection -** Following on from scoping, it is essential to collect all relevant information on the current status of the environment. This study is referred to as a **baseline study.**
5. **Impact prediction & Assessment–** Here all significant environmental impacts (positive & negative) are identified & suitable methods are used to assess the magnitude of the identified impacts.
6. **Preparation of EIA report –** All the details in connection with the project are well documented and made in the form of a report & submitted to the decision maker.
7. **Public hearing –** After completion of EIA report, the public must be informed and the views of the public are taken into consideration.
8. **Decision making –** After going through the EIA report & public hearing report and no objection certificate granted by the government, the decision whether the

proposed project is approved, rejected or needs further change is made by the authorities.

9. **Monitoring the clearance conditions–** Monitoring the environmental clearance condition is carried out during both the constructional and operation phase of the development project

INDUSTRIAL ECOLOGY

- Industrial ecology (IE) is the study of material and energy flows through industrial systems.
- The global industrial economy can be modeled as a network of industrial processes that extract resources from the Earth and transform those resources into commodities which can be bought and sold to meet the needs of humanity.
- Industrial Ecology (IE) is a novel approach to achieve sustainable development.
- It aims to optimize the consumption of natural resources and energy and minimize the generation of waste.
- Industrial ecology is concerned with the shifting of industrial processes from open loop systems, in which resource and capital investments move through the system to become waste, to a closed loop system where wastes can become inputs for new processes.

The benefits of industrial ecology include:

- cost savings (materials purchasing, licensing fees, waste disposal fees, etc);
- improved environmental protection;
- income generation through selling waste
- improved relations with other industries etc..

Limitations to industrial ecology include:

- no market for materials;
- lack of support from government and industry;
- reluctance of industry to invest in appropriate technology;
- reluctance to move to another supplier.

INDUSTRIAL SYMBIOSIS

- Industrial symbiosis a subset of industrial ecology.
- The principle behind industrial symbiosis is quite simple; instead of being thrown away or destroyed; surplus resources generated by an industrial process are captured then redirected for use as a 'new' input into another process by one or more other companies.
- Industrial symbiosis is the process by which wastes or byproducts of an industry or industrial process become the raw materials for another. It also contributes to the reduction of greenhouse gas (GHG) emissions. This process serves to reduce the environmental footprint of the industries involved. Virgin raw materials are required to a lesser degree, and the need for landfill waste disposal is reduced.

Examples of industrial symbiosis are wide ranging and include

- use of waste heat from one industry to warm greenhouses for food production
- recovery of car tyre shavings for use in construction materials
- use of sludge from fish farms as agricultural fertilizer etc.

MODULE 4

RENEWABLE & NON RENEWABLE ENERGY SOURCES

Renewable Energy Sources

- Renewable energy sources are sources of energy that are directly available, immediately accessed and can be replenished in a short period of time. They come from natural sources that are constantly replenished.

  Eg: Solar energy, Wind power, Bio-fuel, Hydro-electric power, Tidal power etc.

Non- Renewable Energy Sources

- Renewable energy sources are sources of energy that cannot be replenished in a short period of time.

  Eg: Coal, Petroleum, natural gas, firewood etc.
- Coal, oil and gas are called "fossil fuels" because they have been formed from the organic remains of prehistoric plants and animals.

BASIC CONCEPTS OF CONVENTIONAL & NON-CONVENTIONAL ENERGY

Conventional Energy Sources

- Conventional sources of energy are non-renewable sources of energy which are being used for a long time. Eg: Coal, Petroleum, natural gas, firewood etc.
- They are exhaustible except water.
- They cause pollution when used, as they emit smoke and ash.
- They are very expensive to be maintained, stored and transmitted as they are carried over long distance through transmission grid and lines

Non-Conventional Energy Sources

- Non-Conventional sources of energy are renewable sources of energy which are inexhaustible.
- They are generally pollution-free and are in the process of development over the past few years. They are less expensive due to local use and easy to maintain.

Eg: Solar energy, Wind power, Bio-fuel, Hydro-electric power, Tidal power etc.

SOLAR ENERGY

- "Solar" is the Latin word for "sun" and solar power is the energy from the sun.
- Solar energy technology can be captured in two forms;
  - **Solar Thermal Conversion** in which solar energy is converted to heat.
  - **Solar photovoltaic Conversion** in which solar energy is converted to voltage (electricity).
- Solar cells use energy from the Sun. Solar panels transfer the Sun's energy directly into electricity.

Advantages

- The energy from the Sun is free.
- The sun does not produce greenhouse gases.
- The sun will always be there during our lifetime.

