Uttar Pradesh Rajarshi Tandon Open University

M.Sc.

Environmental Science

PGEVS-107 (N)

Energy Resources and Climate Change

COURSE INTRODUCTION

The objective of this course is to provide knowledge of Energy Resources and Climate Change is refers to energy in nature and its role in regulation of ecosystem. However, Concept and scope of environmental physics with respect to human environment, energy resources, and energy flow, climate change and global warming along with energy policy are described. The Greenhouse Effect and Global Warming is briefly discussed in this course. The role of Indian climate panel, Ministry of environment, forests & climate change summarised here. The course is organized into following blocks:

Block 1 covers the introduction to environmental Physics related to human environment and their built environment

Block 2 deals the Energy Resources such as renewable and non-renewable energy resources

Block 3 describes in Climate Change and Global Warming and its current scenario

Block 4 this block covers the climate change and policy frameworks and role of ministry of environment, forests & climate change in environment protection

Rajarshi Tandon Open University, Prayagraj

Energy Resources and Climate Change

Block- 1

Environmental Physics

UNIT -1
Introduction to environmental Physics

UNIT-2

Solar Radiation

UNIT-3
Energy Budget

PGEVS-107N

Energy Resources and Climate Change

Rajarshi Tandon Open University, Prayagraj

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Introduction

This first block of Energy Resources and Climate Change, this consists of following three units:

Unit-1: this unit covers the introduction, concept and scope of environmental Physics with respect to human environment, and built environment. Also covers the laws of thermodynamics, irreversible thermodynamics and entropy in natural ecosystem.

Unit-2: This unit describes about the characteristics of electromagnetic radiation. How energy can disperse and regulate is also discuss as concept of thermal regulation in buildings, thermal insulation, thermal conduction effects and convection effects, radiation effects.

Unit-3: This unit covers the energy Budget and energy efficiency in buildings. It also discusses the energy losses, calculation of energy losses, energy gains, air regulation in buildings, heat pumps, condensation.

Unit-1: Environmental Physics

Contents

1.1. Introduction

Environmental Physics is scientific discipline that focuses on measurement and analysis of interactions between organisms and their environment and also to determination of how environmental factors affect biological and physical processes in natural ecosystems. Environmental physicists seek to discover the underlying principles that govern mass and energy transport in the organism-atmosphere system. The principles of physics can be used to determine the energy and heat flowing in and out of ecosystems, the way water carries sediments, how warm and cold ocean currents circulate and influence aquatic ecosystems, and yes, how pollutants and greenhouse gases are transported through our atmosphere and environment. The weather that a particular area experiences, for example, is determined by physical forces such as how much solar radiation the area receives. Environmental Physics observed the behavior of organisms and objects in the environments in which they reside, and mathematically describing the behavior in terms of environmental parameters such as radiant energy, temperature, and concentrations of water, nutrients, and other natural and manmade compounds. Environmental physics integrates the physics processes in the atmosphere, biosphere, hydrosphere, and geosphere etc.

Objectives

- To understand the environmental physics and its scope
- To discuss the build environment and its conservation
- To discuss the law of thermodynamics and its application is environmental sciences
- To discuss heat balance and entropy

1.2.Environmental physics overview

Environmental physics is an interdisciplinary field that applies the principles of physics to study the interactions between the environment and physical systems. It encompasses a wide range of topics, including atmospheric physics, hydrology, oceanography, climate change, and renewable energy. In 2000, the field of environmental physics was rapidly developing, with a focus on understanding the impact of human activities on the environment and developing solutions to mitigate those impacts. This included research on the physics of air pollution, the dynamics of ocean currents, the physics of renewable energy sources, and the physics of climate change. At this time, there was also a growing interest in interdisciplinary collaboration, as scientists recognized that environmental problems require expertise from multiple fields, including physics, chemistry, biology, and engineering. This led to the development of new research programs and the formation of interdisciplinary teams to tackle complex environmental issues.

1.2.1. Principle of environmental physics

Environmental physics is based on a set of fundamental principles that underlie the behavior of the environment and the physical processes that govern it. Some of the key principles of environmental physics include:

- **Conservation of Energy**: The principle of conservation of energy states that energy cannot be created or destroyed, only transformed from one form to another. Environmental physics applies this principle to understand the energy balance of the Earth and the behavior of renewable energy sources.
- **Thermodynamics:** The laws of thermodynamics govern the behavior of energy and matter in the environment. Environmental physicists use these laws to understand the behavior of the atmosphere, oceans, and land surface, and to predict the impacts of climate change.

1.2.2. Scope of environmental physics

The field of environmental physics was broad and encompassed a wide range of applications in last few years. Some of the key areas of focus included:

Climate Change: Environmental physicists were studying the physical processes that underlie climate change, including the greenhouse effect, oceanic and atmospheric circulation, and the carbon cycle. They were also involved in developing models to predict future climate change scenarios and in developing strategies to mitigate its impacts.

Atmospheric Physics: The physics of the atmosphere was an important area of research, with a focus on understanding the dynamics of air pollution, including its transport and dispersion. Environmental physicists were also involved in the development of atmospheric models and in the study of the effects of climate change on atmospheric processes.

Renewable Energy: Environmental physicists were involved in the development of renewable energy sources, including solar, wind, and hydroelectric power. They were studying the physics of these energy sources, including the mechanics of wind and water, and the behavior of solar radiation.

Oceanography: The physics of ocean currents was a key area of study, including the dynamics of tides and waves, and the behavior of ocean currents. Environmental physicists were also involved in studying the impact of climate change on oceanic processes and in developing models to predict future oceanic behavior.

Hydrology: The study of water in the environment was an important area of research, including the behavior of rivers and streams, the dynamics of groundwater, and the study of floods and droughts. Environmental physicists were involved in developing models to predict water behavior and in the study of the impacts of climate change on hydrological processes.

Overall, the application of environmental physics was focused on understanding the physical processes that govern the behavior of the environment, and on developing strategies to address environmental challenges and promote sustainability. This involved collaboration across multiple fields, including physics, chemistry, biology, and engineering, and required a holistic approach to understanding environmental problems.

1.2.3. Application of environmental physics

The application of environmental physics is crucial for understanding and managing environmental challenges, from climate change to air and water pollution, to waste management. By studying the physical processes that govern the behavior of the environment, environmental physicists are able to develop strategies for promoting sustainability and protecting the environment. Here are example of some environmental physics such as

Climate Change: Environmental physics plays a crucial role in understanding and predicting the behavior of the climate system, including the dynamics of the atmosphere, ocean, and land surface. Environmental physicists are involved in developing models that simulate the climate system and in studying the impacts of human activities on the climate.

Air Pollution: Environmental physicists study the physical processes that govern the behavior of air pollutants in the atmosphere, including their transport and dispersion. They use this knowledge to develop models that predict air pollution levels and to design strategies to mitigate air pollution.

Renewable Energy: Environmental physicists are involved in the development and optimization of renewable energy sources, including solar, wind, and hydroelectric power. They study the physics of these energy sources, including the mechanics of wind and water, and the behavior of solar radiation.

Water Resources: Environmental physicists study the behavior of water in the environment, including the dynamics of rivers and streams, the behavior of groundwater, and the study of floods and droughts. They develop models to predict water behavior and to design strategies for managing water resources.

Waste Management: Environmental physicists are involved in the study of the physical processes that govern the behavior of waste in the environment, including the behavior of pollutants in landfills and the transport of pollutants in groundwater. They design strategies to mitigate the environmental impacts of waste disposal.

Environmental Monitoring: Environmental physicists develop and use instruments to monitor environmental parameters such as temperature, humidity, air pressure, and air pollution. They use this data to study environmental processes and to identify trends in environmental behavior.

1.3. Environmental physics and human

Environmental physics has important implications for human beings and our impact on the environment. By studying the physical processes that govern the behavior of the environment, environmental physicists are able to better understand the impacts of human activities and to develop strategies to mitigate them. Some of the key ways in which environmental physics relates to human beings include:

Climate Change: Environmental physics plays a key role in understanding and addressing the impacts of climate change on human societies. By studying the physical processes that underlie climate change, environmental physicists are able to predict the impacts of rising temperatures, changing precipitation patterns, and sea level rise, and to develop strategies to mitigate these impacts.

Air Pollution: Environmental physics is important in understanding and addressing the impacts of air pollution on human health. By studying the physical processes that govern the behavior of air pollutants, environmental physicists are able to design strategies to mitigate air pollution and to promote clean air.

Renewable Energy: Environmental physics plays a key role in the development and optimization of renewable energy sources, such as solar and wind power, which are important for reducing greenhouse gas emissions and mitigating the impacts of climate change. By studying the physics of these energy sources, environmental physicists are able to design more efficient and effective technologies.

Water Resources: Environmental physics is important in understanding and managing water resources, which are crucial for human societies. By studying the behavior of water in the environment, including the dynamics of rivers and streams, the behavior of groundwater, and the study of floods and droughts, environmental physicists are able to design strategies for managing water resources and promoting sustainable water use.

Overall, environmental physics has important implications for human societies and our impact on the environment. By studying the physical processes that govern the behavior of the environment, environmental physicists are able to develop strategies to address environmental challenges and promote sustainability, ensuring a better future for human beings and the planet.

1.4. Built environment and their conservation strategy

The built environment refers to the human-made structures and spaces that we inhabit, including buildings, roads, bridges, and other infrastructure. Conserving the built environment involves preserving these structures and spaces in a way that maintains their historical, cultural, and architectural significance, while also promoting sustainability and efficient use of resources. Conserving the built environment requires a multifaceted approach that balances the preservation of historical and cultural significance with the need for sustainability and efficient resource use. By adopting these strategies, we can ensure that the built environment remains an important part of our cultural heritage while also promoting a more sustainable future. Here are some key strategies for conserving the built environment:

Preservation: One of the most important strategies for conserving the built environment is to preserve historic and culturally significant buildings and structures. This involves maintaining the integrity of the original design and materials, while also ensuring that the structure is safe and functional for modern use.

Adaptive Reuse: In some cases, historic buildings may no longer serve their original purpose or be economically viable for their original use. Adaptive reuse involves repurposing these buildings for new uses that are compatible with their historic character, such as converting a former factory into loft apartments.

Sustainable Design: Conserving the built environment also involves designing new buildings and infrastructure in a way that promotes sustainability and efficient use of resources. This can include using energy-efficient materials and systems, designing buildings to maximize natural light and ventilation, and incorporating green spaces and public transportation into urban planning.

Maintenance: Regular maintenance and repair of buildings and infrastructure are essential for their long-term conservation. This includes routine inspections, repairs, and upgrades to ensure that structures remain safe, functional, and visually appealing.