Disadvantages

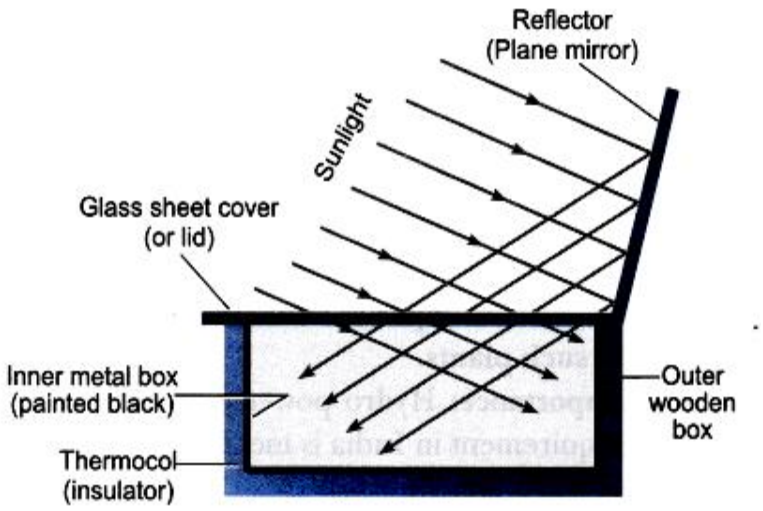
- Solar cells are expensive.
- They take up lots of space.
- They only work in Sun light

Applications of solar technologies include:-

Solar water heating: - Heat from the sun is used to heat water in glass panels on our roof. Water is pumped through pipes in the panel. Using the heat from the sun, water pipes get hot and heat the water without using electricity.

Solar Cars: It is an electrical vehicle which is recharged from solar energy or sunlight. Solar panels are used on this car that absorb light and then convert it into electrical energy. This electrical energy is stored in batteries used within the car, so that we can drive these vehicles in night time too.

Solar cooker: The solar cooker is placed in sunlight and reflector (plane mirror) is adjusted in such a way that a strong beam of sunlight enters the box through the glass sheet.



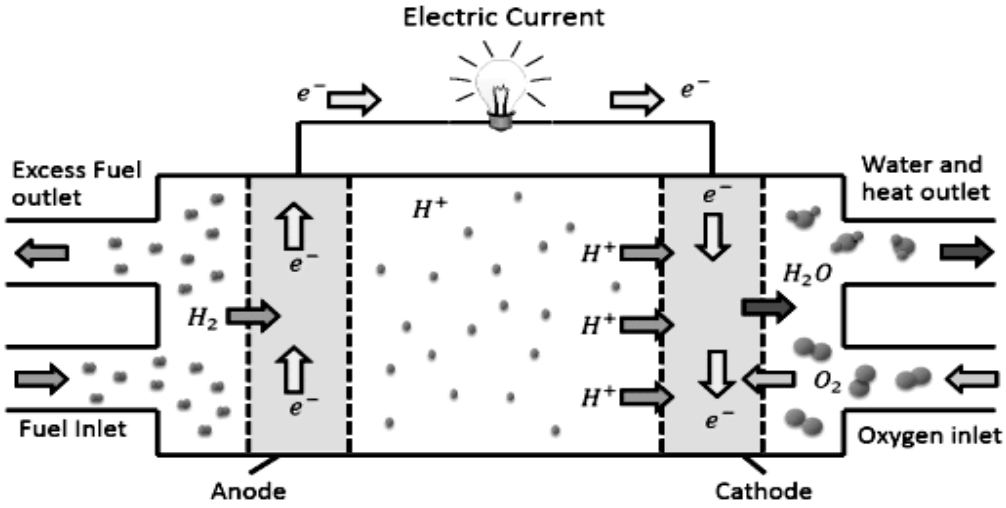
The blackened metal surfaces in the wooden box absorb infra-red radiations from the beam of sunlight and heat produced raises the temperature of blackened metal surface to about 100°C. The food absorbs heat from the black surface and gets cooked.

Solar Electricity — (Photovoltaic): Photovoltaic or PV technology employs solar cells or solar photovoltaic arrays to convert energy from the sun into electricity. Solar cells are made of semiconductor materials. A silicon photovoltaic cell consists of single crystal of p-type silicon with a surface layer of n-type silicon. When light falls on such a p-n junction, electrons and holes move in opposite directions, creating an electric current.

FUEL CELLS

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen. One great advantage of fuel cells is that they generate electricity with very little pollution. A single fuel cell generates a tiny amount of direct current (DC) electricity. In practice, many fuel cells are usually assembled into a stack.