Public Engagement: Finally, conserving the built environment requires the participation and engagement of the public. This can involve educating the public about the historical and cultural significance of buildings and structures, encouraging community involvement in preservation efforts, and promoting sustainable design and development practices.

1.4.1. Types of built environment

The built environment encompasses a wide range of human-made structures and spaces. The built environment is a diverse and complex system that includes a wide range of structures and spaces. By understanding the different types of built environment and their unique characteristics, we can develop strategies to conserve these structures and promote sustainability for future generations. The different types of built environment are as

Residential Buildings: Residential buildings include single-family homes, apartment buildings, and townhouses. These structures are designed to provide housing for individuals and families.

Commercial Buildings: Commercial buildings include office buildings, retail stores, restaurants, and other businesses. These structures are designed to provide space for commercial activities and may include amenities such as parking lots and loading docks.

Industrial Buildings: Industrial buildings include factories, warehouses, and other facilities that are used for manufacturing, storage, and other industrial processes.

Transportation Infrastructure: Transportation infrastructure includes roads, highways, bridges, and tunnels that are designed to facilitate the movement of people and goods.

Public Spaces: Public spaces include parks, plazas, and other outdoor areas that are designed for public use and enjoyment.

Cultural and Historical Sites: Cultural and historical sites include museums, monuments, and other structures that are designed to preserve and showcase important aspects of human history and culture.

Educational Facilities: Educational facilities include schools, universities, and other buildings that are designed for teaching and learning.

Healthcare Facilities: Healthcare facilities include hospitals, clinics, and other buildings that are designed to provide medical care to patients.

1.4.2. Methods adopted for built environment

Methods adopted for the built environment typically involve a combination of design, construction, and maintenance practices that aim to create structures and spaces that are safe, functional, and visually appealing. Here are some common methods that are adopted for the built environment:

Sustainable Design: Sustainable design involves incorporating environmental considerations into the design of buildings and infrastructure. This can include using energy-efficient materials and systems, designing buildings to maximize natural light and ventilation, and incorporating green spaces and public transportation into urban planning.

Building Information Modeling (BIM): BIM is a digital design and construction process that allows architects, engineers, and construction professionals to create 3D models of buildings and infrastructure. This technology can help to reduce errors, improve communication between stakeholders, and optimize building performance.

Construction Management: Construction management involves overseeing the construction process to ensure that it is completed on time, within budget, and to the required standards of quality and safety.

Maintenance and Repair: Regular maintenance and repair of buildings and infrastructure are essential for their long-term conservation. This includes routine inspections, repairs, and upgrades to ensure that structures remain safe, functional, and visually appealing.

Preservation and Adaptive Reuse: Preservation and adaptive reuse are strategies for conserving historic and culturally significant buildings and structures. Preservation involves maintaining the integrity of the original design and materials, while adaptive reuse involves repurposing these buildings for new uses that are compatible with their historic character.

Public Engagement: Public engagement involves educating the public about the importance of the built environment and encouraging community involvement in preservation and sustainability efforts.

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The methods adopted for the built environment are diverse and constantly evolving to meet changing needs and priorities. By adopting sustainable design and construction practices, implementing effective maintenance and repair programs, and engaging the public in conservation efforts, we can ensure that the built environment remains an important part of our cultural heritage while also promoting a more sustainable future.

1.5. Law of thermodynamics

The laws of thermodynamics are fundamental principles of physics that govern the behavior of energy in all physical systems, including the environment. The laws of thermodynamics are expressed mathematically using equations.

1.5.1. First Law of Thermodynamics:

The first law of thermodynamics, also known as the law of conservation of energy, states that energy cannot be created or destroyed, but can only is transformed from one form to another. This means that the total amount of energy in a closed system remains constant.

$$\Delta U = Q - W$$

Where ΔU is the change in internal energy of a system, Q is the heat added to the system and W is the work done by the system. This equation expresses the conservation of energy in a closed system, where the total energy is constant but can be transformed between different forms.

Example: When sunlight falls on a solar panel, the energy of the sunlight is converted into electrical energy, which can be used to power homes and other buildings. The total amount of energy in the system (the sun and the solar panel) remains constant, but the form of energy has been transformed from solar energy to electrical energy.

1.5.2. Second Law of Thermodynamics:

The second law of thermodynamics states that the total entropy (or disorder) in a closed system always increases over time. This means that in any energy transfer or transformation, some energy will always be lost as unusable waste heat.
Example: When gasoline is burned in a car engine, some of the energy is used to move the car forward, but much of the energy is lost as waste heat that dissipates into the environment. This process results in an increase in entropy in the environment.

$$\Delta S \geq Q/T$$

Where ΔS is the change in entropy of a system, Q is the heat added to the system, and T is the absolute temperature. This equation expresses the increase in entropy that occurs in any energy transfer or transformation, where some energy is lost as waste heat.

1.5.3. Third Law of Thermodynamics:

The third law of thermodynamics states that it is impossible to reach absolute zero temperature, which is the theoretical temperature at which all motion of particles stops. This law has implications for the behavior of matter at very low temperatures. As the third law of thermodynamics is a limit law, it does not have a specific equation associated with it.

Example: At extremely low temperatures, certain materials can exhibit interesting behaviors, such as superconductivity or super fluidity. These behaviors are related to the behavior of particles at very low energies and temperatures.

The laws of thermodynamics are important principles that help us to understand the behavior of energy in the environment and other physical systems. By understanding these laws, we can develop more efficient and sustainable energy systems and minimize waste and environmental impact and also we can make predictions and develop strategies for managing energy in a sustainable and efficient way.

1.6.Irreversible thermodynamics

Irreversible thermodynamics is a branch of thermodynamics that deals with the study of systems that are not in thermodynamic equilibrium and undergo irreversibility due to the presence of entropy generation. The concept of irreversibility is important in understanding real-world processes, as many processes in nature are inherently irreversible. The mathematical formulation of irreversible thermodynamics involves the use of the Onsager reciprocal relations and the entropy production inequality.

The Onsager reciprocal relations were first proposed by Lars Onsager in 1931 and relate the transport coefficients of a system to their corresponding fluxes. The entropy production inequality is a statement of the second law of thermodynamics that states that the total entropy production of a system and its surroundings must always be greater than or equal to zero.

The Onsager reciprocal relations can be expressed mathematically as follows:

$$J_i = L_{ij} X_j$$

where J_i is the flux of the ith variable, X_j is the thermodynamic force of the jth variable, and L_{ij} is the Onsager coefficient that relates the two. The Onsager coefficients are symmetric, which means that $L_{ij} = L_{ji}$.

The entropy production inequality can be expressed mathematically as follows:

$$dS/dt = \sigma \geq 0$$

where dS/dt is the rate of change of entropy, and σ is the entropy production rate.

The entropy production rate σ can be expressed as follows:

$$\sigma = \sum_i J_i X_i/T$$

where T is the absolute temperature, and J_i and X_i are the flux and thermodynamic force, respectively, of the ith variable.

Examples of Irreversible Processes:

Heat Transfer: When a hot object is placed in contact with a cold object, heat flows from the hot object to the cold object until the two objects reach thermal equilibrium. This process is irreversible, as entropy is generated due to the temperature difference between the two objects.

Diffusion: When a solute is dissolved in a solvent, the solute molecules diffuse from areas of high concentration to areas of low concentration until the concentration is uniform throughout the solution. This process is irreversible, as entropy is generated due to the concentration gradient between the solute and solvent.

Chemical Reactions: Chemical reactions involve the conversion of reactants into products, and many chemical reactions are irreversible. For example, the combustion of fossil fuels involves the conversion of hydrocarbons into carbon dioxide and water, which is an irreversible process.

Biological Processes: Many biological processes involve irreversible thermodynamic processes. For example, the conversion of food into energy in the human body involves a series of irreversible biochemical reactions that generate entropy.

Electronic Devices: Electronic devices, such as computers and smart phones, operate based on irreversible thermodynamic processes. The flow of electrical current through a circuit generates heat due to resistance, which is an irreversible process.

Global Warming: The increase in greenhouse gases in the atmosphere, such as carbon dioxide, methane, and nitrous oxide, is leading to global warming. The absorption and emission of infrared radiation by these gases generate entropy and cause irreversibility.

Air Pollution: The emission of pollutants from industries, vehicles, and other sources causes air pollution. The diffusion and mixing of these pollutants in the air generate entropy and cause irreversibility.

Water Pollution: The discharge of untreated wastewater, agricultural runoff, and industrial effluents into water bodies causes water pollution. The mixing and dispersion of these pollutants in water generate entropy and cause irreversibility.

Land Degradation: The overuse and mismanagement of land for agriculture, urbanization, and industrialization cause land degradation. The loss of topsoil, soil erosion, and desertification generate entropy and cause irreversibility.

Renewable Energy Generation: The conversion of renewable energy sources, such as solar, wind, and hydro, into electricity involves irreversible thermodynamic processes. The conversion of sunlight into electricity using photovoltaic cells generates entropy due to the non-ideal conversion efficiency.

Ocean Acidification: The absorption of carbon dioxide by the oceans causes ocean acidification. The chemical reactions that occur when carbon dioxide dissolves in seawater generate entropy and cause irreversibility.

Natural Disasters: Natural disasters, such as earthquakes, hurricanes, and floods, cause irreversibility in the environment. The sudden release of energy and the changes in temperature and pressure during these events generate entropy and cause irreversibility.

The irreversible thermodynamics is an important concept in environmental physics that describes the behavior of systems that undergo irreversibility due to the presence of entropy generation. The mathematical equations of irreversible thermodynamics, such as the Onsager reciprocal relations and the entropy production inequality, provide a framework for analyzing and predicting irreversible processes in the environment. Environmental processes that exhibit irreversibility, such as global warming, air pollution, water pollution, land degradation, renewable energy generation, ocean acidification, and natural disasters, have significant.

1.7. Entropy

Entropy is a fundamental concept in thermodynamics that measures the degree of disorder or randomness in a system. In the context of the environment, entropy is an important concept because it can be used to understand and quantify the effects of human activities on natural systems. In this answer, we will discuss entropy in the environment and provide examples of how it is manifested in various environmental processes.

The Second Law of Thermodynamics states that the total entropy of a closed system (i.e., a system that does not exchange matter or energy with its surroundings) always increases over time. This law is also known as the law of entropy increase. The reason for this is that as a system becomes more disordered, the number of possible states it can occupy increases, and so the system's entropy increases.

The calculation of entropy in the environment involves the analysis of the flow of energy and matter between different systems. Entropy can be calculated using the formula:

$$\Delta S = Q/T$$

Where ΔS is the change in entropy, Q is the heat transfer, and T is the absolute temperature. The formula can be used to calculate the entropy change for any process that involves the transfer of heat, such as chemical reactions, heat flow, and biological processes. Here are some examples of how the formula can be used to calculate entropy in the environment:

Heat Transfer: When heat is transferred from a hot object to a cold one, entropy is generated. This is because the heat flow increases the randomness of the molecules in the system. For example, when the sun heats the Earth's surface, the absorbed energy increases the entropy of the atmosphere and the ground. To calculate the entropy change, we can use the formula:

$$\Delta S = Q/T$$

Where Q is the heat transfer and T is the temperature. Assuming that the sun transfers 1 joule of heat to the Earth's surface, and the temperature of the Earth is 288 K, we can calculate the entropy change as follows

Chemical Reactions: Chemical reactions that occur in natural systems can also generate entropy. For example, when organic matter decays, the process generates heat and releases gases such as carbon dioxide and methane, increasing the entropy of the surrounding environment. To calculate the entropy change for a chemical reaction, we can use the formula: $\Delta S = Q/T$

where Q is the heat transfer associated with the reaction, and T is the temperature. Assuming that the combustion of 1 mole of methane releases 890 kJ of heat at 298 K, we can calculate the entropy change as follows:

$\Delta S = -890{,}000\ J/298\ K = -2986\ J/K$

This means that the combustion of methane decreases the entropy of the surrounding environment by 2986 J/K.

Biological Processes: Biological systems are complex and often involve multiple energy and matter transfers. However, in general, the metabolic processes that take place in living organisms generate entropy. For example, when an animal consumes food, some of the energy is used to maintain the body's functions, but the rest is released as heat, increasing the entropy of the environment. To calculate the entropy change associated with a biological process, we can use the formula:

$\Delta S = Q/T$

where Q is the heat transfer associated with the process, and T is the temperature. Assuming that the metabolism of 1 mole of glucose releases 2800 kJ of heat at 310 K, we can calculate the entropy change as follows:

$\Delta S = -2800{,}000\ J/310\ K = -9032\ J/K$

This means that the metabolism of glucose decreases the entropy of the surrounding environment by 9032 J/K.

Air and Water Pollution: Human activities such as burning fossil fuels or releasing untreated wastewater into rivers and oceans generate pollution, which can also increase the entropy of the environment. For example, the production and burning of coal to generate electricity releases greenhouse gases into the atmosphere, increasing the entropy of the atmosphere.

Land Use Change: Human activities such as deforestation and urbanization can also alter the entropy of the environment. For example, when forests are cleared, the soil is exposed to sunlight and heat, increasing the entropy of the soil and the atmosphere.

Entropy and Environmental Sustainability:

The concept of entropy can also be used to analyze the sustainability of natural systems. In general, a sustainable system is one that can maintain its energy and matter flows over time without degrading or becoming less efficient. To achieve sustainability, it is essential to minimize entropy generation by reducing waste, increasing energy efficiency, and conserving resources. For example, the use of renewable energy sources such as wind and solar power can help reduce the entropy generation associated with burning fossil fuels. Similarly, waste reduction and recycling can help reduce the entropy associated with waste disposal.

1.8. Heat balance

Heat balance is a critical concept in environmental physics that refers to the balance between the incoming and outgoing radiation in the Earth's atmosphere. The heat balance determines the overall temperature and climate of the planet and is influenced by various factors such as solar radiation, greenhouse gases, and cloud cover. The heat balance equation can be expressed as:

$$Q^* = Qs - Qr - Qh – Qe$$

Where Q* is the net heat transfer, Qs is the incoming solar radiation, Qr is the outgoing radiation, Qh is the sensible heat transfer, and Qe is the latent heat transfer. The heat balance equation is based on the First Law of Thermodynamics, which states that the energy cannot be created or destroyed, but it can be transferred from one form to another. The components of the heat balance equation is

Incoming Solar Radiation (Qs):

The Earth receives solar radiation from the Sun, which is the primary source of energy for the planet. The incoming solar radiation is also known as the solar constant, which is estimated to be about 1366 watts per square meter (W/m^2) at the top of the atmosphere. However, this value can vary due to factors such as the Earth's orbital position and solar activity.

Outgoing Radiation (Qr):

The Earth emits radiation in the form of longwave infrared radiation, which is absorbed by greenhouse gases in the atmosphere. The outgoing radiation is also known as the Earth's radiation budget, which is estimated to be about 235 W/m^2. However, this value can vary depending on factors such as cloud cover and greenhouse gas concentrations.

Sensible Heat Transfer (Qh):

Sensible heat transfer refers to the transfer of heat between the Earth's surface and the atmosphere due to temperature differences. This heat transfer occurs through conduction, convection, and radiation. Sensible heat transfer is influenced by factors such as the surface properties, wind speed, and atmospheric stability.

Latent Heat Transfer (Qe):

Latent heat transfer refers to the transfer of heat between the Earth's surface and the atmosphere due to the evaporation or condensation of water. This heat transfer occurs through the phase change of water from liquid to vapor or vapor to liquid. Latent heat transfer is influenced by factors such as the surface moisture content, wind speed, and atmospheric moisture content.

1.8.1. Factors Influencing the Heat Balance:

Greenhouse Gases:

Greenhouse gases such as carbon dioxide, methane, and water vapor play a significant role in the Earth's heat balance. These gases absorb and re-emit longwave radiation, trapping heat in the atmosphere and contributing to the greenhouse effect. The concentration of greenhouse gases in the atmosphere is influenced by factors such as human activities and natural processes such as volcanic activity and the carbon cycle.

Cloud Cover:

Clouds can either absorb or reflect solar radiation, depending on their properties such as thickness and altitude. Low clouds tend to reflect more solar radiation than high clouds, which tend to absorb more solar radiation. Cloud cover is influenced by factors such as atmospheric moisture content, wind speed, and atmospheric stability.

Albedo:

Albedo refers to the reflectivity of the Earth's surface, which can influence the heat balance. Surfaces with high albedo, such as snow and ice, reflect more solar radiation than surfaces with low albedo, such as forests and oceans. The albedo of the Earth's surface is influenced by factors such as land use, vegetation cover, and snow cover.

Topography:

The topography of the Earth's surface can also influence the heat balance. Mountainous regions tend to receive more solar radiation than flat regions.

1.8.2. Heat balance in steady state

Heat balance in steady state refers to a condition where the incoming and outgoing heat fluxes in the environment are in equilibrium, resulting in a stable temperature. In this state, the net heat transfer is zero, and there is no accumulation or loss of heat in the system. In this article, we will discuss the heat balance in steady-state, its components, and examples of steady-state systems in the environment.

The heat balance equation in steady-state can be expressed as:

$$Qs = Qr + Qh + Qe$$

Where Qs is the incoming solar radiation, Qr is the outgoing radiation, Qh is the sensible heat transfer, and Qe is the latent heat transfer. Examples of Steady-State Systems in the Environment are

Oceans:

The Earth's oceans are an example of a steady-state system in the environment. The incoming solar radiation heats the surface of the ocean, which is balanced by the outgoing radiation, sensible heat transfer, and latent heat transfer. The ocean currents and wind patterns maintain the balance of heat fluxes, resulting in a stable temperature.

Deserts:

Desserts are also an example of a steady-state system in the environment. The incoming solar radiation heats the surface of the desert, which is balanced by the outgoing radiation, sensible heat transfer, and latent heat transfer. The lack of moisture in the atmosphere results in a low latent heat transfer, which is compensated by a high sensible heat transfer.

Forests:

Forests are another example of a steady-state system in the environment. The incoming solar radiation heats the surface of the forest, which is balanced by the outgoing radiation, sensible heat transfer, and latent heat transfer. The evapotranspiration from the forest results in a high latent heat transfer, which is balanced by a low sensible heat transfer.

The heat balance in steady-state is an important concept in environmental physics that describes the balance of heat fluxes in a stable temperature system. The components of the heat balance equation include the incoming solar radiation, outgoing radiation, sensible heat transfer, and latent heat transfer. Examples of steady-state systems in the environment include oceans, deserts, and forests, which are characterized by a balance of heat fluxes that maintain a stable temperature.

1.8.3. Heat balance in transient state

Heat balance in transient state refers to a condition where the incoming and outgoing heat fluxes in the environment are not in equilibrium, resulting in a changing temperature. In this state, the net heat transfer is not zero, and there is a temporary accumulation or loss of heat in the system. In this article, we will discuss the heat balance in transient state, its components, and examples of transient systems in the environment.

The heat balance equation in transient state can be expressed as:

$$dQ/dt = Qs - Qr - Qh - Qe$$

Where dQ/dt is the rate of change of heat energy, Qs is the incoming solar radiation, Qr is the outgoing radiation, Qh is the sensible heat transfer, and Qe is the latent heat transfer. The examples of transient systems in the Environment are

Heat Waves:

Heat waves are an example of a transient system in the environment. During a heat wave, the incoming solar radiation is higher than the outgoing radiation, resulting in a temporary accumulation of heat in the system. The sensible heat transfer also increases, contributing to the rise in temperature.

Forest Fires:

Forest fires are another example of a transient system in the environment. The heat released from the fire increases the incoming radiation, resulting in a temporary accumulation of heat in the system. The smoke from the fire can also affect the outgoing radiation, causing a change in temperature.

El Nino:

El Nino is a weather phenomenon that occurs when the surface water temperature in the Pacific Ocean rises. This results in changes in the global climate, including changes in temperature and precipitation patterns. The increase in temperature is caused by a combination of the incoming solar radiation and the sensible and latent heat transfer.

The heat balance in transient state is an important concept in environmental physics that describes the balance of heat fluxes in a changing temperature system. The components of the heat balance equation include the rate of change of heat energy, incoming solar radiation, outgoing radiation, sensible heat transfer, and latent heat transfer.

1.9. Summary

The field of environmental physics was characterized by a focus on understanding the physical processes that govern the behavior of the environment, and using that knowledge to address environmental challenges and promote sustainability. Entropy is a fundamental concept in thermodynamics that can be used to understand and quantify the effects of human activities on natural systems. In the environment, many processes involve the transfer of energy and matter between different systems, and these processes can be analyzed using the concepts of entropy and the Second Law of Thermodynamics. The understanding of entropy is essential to achieving environmental sustainability and reducing the negative impacts of human activities on the environment.

$$\Delta S = 1 \text{ J}/288 \text{ K} = 0.0035 \text{ J/K}$$

This means that the heat transfer from the sun increases the entropy of the Earth's surface and the atmosphere by 0.0035 J/K. The components of the heat balance equation include the rate of change of heat energy, incoming solar radiation, outgoing radiation, sensible heat transfer, and latent heat transfer. Examples of transient systems in the environment include heat waves, forest fires, and El Nino, which are characterized by changes in temperature due to imbalances in heat fluxes.