At the anode a catalyst causes the fuel to undergo oxidation reactions that generate ions (often positively charged hydrogen ions) and electrons. The ions move from the anode to the cathode through the electrolyte. At the same time, electrons flow from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, another catalyst causes ions, electrons, and oxygen to react, forming water and possibly other products.

Advantages

- It is compact, light weight and has no moving parts.
- Non Toxic and does not contribute to climatic change
- Available and Renewable
- Energy conversion efficiency is very high (60%)

Disadvantages

- Overall production cost is high.
- Hydrogen is very prone to catch fire, or even exploding

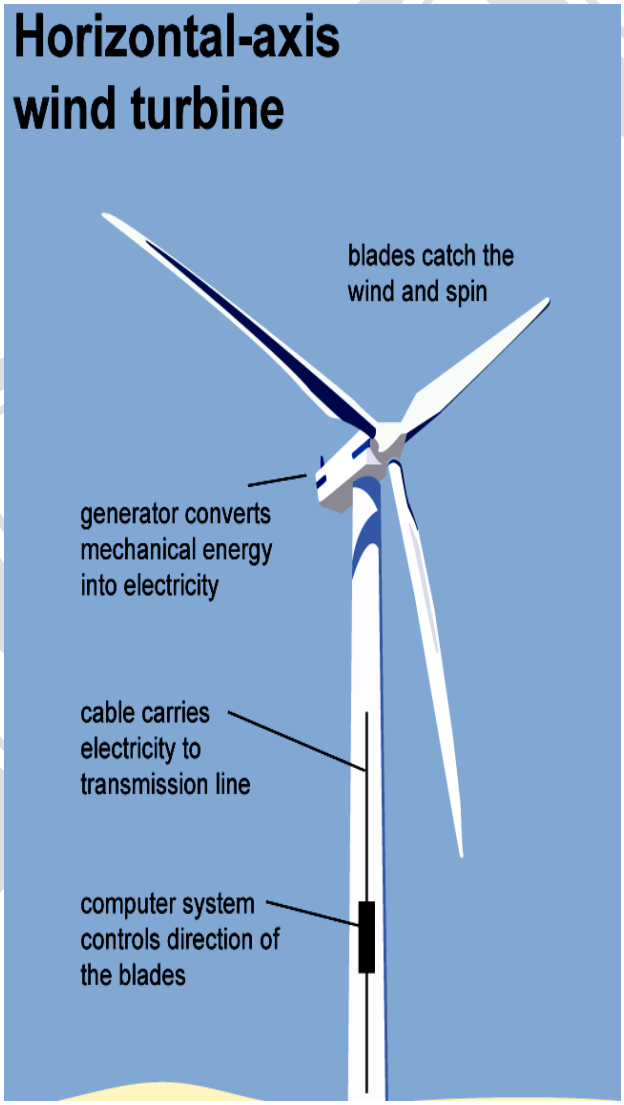
WIND ENERGY

The origin of wind energy is from the sun. When rays from the sun falls on our planet, its surface get heated unevenly and as a consequence wind is formed. Wind always blows from a region of high pressure to a region of low pressure.

Wind Turbines

- A **wind turbine**, or a **wind energy converter**, is a device that converts the wind's kinetic energy into electrical energy.
- Windmills are erected at high altitudes & its blades are attached to the turbines.

- In a wind turbine, the kinetic energy in the wind turns the propeller-like blades around a rotor and gets converted to mechanical energy. The rotor is connected to the main shaft, where the mechanical power spins a generator to produce electricity.
- Depending on the orientation of the main rotor shaft, wind turbines can be classified as
  - Horizontal Axis Wind Turbine (HAWT)
  - Vertical Axis Wind Turbine (VAWT)
- Turbines generally require a wind speed of 20km/hr.
- The best places for wind farms are in coastal areas, at top of rounded hills, open plains, gaps in mountains etc.