1.10. Terminal questions

Q.1. What do you understand by environmental physics? Discuss the scope and principle of environmental physics.

Answer:--

Q.2. What is the means of built environment? Discuss the types and conservational strategy of build environment.

Answer:--

Q.3. What is the heat balance, discuss briefly with suitable examples.

Answer:--

Q.4. Discuss the heat balance in transient state with formula and examples.

Answer:--

Q.5. Discuss the low of Law of thermodynamics.

Answer:--

Q.6. Discuss the entropy and its role in environmental heat balance.

Answer:--

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a. Further suggested readings

2. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011

3. Non conventional Energy Resources, D.S. Chauhan, New Age International.

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

5. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.

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

Unit-2: Solar Radiation

Contents

2.1. Introduction

The solar radiation, which reaches the earth surface, warms the surface. However, the earth's average temperature does not change because the earth is turn radiates energy to the atmosphere and to space. It can be captured and turned into useful forms of energy such as heat and electricity, using variety of technologies. This can affect earth's average temperature, which can alter the distribution of snow and ice cover. The growth of photosynthesizing organism and in turn affects the productivity and biomass in ecosystems.

Radiation is the process by which the earth receives heat energy form the sun, about 93 million miles away. This energy is produced in the sun by nuclear fusion, a process in which hydrogen is converted into helium and some of the suns mass is converted to thermal energy. The sun emits radiation at a temperature of about 10,000 °C. so its maximum is in the visible portion of the electromagnetic spectrum and lesser amours appear on either side in the ultraviolet and infrared. Some solar radiation us scattered in the atmosphere by gas molecules and by minutes particles of solid matter. When cloudiness is average, the earth's surface absorbs about 43%, the atmosphere absorbs about 22% and 35% is reflected.

Solar radiation is the primary source of energy for many natural processes on Earth, including photosynthesis in plants and the water cycle. It also plays a crucial role in climate and weather patterns, as well as the formation of the ozone layer. The amount of solar radiation that reaches the Earth's surface varies depending on factors such as time of day, season, latitude, and atmospheric conditions. Understanding solar radiation is essential of solid matter, astronomy, meteorology, and renewable energy.

Objectives:

After editing this unit, the learner will able to understand

- About concept and principle of solar radiation
- About Electromagnetic radiation
- About Thermal regulation and isolation of in building environment
- About thermal conduction effect in environmental systems

2.2. Electromagnetic radiation

Light is also described as electromagnetic wave because it changing electric field creates a changing magnetic field. Electromagnetic radiation consists of the electromagnetic field, which propagate through space and carry momentum and electromagnetic radiant energy. Electromagnetic radiation is an electric and magnetic disturbance traveling through space at the speed of light (2.998 X 108 m/s). It contains neither mass nor charge but travels in packets of radiant energy called photons or quanta. Examples include radio waves and microwaves, X-rays. Some source of electromagnetic radiation includes source in the cosmos (sun and stars), radioactive elements and manufactured devices. Electromagnetic radiation was first predicted in Maxwell's equation in 1864 and its existence was demonstrated by Heinrich Hertz in 1888. A wave is defined as a disturbance which travels and spreads out through some medium. Wave only moves up and down, normal to the direction of propagation of the wave. Such waves are called transverse waves, and light waves are also transverse. The other kinds of waves are longitudinal, in which the motion is parallel to the direction of motion for example sound wave, which require a medium for their propagation that is known as mechanical waves. Transverse waves can travel in vacuum.

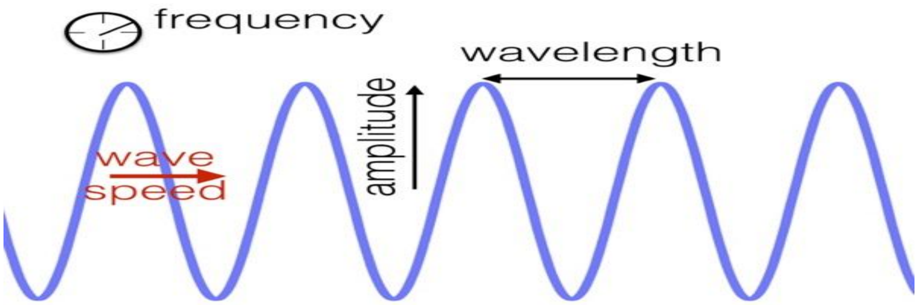


Fig.2.1: Spectra of light

However, the electromagnetic radiation is the source of radiated energy used in spectroscopic investigation of molecules. The electromagnetic spectrum encompasses a wide range of energies, of which visible radiation is only a small part. Electromagnetic radiation consists of radio waves, microwaves, infrared waves, visible light, ultraviolet radiation, X-rays, and gamma rays.

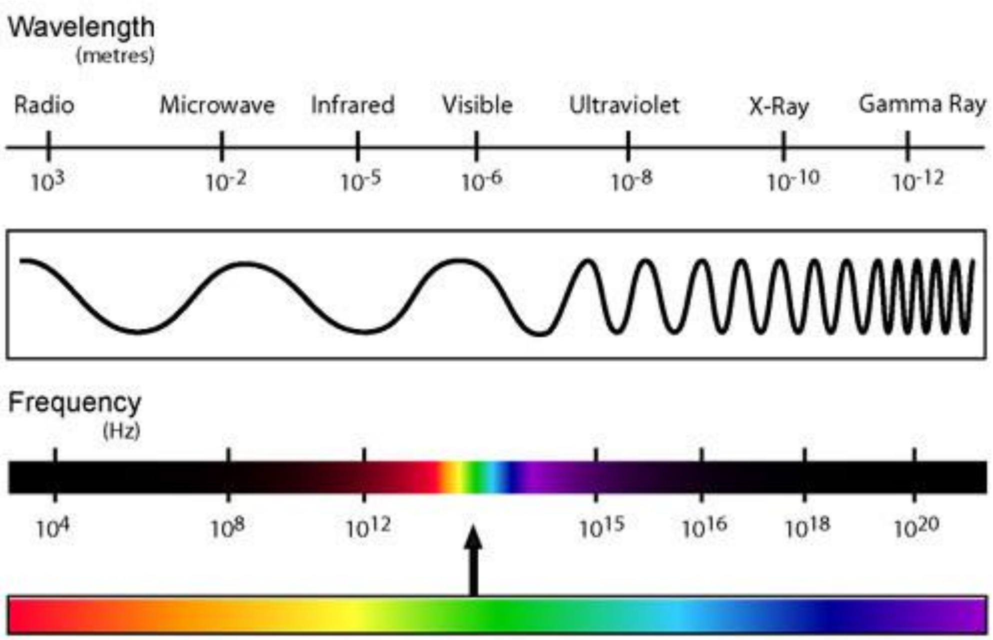


Fig.2.2: Diagram of the electromagnetic spectrum

Every radiation has different wavelength, frequency and energy. The wavelength refers for special distance between two consecutive peaks in sinusoidal waveform and is measured in nanometer (nm). The frequency (υ) of electromagnetic radiation defines the number of oscillator made by the wave within the timeframe of 1 second. If we consider the range of different wave length, the electromagnetic spectrum is useful to reveal in interpretation of frequencies, wavelengths and photon energies of radiation. The electromagnetic radiation cover frequencies form below 1 hertz to above 1025 Hz corresponding to wavelengths which are a few kilometers to a fraction of the size of an atomic nucleus in the spectrum of electromagnetic waves.

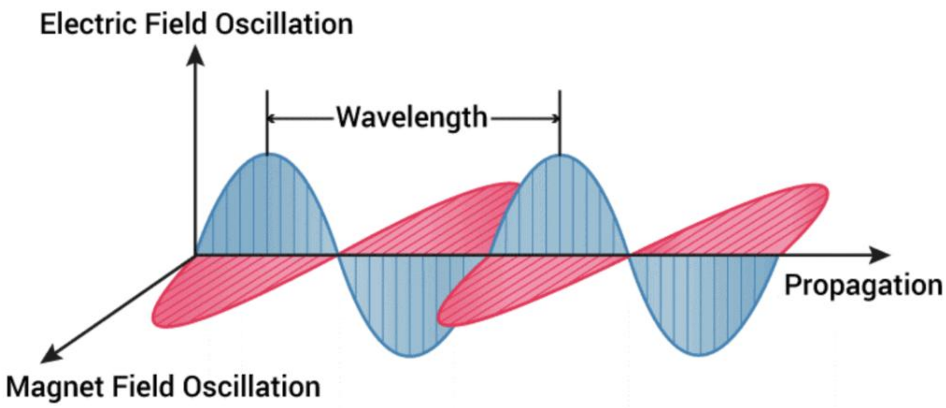


Fig.2.3: Nature of electromagnetic waves

The energy in electromagnetic radiation exists in the form of photons. The quantum phenomenon of electromagnetic radiation depends upon both; properties of the radiation and the appropriate structural part of the samples involves. The electromagnetic radiation is propagated through free space or through a medium and composed of both electric and magnetic waves. The electric and magnetic waves have oscillations that are perpendicular to each other and also to the direction of travel of the wave. There are many sources of electromagnetic radiation, both natural and man-made. Different electromagnetic radiations are given below in Table (1.1) along with their wavelength and frequency. As the wavelength of waves increases frequency get decreases.

Table2.1: Region of electromagnetic spectrum.

Electromagnetic Rays	**Wavelength Range**	**Frequency range(Hz)**
Gamma Rays	$< 10^{-12}$ m	$10^{20} – 10^{24}$
X-Rays	1 nm – 1 pm	$10^{17} – 10^{20}$
Ultraviolet	400 nm – 1 nm	$10^{15} – 10^{17}$
Visible	750 nm – 400 nm	$4 \times 10^{14} – 7.5 \times 10^{14}$
Near Infrared	2.5 µm – 750 nm	$1 \times 10^{14} – 4 \times 10^{14}$

Infrared	25 µm – 2.5 µm	$10^{13} – 10^{14}$
Microwaves	1 mm – 25 µm	$3 \times 10^{11} – 10^{13}$
Radiowaves	> 1 mm	$< 3 \times 10^{11}$

2.3.Types of electromagnetic radiation

The electromagnetic spectrum consists of all type of electromagnetic radiation. However, we know that radiation is energy that travel and spreads out in environment. It is produce from different source that consist of basic properties of electromagnetic. The visible light that comes from a lamp in our house, and the radio waves that come from a radio station are two types of example of electromagnetic radiation. Some other types of radiation produce from different sources that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet light, X-rays and gamma-rays.

Radio waves: The radio wave is the lowest range of electromagnetic radiation having frequency about 30 billion hertz, or 30 gigahertz (GHz), and wavelengths greater than about 10 millimeters (0.4 inches). It is used primarily for communications including voice, data and entertainment media.

Microwaves: Microwaves fall in the range of the electromagnetic spectrum between radio and IR. It has frequency between 3 GHz up to about 30 trillion hertz. It use for high-bandwidth communications, radar and as a heat source for microwave ovens and industrial applications.

Infrared: Infrared is in the range of the electromagnetic (EM) spectrum between microwaves and visible light. Infrared EMR commonly interacts with dipoles present in single molecules, which change as atoms vibrate at the ends of a single chemical bond. Infrared light is invisible to human eyes, but we can feel it as heat if the intensity is sufficient. Infrared radiation is divided into several spectral range such as near-infrared (0.75–1.4 µm), short-wavelength infrared (1.4–3 µm), mid-wavelength infrared (3–8 µm), long-wavelength infrared (8–15 µm) and far infrared (15–1000 µm).

Visible light: Natural sources produce EM radiation across the spectrum. EM radiation with a wavelength between approximately 400 nm and 700 nm is directly detected by the human eye and perceived as visible light. It has frequencies of about 400 THz to 800 THz and wavelengths of about 740 nm (0.00003 inches) to 380 nm (0.000015 inches). More generally, visible light is defined as the wavelengths that are visible to most human eyes. Photosynthesis becomes possible in this range as well, for the same reason.

Ultraviolet: Ultraviolet light is in the range of the EM spectrum between visible light and X-rays. It has frequencies of about 8 × 1014 to 3 × 1016 Hz and wavelengths of about 380 nm. UV light is a component of sunlight; however, it is invisible to the human eye. It has numerous medical and industrial applications, but it can damage living tissue.

X-rays: X-rays are a type of radiation called electromagnetic waves. X-ray imaging creates pictures of the inside of your body. It is a penetrating form of high-energy electromagnetic radiation. Most X-rays have a wavelength ranging from 10 picometers to 10 nanometers, corresponding to frequencies in the range 30 petahertz to 30 exahertz X-rays are roughly classified into two types: soft X-rays and hard X-rays. Different types of X-rays are used for different purposes. For example, doctor may order a mammogram to examine breasts. Or they may order an X-ray with a barium enema to get a closer look at your gastrointestinal tract.

Gamma-rays: A gamma ray, also known as gamma radiation, is a penetrating form of electromagnetic radiation arising from the radioactive decay of atomic nuclei. Gamma rays have the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum. Gamma-rays have frequencies greater than about 1018 Hz and wavelengths of less than 100 pm (4 × 10−9 inches). Gamma radiation causes damage to living tissue, which makes it useful for killing cancer cells when applied in carefully measured doses to small regions.

Table2.2. : List of electromagnetic radiation of different types of spectroscopy techniques

Region of electromagnetic radiation (energy per photon)	**Process that occur and the corresponding spectroscopy techniques**
Gamma rays 10^5-10^6 eV/photon	Nuclear transitions, change of nuclear configuration **Mössbauer spectroscopy**
X-rays 10^2-10^4 eV/photon	Inner shell electronic transitions Electron **spectroscopy, XPS, Aüge**

Ultraviolet and visible rays 1-10^2 eV/photon	Valence shell electronic transitions in molecules **Electronic spectroscopy** also known **as UV-Vis spectroscopy**
Infrared rays 10^{-2}-1 eV/photon	Transition among vibrational levels of molecules Vibrational spectroscopy also known as **Infrared Spectroscopy**
Infrared rays 10^{-2} – 1 eV/photon	Transitions among rotational levels of molecules **Rotational spectroscopy**
Radio wave rays 10^{-9} – 10^{-6} eV/photon	Change of electron and nuclear spins in the presence of a magnetic field. **Nuclear Magnetic Resonance (NMR)** and **Electron Spin Resonance (ESR) spectroscopy**

2.4.Thermal regulation in building

Thermal control regulates the temperature within a structure. It aids is maintain steady heating and cooling temperatures during season changes throughout the year. Additionally it helps to ensure quality and comfort among the occupants inside and increase satisfaction.

Thermal regulation in buildings refers to the control of heat flow to maintain a comfortable and healthy indoor environment. This involves the use of various design strategies and technologies to optimize thermal comfort, reduce energy consumption, and improve indoor air quality. One of the key aspects of thermal regulation in buildings is insulation. Insulation materials are used to reduce the heat transfer between the interior and exterior of a building. This helps to keep the interior temperature stable and reduce the energy needed for heating and cooling. Another important aspect is ventilation. Proper ventilation can help to remove indoor air pollutants, control humidity levels, and regulate temperature. It can also help to reduce the need for air conditioning in hot climates. Other strategies for thermal regulation in buildings include the use of shading devices to block direct sunlight, the selection of energy-efficient windows, the use of thermal mass to absorb and release heat, and the installation of high-efficiency heating and cooling systems. The design and implementation of thermal regulation strategies in buildings is important not only for occupant comfort but also for reducing energy consumption and greenhouse gas emissions. Building codes and standards often include requirements for insulation, ventilation, and energy efficiency to promote sustainable building practices. Thermal control regulates the temperature within a structure. It focuses on the transfer of heat within a building to either keeps it cools or warm.

Types of thermal regulation in building

Thermal regulation in buildings refers to the methods and systems used to control and maintain comfortable temperatures within a structure. There are several types of thermal regulation techniques commonly employed in buildings. The most common examples are such as

Insulation: Insulation is one of the primary methods used to regulate thermal conditions in buildings. It involves using materials with high thermal resistance to reduce heat transfer between the interior and exterior of the building. Common insulation materials include fiberglass, cellulose, foam boards, and reflective barriers.

Heating, Ventilation, and Air Conditioning (HVAC) Systems: HVAC systems are designed to control the temperature, humidity, and air quality within a building. They typically consist of heating systems (e.g., boilers, furnaces), cooling systems (e.g., air conditioners, chillers), and ventilation systems (e.g., fans, air ducts). HVAC systems can be used to both heat and cool a building as needed.

Passive Solar Design: Passive solar design utilizes the building's orientation, layout, and materials to maximize solar heat gain during winter and minimize it during summer. This technique often involves features such as large south-facing windows, thermal mass (e.g., concrete or masonry floors), and shading devices (e.g., overhangs, awnings).

Natural Ventilation: Natural ventilation relies on the movement of air through windows, doors, and other openings to provide cooling and fresh air exchange. It can be facilitated through the strategic placement of openings and the use of cross-ventilation techniques to take advantage of natural breezes.

Radiant Heating and Cooling: Radiant systems use radiant panels or pipes embedded in floors, walls, or ceilings to directly heat or cool surfaces. The surfaces then radiate heat or absorb heat from occupants, providing a comfortable thermal environment.

Thermal Mass: Thermal mass refers to materials with high heat storage capacity, such as concrete or masonry. These materials can absorb excess heat during the day and release it gradually during cooler periods, helping to stabilize indoor temperatures.

Energy-Efficient Windows and Glazing: High-performance windows and glazing systems with low U-values and solar heat gain coefficients (SHGC) can reduce heat transfer through windows. They help to retain heat during winter and minimize heat gain during summer.

Zoning and Controls: Zoning systems divide a building into different areas or zones, allowing for customized temperature control in each zone. This enables more efficient use of energy by heating or cooling only occupied areas. Building automation systems and smart thermostats can further enhance control by adjusting temperature settings based on occupancy and time schedules.

The thermal regulation in the building is carried out by

i. By regulating thermal conditions in a building, can implement the following strategies:

ii. By proper insulate the walls, roofs, floors, and attics using materials like fiberglass, cellulose, foam boards, or reflective barriers.

iii. By identify and seal any air leaks in the building envelope, such as around windows, doors, vents, and electrical outlets. This helps prevent unwanted heat exchange and ensures better control of indoor temperatures.

iv. By upgrading to energy-efficient windows and glazing systems with low U-values and solar heat gain coefficients (SHGC). These windows help reduce heat transfer, block UV rays, and provide better insulation.

v. By maximize the use of natural lighting to reduce the need for artificial lighting and associated heat generation. Utilize windows, skylights, and light-colored interior surfaces to enhance day lighting while minimizing heat gain.

vi. By installing the shading devices like blinds, shades, awnings, or overhangs to block direct sunlight during hot periods. This prevents excessive heat gain while still allowing for natural light and views.

vii. By incorporate the features like large south-facing windows for winter solar heat gain and appropriate shading for summer heat reduction.

viii. By installing the energy-efficient heating, ventilation, and air conditioning (HVAC) systems that are properly sized for the building's needs. Regularly maintain and clean the systems to ensure optimal performance.

ix. By install the programmable or smart thermostats to automatically adjust temperature settings based on occupancy and time schedules. This prevents unnecessary heating or cooling when the building is unoccupied.

x. By dividing the building into zones and install separate thermostats or temperature controls for each zone. This allows for customized temperature regulation in different areas based on occupancy and specific requirements.

xi. By taking the advantage of natural ventilation by opening windows and using cross-ventilation techniques to promote airflow and cool the building naturally.

xii. By designing the home with materials that have high thermal mass, such as concrete or masonry. These materials absorb and store heat, helping to stabilize indoor temperatures by releasing it gradually during cooler periods.

xiii. By installing the radiant systems that utilize panels or pipes embedded in floors, walls, or ceilings to provide heating or cooling directly to surfaces. This can offer localized comfort and reduce energy consumption.

xiv. By regularly monitor indoor temperatures and energy usage to identify any inefficiencies or deviations from desired comfort levels. Adjust settings or make improvements as necessary.

Characteristics of thermal regulation building:

- It has adequate insulation throughout the building envelope.
- It has energy-efficient windows and glazing systems with low U-values and SHGC.
- It has proper sealing of air leaks to minimize unwanted heat transfer.
- It has passive solar design principles, such as strategic orientation and shading.
- It has utilization of natural lighting to reduce the need for artificial lighting.
- It has integration of shading devices, such as blinds, shades, or overhangs.
- It has high-efficiency HVAC systems properly sized for the building's needs.
- It has programmable or smart thermostats for optimized temperature control.
- It has zoning and controls to allow customized temperature regulation in different areas.
- It has utilization of natural ventilation techniques for airflow and cooling.