Advantages of wind energy

- Wind energy is free, wind farms need no fuel.
- Produce no waste or green house gas (GHG) problems

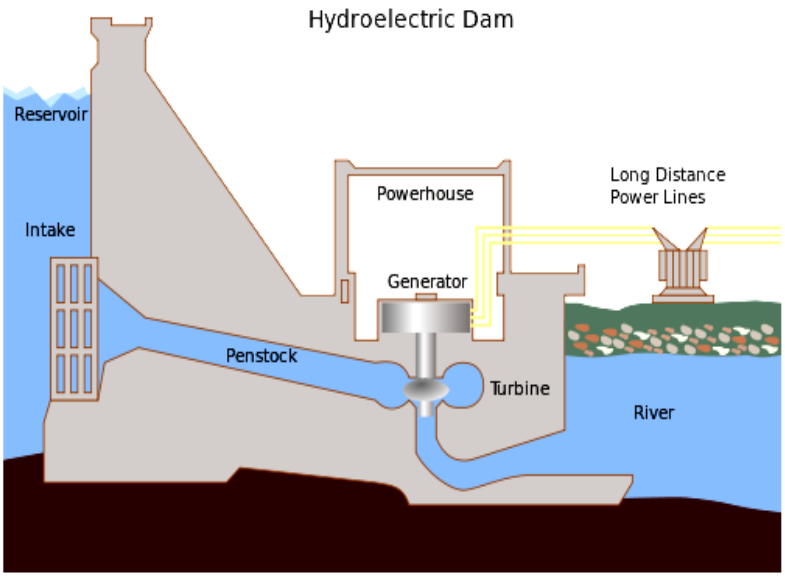
- Individual turbines are repairable and no need of farm shutdown.
- The land beneath the wind mill can be used for agriculture or farming activities

Disadvantages of wind energy

- It cover large areas usually on hill tops.
- They are noisy.
- Need huge amount of cabling and complex electrical technology.
- Wind is not always predictable and hence do not produce same amount of power at all times

SMALL HYDRO PLANTS (SHP)

- Hydroelectricity refers to the electricity generated by hydropower; the production of electric power through the use of gravitational force of the falling or flowing water.
- Hydropower is renewable, clean and non-polluting energy resource. Through hydropower, the energy in falling water is converted into electricity.
- Flowing water is directed to a turbine through a passage called "penstock". The flowing water causes the turbine to rotate, converting the water's **kinetic energy to mechanical energy**. The **mechanical energy** produced by the turbine is converted **into electrical energy** using a turbine generator. The electrical energy is then fed into gridlines to be used in homes industries etc.



Hydro plants can be of Large scale or Small scale. Hydel power plants with capacity more than 15 KW can be categorized as Large scale. Small Hydro Plants (SHP) can provide clean, renewable and inexpensive energy. SHP does not require a reservoir always and can

be constructed across the irrigation canals, waterfalls or hill streams without affecting the environment adversely.

CLASSIFICATION OF SHP IN INDIA

Class	Station Capacity
Micro	Upto 100 kW
Mini	101 kW to 2000 kW
Small	2001 kW to 25000 kW

Advantages of SHP

- It is a clean energy source, producing minimal impact on environment.
- Able to achieve high efficiency compared to other renewable resources.
- Relatively short time for construction and operation.

Disadvantages of SHP

- Consumers needs to be located near the hydropower scheme
- Stream flow limits the power generation

BIO-FUELS

- Bio-fuels are the fuels that are derived from **biomass (organic material** derived from living, or recently living organisms). Biomass can be directly used as a fuel or to produce liquid bio-fuels.
- Bio-fuel is burned to release its stored chemical energy. Bio-fuels can be produced from any photosynthetic plant. Almost all types of materials derived from the plants are used for manufacturing bio-fuel.
- There are two methods currently used to convert the biomass energy to liquid fuel.
    1. Sugar crops are grown and through the process of fermentation, ethanol is produced
    2. Plants are grown that naturally produce oil . These oils are heated and treated to produce bio-diesel.

- The class of bio-fuels can be subdivided into three generations.

1. First generation bio-fuels

- It constitute majority of bio-fuels currently in use. They are made from sugar, starch, or vegetable oil. They are not sustainable and if used in large quantity would have a large impact on the food supply.

2. Second generation bio-fuels

- They are 'greener', as they are made from sustainable plants materials. A series of physical and chemical treatments might be required to convert biomass to liquid fuels suitable for transportation. Most second generation fuels are under development and not widely available for use.

3. Third generation bio-fuels

- It has only recently developed. It refers to bio-fuel derived from algae.

List of biofuels - derived from biomass

1. Bio alcohols (Made when sugar is fermented)
2. Biodiesel & green diesel (Made from vegetable oil)
3. Bioethers (Made from wheat or sugar beat)
4. Biogas
5. Aviation biofuel
6. Solid biofuels (Includes things like wood, saw dust, solid waste etc)
7. Advanced biofuels

MODULE 5

SUSTAINABLE HABITAT

- A *sustainable* habitat is an ecosystem that produces food and shelter for people and other organisms, without resource depletion and in such a way that no external waste is produced. A sustainable habitat that is created and designed by human intelligence will mimic nature, if it is to be successful.