- It has incorporation of materials with high thermal mass to stabilize indoor temperatures.
- It has radiant heating and cooling systems for localized comfort and energy efficiency.
- It has monitoring and adjustment of indoor temperatures and energy usage.
- It overall focuses on energy efficiency, occupant comfort, and environmental sustainability.

2.5.Thermal isolation in environment

The thermal insulation is done in order to optimize the environment we live in with minimum energy. It is to reduce or enhance heat exchanges between two bodies of different temperature. Thermal isolation in the environment refers to the separation of two areas with different temperatures to reduce or prevent the transfer of heat between them. This can be achieved through various natural or artificial methods.

One natural method of thermal isolation is the use of natural barriers such as vegetation or bodies of water. Vegetation can provide shade that reduce solar radiation, and create a microclimate with lower temperatures. Bodies of water, such as lakes or oceans, can also provide thermal isolation by absorbing and dissipating heat.

Artificial methods of thermal isolation include the use of insulation materials, such as blankets or foam, to reduce heat transfer between two surfaces. Insulation materials work by trapping air pockets that create a barrier against heat transfer. Other methods include the use of reflective coatings or films to reduce the absorption of solar radiation and the installation of double or triple pane windows to reduce heat transfer through glass. Thermal isolation is important in many applications, including building construction, transportation, and energy production. It can help to improve energy efficiency, reduce costs, and increase comfort and safety. Understanding and implementing thermal isolation strategies is essential for promoting sustainable practices and mitigating the impacts of climate change. Some examples of thermal isolation in various environments are such as:

- **Building insulation**: Insulation materials, such as fiberglass, cellulose, or foam boards, are commonly used in buildings to reduce heat transfer between the interior and exterior. This helps to maintain comfortable indoor temperatures and improve energy efficiency.

- **Refrigerators and freezers:** The walls and doors of refrigerators and freezers are designed with insulation materials to prevent heat from entering the cooling compartments. This insulation helps to maintain low temperatures and preserve the stored food or perishable items.
- **Thermal flasks**: Thermal flasks or vacuum flasks have a double-walled structure with a vacuum or insulating material between the walls. This design minimizes heat transfer by conduction, convection, and radiation, allowing the contents of the flask to remain hot or cold for an extended period.
- **Pipes and ducts insulation:** Insulating materials are commonly used to cover pipes and ducts to prevent heat loss or gain during the transportation of hot or cold fluids. This insulation ensures that the desired temperature of the fluid is maintained while minimizing energy losses.
- **Insulated containers for transportation:** Shipping containers used for transporting temperature-sensitive goods, such as food or pharmaceuticals, are often equipped with insulation materials. This helps to maintain the desired temperature range during transit and prevent spoilage or damage.
- **Thermal clothing and blankets:** Specialized thermal clothing and blankets, often made with insulating materials like wool or synthetic fibers, are used to provide thermal isolation for individuals in cold environments. These materials trap body heat and create a layer of insulation to keep the wearer warm.
- **Thermal windows and glazing:** Windows with thermal insulation properties, such as low-emissivity (low-e) coatings and double or triple glazing are used to reduce heat transfer through windows. This helps to maintain comfortable indoor temperatures and improve energy efficiency in buildings.

2.6. Thermal conduction effect in environmental systems

Thermal conductivity can be defined as the rate at which heats is transferred by conduction through a unit cross-section area of a material, when a temperature gradient exists perpendicular to the area. Thermal conduction is a process of heat transfer between two materials or substances that are in direct contact with each other. The rate of heat transfer by conduction depends on the temperature difference between the materials, the thermal conductivity of the materials, and the thickness of the materials. In environmental systems, thermal conduction plays a significant role in the transfer of heat between the Earth's surface and the atmosphere. For example, the ground surface absorbs solar radiation during the day and releases this heat at night, which is conducted through the ground and into the atmosphere. The rate of heat transfer by conduction depends on the thermal conductivity of the ground material, which can vary depending on factors such as moisture content and soil type. Thermal conduction also plays a role in the design and operation of heating and cooling systems in buildings. For example, heat is transferred by conduction through the walls, roof, and floors of a building, which can contribute to heat loss or gain. Proper insulation and the use of materials with high thermal conductivity can help to reduce the rate of heat transfer and improve energy efficiency. Understanding the effects of thermal conduction in environmental systems is important for predicting and mitigating the impacts of climate change, designing sustainable buildings and infrastructure, and promoting energy efficiency. Examples of thermal conduction effect in environmental systems are:

Heat transfer through solid structures: In buildings, heat can be conducted through walls, floors, and ceilings, transferring heat from warmer areas to cooler areas. This can lead to the loss or gain of heat, impacting the overall thermal conditions inside the building.

Conductive heat loss in cold environments: In colder climates, heat can be conducted from the interior of a building to the exterior through materials with high thermal conductivity, such as metal or uninsulated walls. This can result in heat loss, requiring additional heating to maintain comfortable indoor temperatures.

Thermal conduction in the ground: Underground, thermal conduction plays a role in geothermal systems. Heat from the Earth's core is conducted through the ground to the surface, influencing the temperature of soil, rocks, and groundwater.

Heat transfer in HVAC systems: HVAC systems utilize thermal conduction in heat exchangers or coils to transfer heat between different fluids or air streams. For example, in air conditioning systems, the indoor air is cooled by passing over cold evaporator coils through which refrigerant flows, facilitating heat transfer.

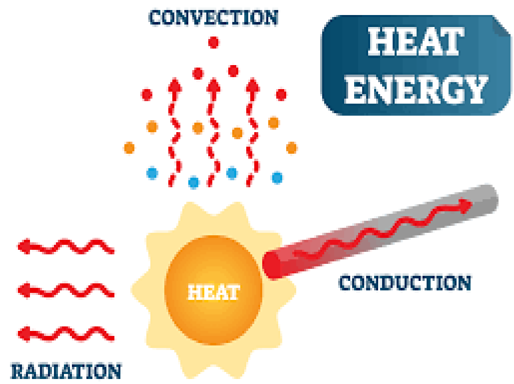
Thermal conduction in pipes and conduits: Pipes used for the transportation of fluids, such as hot water or steam, can transfer heat through thermal conduction. For instance, uninsulated hot water pipes can lose heat to the surroundings, impacting the efficiency of the system.

Conductive heat transfer in cooking: Thermal conduction is involved in cooking processes, such as using a stovetop or grill. Heat is conducted from the heat source (e.g., burner or coals) to the cooking vessel or food, allowing for the transfer of heat energy and cooking of the ingredients.

Heat transfer in thermal storage systems: Thermal conduction plays a role in the heat transfer process within thermal storage systems, such as water tanks or phase change materials. Heat is conducted into or out of the storage medium, depending on the temperature difference, allowing for heat storage or release.

2.7. Convection effect in environmental systems

Convection is the rising motion of warmer areas of a liquid or gas and he sinking motion of cooler areas of liquid or gas, sometimes forming a complete cycle. Convection is a vital process of heat transfer in which heat is transferred through the movement of fluids, such as air or water. The movement of fluids is driven by differences in temperature, which causes the fluid to expand and become less dense; creating a buoyant force that drives the fluid to move. In environmental systems, convection plays an important role in the transfer of heat between the Earth's surface and the atmosphere. For example, warm air rises from the Earth's surface and is replaced by cooler air, which creates convective currents that transport heat upward into the atmosphere. These currents can influence weather patterns, such as the formation of thunderstorms, and also contribute to the mixing of pollutants in the atmosphere. Ocean currents act as conveyor like circulations which help distribute heat away from the equator and nearer to poles. These currents are affected by convention due to the influence of ocean temperature and salinity on density.



Convection also plays a role in the operation of heating and cooling systems in buildings. For example, warm air rises and cool air sinks, which can be harnessed in natural ventilation strategies to provide cooling and improve indoor air quality. In forced-air heating and cooling systems, fans are used to circulate air and create convective currents that distribute heated or cooled air throughout the building. There are two types of conventional natural and forced natural is caused by buoyant force forces due to difference in density connected to temperature differential e.g. Hot air rising due above affair, sea breeze or laud breeze caused by a difference in pressure and blood circulation in warm blood animals forced convection is when fluid undergoes forced flow from an outside source such as water heater, hump or fau e.g. Air conditioning, car radiators, water heaters/boilers and convention ovens.

Understanding the effects of convection in environmental systems is important for predicting and mitigating the impacts of climate change, designing sustainable buildings and infrastructure, and promoting energy efficiency. By harnessing natural convection processes and designing systems that minimize convective heat loss or gain, we can improve energy efficiency and reduce the environmental impact of our built environment.

To control radiation effects we can take following measures.

1. Minimize times spent in areas with elevated radiation levels.
2. Maximize distance form, source of radiations
3. Use shielding for radiation for sources of radiation

2.8. Radiation effect in environmental systems

Radiation is a process of heat transfer that occurs through the emission and absorption of electromagnetic waves. In environmental systems, radiation plays an important role in the transfer of heat between the Earth's surface and the atmosphere, as well as between the Earth and the sun.

The sun emits solar radiation, which is absorbed by the Earth's surface, and then re-emitted as terrestrial radiation. Greenhouse gases, such as carbon dioxide and water vapor, trap some of this terrestrial radiation in the atmosphere, which helps to maintain a stable temperature range on Earth. However, the increased levels of greenhouse gases resulting from human activities have led to an enhanced greenhouse effect, causing the Earth's temperature to rise and contributing to climate change. Radiation also plays a role in the design and operation of heating and cooling systems in buildings. For example, the use of solar panels to capture solar radiation can provide a renewable energy source for heating and electricity. Infrared radiation can also be used in heating systems to directly warm objects, rather than heating the surrounding air. Understanding the effects of radiation in environmental systems is important for predicting and mitigating the impacts of climate change, designing sustainable buildings and infrastructure, and promoting energy efficiency. By harnessing renewable sources of radiation, such as solar or infrared radiation, and reducing greenhouse gas emissions, we can help to mitigate the negative impacts of climate change and promote a sustainable future. Examples of radiation effect in environmental systems are:

Solar radiation: The sun emits radiant energy, primarily in the form of visible light, ultraviolet (UV) rays, and infrared (IR) radiation. Solar radiation is a significant factor in determining the Earth's climate, providing heat and light energy to the planet.

Heat gain from the sun: Solar radiation can directly heat objects and surfaces exposed to sunlight. This effect is particularly noticeable in buildings, where windows and surfaces absorb solar radiation, leading to increased temperatures inside.

Radiative cooling at night: During the nighttime, objects and surfaces can radiate heat energy to the cooler atmosphere through thermal radiation. This radiative cooling effect contributes to temperature reduction, especially under clear sky conditions.

Infrared heating: Infrared heaters utilize the principle of thermal radiation to provide localized heating. These heaters emit infrared radiation that directly heats objects and people within the heating zone, rather than heating the surrounding air.

Radiant floor heating: Radiant floor heating systems employ the transfer of thermal radiation from warm surfaces to heat indoor spaces. Heat is radiated from heated floors to objects and occupants in the room, creating a comfortable heating effect.

Radiative heat exchange in space heating: Radiators and heating panels in space heating systems radiate heat energy into the surrounding space, heating the air and objects in the room. This radiative heat exchange helps maintain desired temperatures.

Thermal radiation from electronic devices: Electronic devices such as computers, televisions, and cooking appliances emit thermal radiation as a byproduct of their operation. This radiation contributes to the overall heat load in indoor spaces.

Thermal radiation in industrial processes: Various industrial processes involve thermal radiation. For example, in high-temperature furnaces or kilns, radiant heat is utilized to achieve specific material transformations, such as metal melting or ceramic firing.

Radiant cooling systems: Radiant cooling systems use chilled surfaces to absorb heat radiated by objects and occupants in a space. This helps to cool the indoor environment by removing heat through thermal radiation.

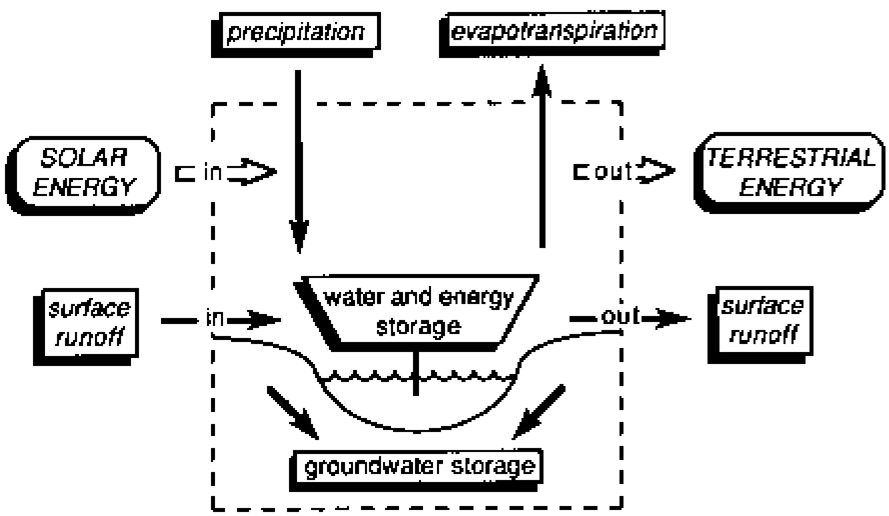
Radiative heat transfer in energy systems: Radiation plays a role in energy systems such as solar panels and thermal collectors. Solar panels absorb incoming solar radiation and convert it into electricity, while thermal collectors absorb solar radiation to heat a fluid for various applications.

2.9. Energy flow diagram in the earth system

An energy flow diagram is a visual representation of the transfer of energy between different components of a system. In the Earth system, energy flows through various processes, including radiation, convection, and conduction, and is constantly being transferred between the Earth's surface and the atmosphere. The energy flow diagram in the Earth system can be represented as follows:

- The sun emits solar radiation, which is the primary source of energy for the Earth system.
- The Earth's surface absorbs some of this solar radiation, which is converted into heat.

- This heat is then transferred through conduction, convection, and radiation to the atmosphere and oceans.
- Some of the heat is also stored in the Earth's crust and mantle, contributing to geothermal energy.
- The atmosphere and oceans then redistribute this heat through convection, which creates weather patterns and drives ocean currents.
- Heat is also exchanged between the atmosphere and the Earth's surface through processes such as evaporation and condensation, which contribute to the water cycle.
- Human activities, such as the burning of fossil fuels, also contribute to the transfer of energy in the Earth system, releasing heat-trapping gases into the atmosphere and contributing to the enhanced greenhouse effect.



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Understanding the energy flow diagram in the Earth system is important for predicting and mitigating the impacts of climate change, designing sustainable buildings and infrastructure, and promoting energy efficiency. By understanding the processes involved in the transfer of energy, we can develop strategies to reduce greenhouse gas emissions, promote renewable energy sources, and create a more sustainable future.

2.10. Summary

Solar radiation refers to the electromagnetic waves emitted by the sun, which provide the primary source of energy for the Earth's climate and ecosystems.

Solar radiation includes visible light, ultraviolet radiation, and infrared radiation, which are absorbed by the Earth's atmosphere, oceans, and land surfaces, and drive processes such as photosynthesis, evaporation, and weather patterns. Understanding the effects of solar radiation is important for predicting and mitigating the impacts of climate change, designing sustainable buildings and infrastructure, and promoting energy efficiency. By harnessing renewable sources of solar radiation, such as solar panels, and reducing greenhouse gas emissions, we can help to mitigate the negative impacts of climate change and promote a sustainable future. To control the effects we can take following: 1) Minimize time spent in areas with evaluated radiation levels.2) Maximum distance form source of radiations. 3) Use shielding for reradiating sources of radiation.

2.11. Terminal questions

Q.1. What is electromagnetic radiation? Types of electromagnetic radiation.

Answer: --

Q.2. What is thermal regulation in building? Discuss the thermal isolation in environment.

Answer: --

Q.3. Discuss about thermal conduction effect in environmental systems.

Answer: --

Q.4. Write the convection effect in environmental systems.

Answer: --

Q.5. Write the radiation effect in environmental systems.

Answer: --

Q.6. Write about energy flow diagram in the earth system.

Answer: --

2.12. Further suggested readings

7. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011

8. Non conventional Energy Resources, D.S. Chauhan, New Age International.

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

10. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.

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

Unit-3: Energy Budget

3.1. Introduction

The earth energy budget describes the balance between the radiant energy that reaches Earth from the Sun and the energy that flows from Earth back out to space. Energy form the Sun is mostly in the visible portion of the electromagnetic spectrum. It is a quantitative analysis of the amount of energy entering and leaving a particular system. It is often used to describe the energy flow in ecosystems, as well as in other physical systems such as buildings, vehicles, or industrial processes. The energy budget concept is based on the principle of the conservation of energy, which states that energy cannot be created or destroyed but can only be converted from one form to another. In an energy budget analysis, the total energy entering a system is called the input, while the energy leaving the system is called the output. The difference between the input and output is the net energy, which represents the change in energy content of the system. If the input and output are equal, the net energy is zero, indicating that the system is in equilibrium. Energy budgets are useful in understanding the energy dynamics of a system and can be used to identify areas where energy is being wasted or inefficiently used. By analyzing the energy flows, it is possible to identify opportunities for energy conservation and cost savings. Energy budget analysis can also be used to evaluate the environmental impact of a system by quantifying the amount of greenhouse gas emissions associated with energy use.

Objectives:

- To discuss the energy conservation and losses
- To calculation energy loss in ecosystem
- To calculation of energy gain in ecosystem
- To discuss heat pump and air regulation in building

3.2. Energy use and efficiency in building

Buildings are a significant contributor to global energy consumption and greenhouse gas emissions. The energy use and efficiency of buildings depend on several factors, including the building design, construction, occupancy patterns, and maintenance. Here are some key points to consider:

Building design: The design of a building can significantly impact its energy efficiency. Features such as building orientation, insulation, ventilation, and glazing can affect the amount of energy needed for heating, cooling, and lighting.

HVAC systems: Heating, ventilation, and air conditioning (HVAC) systems can account for a significant portion of a building's energy consumption. Choosing energy-efficient HVAC equipment and properly maintaining can help to reduce energy use.

Lighting: Lighting can also account for a significant portion of a building's energy consumption. Using energy-efficient lighting technologies such as LED and CFL bulbs, as well as installing daylight sensors and occupancy sensors, can help to reduce energy use.

Building envelope: The building envelope (i.e., the exterior walls, roof, windows, and doors) can also affect energy efficiency. Proper insulation, air sealing, and window shading can help to reduce energy loss.

Occupancy patterns: The way occupants use a building can also affect its energy use. For example, turning off lights and electronics not in use, using natural ventilation instead of HVAC systems when possible, and setting the thermostat to energy-saving levels can help to reduce energy consumption.

Maintenance: Proper maintenance of building systems and equipment can also help to reduce energy use. Regularly servicing HVAC systems, sealing air leaks, and replacing inefficient equipment can all help to improve energy efficiency.

Overall, improving the energy efficiency of buildings can help to reduce energy consumption, lower greenhouse gas emissions, and save money on energy bills.

3.3. Calculation of energy losses

When energy is transferred from one form to another or moved from one place to another or from one system to another there is energy loss. This meaning that when energy is converted to a different form, some of the input energy is turned into a highly disordered from of energy like heat. Energy loss is defined as any negative change in energy of a system. Thus energy loss can be through heat radiation movement or friction.

Energy is the ability to do work or produce heat. It can take various forms such as mechanical, thermal, electrical, chemical, and nuclear energy. In nature, energy is constantly being transformed from one form to another, and some of it is lost during these transformations. Energy loss in nature is an important concept in many scientific fields such as physics, ecology, and environmental science. In this essay, we will discuss the calculation of energy loss in nature with an emphasis on the equations that are used to quantify this loss.

Before we discuss energy loss in nature, it is important to understand the Law of Conservation of Energy. This law states that energy cannot be created or destroyed, but it can be transformed from one form to another. In other words, the total amount of energy in a closed system remains constant, but the form of energy can change. This law is a fundamental principle of physics and applies to all energy transformations, including those that occur in nature. The calculation of energy losses in a system typically involves measuring the input and output of energy and then determining the difference between the two. Here are some general steps to follow when calculating energy losses:

Determine the input energy: The first step is to determine the amount of energy that is entering the system. This could include factors such as electrical input, fuel input, or solar radiation.

Determine the output energy: The next step is to determine the amount of energy that is leaving the system. This could include factors such as heat loss, radiation, or mechanical work.

Calculate the difference: Once the input and output energy have been determined, the difference between the two can be calculated. If the output energy is greater than the input energy, then energy losses have occurred.

Identify the sources of energy losses: Once energy losses have been identified, the next step is to determine the sources of these losses. This could include factors such as inefficiencies in the energy conversion process, heat loss due to poor insulation, or mechanical friction.

Determine strategies for reducing energy losses: Finally, strategies can be identified for reducing energy losses in the system. This could include measures such as improving insulation, reducing mechanical friction, or increasing the efficiency of energy conversion processes.