GREEN ENGINEERING

- Green engineering is the design, commercialization, and use of processes and products in a way that reduces pollution, promotes sustainability, and minimizes risk to human health and the environment without sacrificing economic viability and efficiency.
- Green Engineering is an intentional approach towards sustainability focusing on the following
    - Waste minimization
    - Pollution prevention
    - Conserving resources
    - Manufacturing environmentally responsible products

12 principles of Green Engineering

- Principle 1: Designers need to strive to ensure that all material and energy inputs and outputs are as inherently non-hazardous as possible.
- Principle 2: It is better to prevent waste than to treat or clean up waste after it is formed.
- Principle 3: Separation and purification operations should be designed to minimize energy consumption and materials use.
- Principle 4: Products, processes and systems should be designed to maximize mass, energy, space and time efficiency.
- **Principle 5:** System components should be output pulled rather than input pushed through the use of energy and materials.

- **Principle 6:** Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse or beneficial disposition.
- **Principle 7:** Targeted durability, not immortality, should be a design goal (This reduces undesirable substances coming to the environment).
- **Principle 8:** Design for unnecessary capacity or capability should be considered a design flaw (Over design and unrealistic conditions should be avoided).
- **Principle 9:** Material diversity in multicomponent products should be minimized to promote disassembly and value retention.
- **Principle 10:** Design of processes and systems must include integration and interconnectivity with available energy and materials flows.
- **Principle 11:** Products processes and systems should be designed for performance in a commercial "afterlife"(At the end of the commercial life of a product, the components of that product should be such that it could be recovered or recycled).
- **Principle 12:** Material and energy inputs should be renewable rather than depleting

SUSTAINABLE URBANISATION

- In 2007 statics –more than half of the global population was living in cities and towns
- If this rate prevails, by 2050 about two third of the world population may live urban areas
- **Cities have more positive features like**
  - job opportunities and other facilities like education, hospital,transportation, easy access to goods and services, etc
- **Drawbacks**
  - Higher pollution rates
  - High density of population
  - Water scarcity and Sanitation problems
  - Traffic issues, etc

The reason why people move from rural areas to urban areas can be classified into:

1. Push factors:-

Factors (negative reasons) that encourage people to leave rural areas.

2. Pull factors:-

Factors (positive reasons) that attract people to urban areas.

Push Factors	Pull Factors
1. **Economic** No Job, No Money, Less choices	**1. Economic** More Job, More Money, Low price
2. Social Poor education, Poor healthcare Unemployment	**2. Social** Good education, Good healthcare Good facilities
3. Environmental Extreme weather, Natural disasters, Pollution	**3. Environmental** Fine weather, Low natural disasters, Nice environment
4. Political War, Tyrannical corruption	**4. Political** Good government, Less corruption

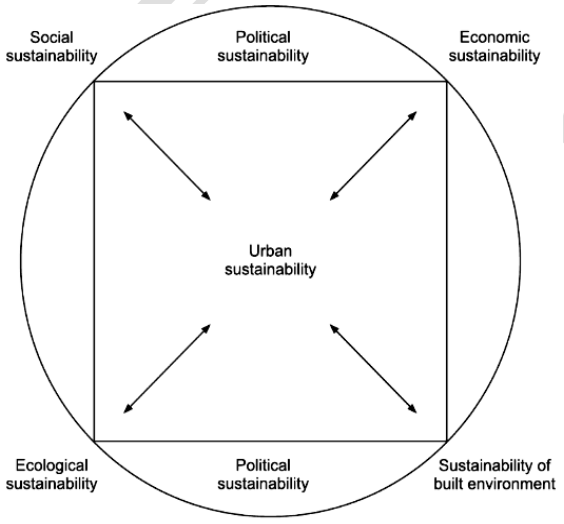
For sustainable urbanisation, the following points must be kept in mind:

- **Economic sustainability :**
  - Use local/regional resources for productive use for the long-term benefit of the community
- **Social sustainability:**
  - promote equal rights for all

- respects cultural heritage and cultural diversity.

- **Ecological sustainability:**
  - Considers environmental impacts that directly influences
  - sustainability of cities
  - Carrying capacity of land and other resources should be analyzed properly
- **Sustainability of the built environment**
  - Too many buildings, roads, flyovers and other construction may cause many environmental and health issues.
- **Political Sustainability**
  - concerned with the quality of governance systems
  - Policies and decisions of government influence better functioning of cities

All the above factors can be summarized as follows:



Sustainable urbanisation concept.