Energy losses can be quantified using a variety of units, depending on the type of energy being measured. Common units of energy include joules (J), kilowatt-hours (kWh), and British thermal units (BTUs). The calculation of energy losses can be complex, and it may require the use of specialized equipment and measurement techniques, depending on the system being analyzed.

In nature, energy is constantly being transformed from one form to another. For example, when the sun's energy is absorbed by plants, it is converted into chemical energy through the process of photosynthesis. This chemical energy is then transferred to animals that eat the plants. However, not all of the energy is transferred from one organism to another. Some of the energy is lost during these transformations, and this loss is referred to as energy loss in nature. There are several ways in which energy can be lost in nature. One common way is through heat transfer. Whenever energy is transformed from one form to another, some of it is inevitably converted into heat energy. This heat energy is then dissipated into the surrounding environment, resulting in energy loss. Another way energy can be lost is through mechanical work. Whenever an object moves, some of its energy is lost due to friction with the surrounding environment.

Calculating Energy Loss:

The amount of energy lost in nature can be calculated using various equations depending on the specific situation. In general, energy loss can be quantified by comparing the amount of energy input to the amount of energy output. If the amount of energy output is less than the amount of energy input, then the difference represents the amount of energy that was lost.

One common equation used to calculate energy loss due to heat transfer is the following:

$$Q = mC\Delta T$$

Where Q is the amount of heat energy transferred, m is the mass of the object, C is the specific heat capacity of the object, and ΔT is the change in temperature. This equation can be used to calculate the amount of heat energy lost by an object due to heat transfer.

Another equation used to calculate energy loss due to friction is the following:

$$W = Fd$$

Where W is the work done, F is the force required to move the object, and d is the distance over which the force is applied. This equation can be used to calculate the amount of mechanical energy lost due to friction.

Applications of Energy Loss Calculations:

Calculating energy loss in nature has important applications in many scientific fields. For example, in ecology, energy loss calculations can be used to study the flow of energy through ecosystems. By quantifying the amount of energy that is lost at each trophic level, ecologists can better understand the efficiency of energy transfer between different organisms.

In environmental science, energy loss calculations can be used to study the impact of human activities on the environment. For example, by calculating the amount of energy lost due to friction in a car engine, scientists can better understand the impact of transportation on the environment and develop strategies to reduce energy loss. Here are some examples that how energy loss calculations are used in this field:

Renewable Energy: Energy loss calculations are used to determine the efficiency of renewable energy systems such as solar panels, wind turbines, and hydroelectric dams. For example, if you want to calculate the energy loss in a solar panel, you would need to consider factors such as the angle of incidence of the sunlight, the reflectivity of the panel, and the efficiency of the photovoltaic cells.

Building Energy Efficiency: Energy loss calculations are used to evaluate the energy efficiency of buildings and identify opportunities for improvement. For example, if you want to calculate the energy lost through a building envelope, you would need to consider factors such as the insulation level, air leakage, and thermal bridging.

Environmental Impact: Energy loss calculations are used to evaluate the environmental impact of human activities such as transportation and manufacturing. For example, if you want to calculate the energy lost in the production of a certain material, you would need to consider factors such as the energy required to extract raw materials, process them into the final product, and transport the product to its destination.

Climate Change Mitigation: Energy loss calculations are used to evaluate the potential impact of various strategies for reducing greenhouse gas emissions and mitigating climate change. For example, if you want to calculate the energy lost through the use of fossil fuels in a certain industry, you would need to consider factors such as the efficiency of the energy conversion process and the carbon emissions associated with the fuel.

In all of these applications, energy loss calculations are essential for evaluating the sustainability and efficiency of various systems and identifying opportunities for improvement. By accurately quantifying the amount of energy lost in a system, scientists and engineers can make informed decisions about how to reduce energy waste and improve the environmental performance of these systems.

3.4. Energy loss in ecosystem

Energy loss is a natural occurrence in ecosystems, as energy is constantly being transformed and transferred between different living and non-living components of the ecosystem. Here are some of the key ways that energy is lost in ecosystems:

Respiration: All living organisms require energy to carry out their metabolic processes, and this energy is obtained through the process of respiration. However, respiration also results in the loss of energy in the form of heat, which is released into the environment.

Heat loss: In addition to respiration, heat loss occurs in other ways in ecosystems. For example, animals can lose heat to the environment through convection, conduction, and radiation. Plants can also lose heat through transpiration, which is the process by which they release water vapor into the air.

Energy transfer: As energy is transferred between different trophic levels in an ecosystem (e.g., from plants to herbivores to carnivores), some energy is inevitably lost in each transfer due to inefficiencies in energy conversion. This loss of energy is known as ecological efficiency.

Decomposition: When organisms die, their bodies are broken down by decomposers such as bacteria and fungi. During this process, some of the energy stored in the organic matter is lost as heat.

Photosynthesis: While photosynthesis is the process by which plants convert sunlight into energy-rich organic compounds, some energy is lost during the process due to factors such as reflection, absorption by non-photosynthetic pigments, and inefficiencies in the photosynthetic machinery.

Overall, energy loss is a natural part of ecosystem dynamics, and it is an important factor to consider when studying ecosystem processes and energy flow. By understanding the ways in which energy is lost in ecosystems, scientists can better predict the impacts of disturbances such as climate change and habitat loss on ecosystem function.

3.5. Calculation of energy gain in ecosystem

The calculation of energy gain in an ecosystem involves measuring the amount of energy that is being produced by primary producers (e.g., plants) through photosynthesis, and then tracking the flow of energy through different trophic levels (e.g., herbivores, carnivores) in the ecosystem. Before discussing energy losses in ecosystems, it is important to understand how energy flows through these systems. In general, energy enters ecosystems as sunlight, which is converted into organic matter through the process of photosynthesis. This organic matter is then transferred between organisms through feeding relationships. At each trophic level, some of the energy is lost as heat or other forms of energy. This energy loss is referred to as ecological inefficiency. Ecological inefficiency is a natural process that occurs in all ecosystems, and it is due to the fact that energy transformations are never 100% efficient. However, human activities can also increase ecological inefficiency, leading to greater energy losses in ecosystems.

Here are some general steps to follow while calculating energy gain in an ecosystem:

Measure primary productivity: The first step is to measure the amount of energy that is being produced by primary producers through photosynthesis. This can be done by measuring factors such as the rate of carbon dioxide uptake or the amount of biomass produced.

Calculate the amount of energy stored: Once the amount of primary productivity has been determined, the next step is to calculate the amount of energy that is being stored in the organic matter produced by primary producers. This can be done using conversion factors that relate biomass production to energy content.

Determine the amount of energy transferred: As energy flows through the ecosystem, some of it is transferred between different trophic levels. The amount of energy transferred can be estimated using conversion factors that relate the biomass of one trophic level to the biomass of the next.

Calculate the energy gain at each trophic level: Once the amount of energy transferred has been determined, the energy gain at each trophic level can be calculated. This involves subtracting the amount of energy lost during the transfer from the initial energy stored in the organic matter.

Determine the efficiency of energy transfer: The efficiency of energy transfer between trophic levels can be calculated by dividing the energy gained by the energy available at the previous trophic level.

Another way Energy is also lost in ecosystems through movement. Animals spend energy to move from one place to another, and this energy is lost as heat due to friction with the environment. In addition, energy can also be lost during digestion and excretion. When organisms consume food, they spend energy to break it down and extract nutrients. Some of this energy is lost during the digestive process, and it is excreted as waste.

Energy gain can be quantified using a variety of units, depending on the type of energy being measured. Common units of energy include joules (J), kilowatt-hours (kWh), and British thermal units (BTUs). The calculation of energy gain in an ecosystem can be complex and may require the use of specialized equipment and measurement techniques, depending on the ecosystem being analyzed.

Equations Used to Quantify Energy Losses:

There are several equations that can be used to quantify energy losses in ecosystems. One common equation is the following:

Net Primary Productivity = Gross Primary Productivity – Respiration

Net primary productivity (NPP) is the amount of energy available for consumption by organisms in an ecosystem, and it is calculated by subtracting the amount of energy lost through respiration from the amount of energy captured through photosynthesis (gross primary productivity, or GPP). This equation is useful for understanding the amount of energy that is available to support ecosystems and the amount of energy that is lost through metabolic activity.

Another equation used to quantify energy losses in ecosystems is the following:

$$\text{Ecological Efficiency} = \frac{(\text{Energy Transferred to Next Trophic Level}}{\text{Energy Available at Current Trophic Level})} \text{ x } 100$$

Ecological efficiency measures the amount of energy that is transferred between trophic levels in an ecosystem. It is calculated by dividing the amount of energy transferred to the next trophic level by the amount of energy available at the current trophic level and multiplying by 100. This equation is useful for understanding the efficiency of energy transfer between organisms in an ecosystem.

Examples of Energy Losses in Ecosystems:

Energy losses in ecosystems can have significant impacts on ecological processes. For example, energy losses can affect predator-prey relationships. If energy losses are high, predators may not obtain enough energy from their prey to sustain themselves, leading to declines in predator populations.

Energy losses can also affect the productivity of ecosystems. If energy losses are high, there may not be enough energy available to support a large number of organisms, leading to declines in biodiversity and ecosystem health. Human activities can also increase energy losses in ecosystems. For example, deforestation can reduce the amount of energy available to support ecosystems by removing plant of biomass of agricultural practices.

3.6. Air regulation in building

Air regulation in buildings is essential for maintaining indoor air quality and ensuring the comfort of occupants. Poor air quality can lead to health problems and reduced productivity, while inadequate ventilation can result in discomfort and dissatisfaction among occupants. We will now discuss air regulation in buildings, including examples, images, and equations used to understand and improve air quality. Air regulation in buildings is important for maintaining indoor air quality, controlling temperature and humidity levels, and reducing energy consumption.

Air Quality Standards:

Before discussing air regulation in buildings, it is important to understand air quality standards. The World Health Organization (WHO) has established guidelines for indoor air quality that recommend maximum concentrations of various pollutants. The guidelines cover pollutants such as particulate matter, carbon monoxide, nitrogen dioxide, ozone, and volatile organic compounds (VOCs). In addition to these guidelines, many countries have established their own regulations for indoor air quality.

Air Regulation in Buildings:

There are several strategies that can be used to regulate air in buildings. One common strategy is the use of HVAC (heating, ventilation, and air conditioning) systems. HVAC systems are designed to provide heating, cooling, and ventilation to buildings. These systems can include air filters, which can remove pollutants from the air, and ventilation systems, which can bring fresh air into the building and remove stale air.

Another strategy for regulating air in buildings is the use of natural ventilation. This can include the use of windows and doors to allow fresh air into the building, as well as the use of passive ventilation systems such as chimneys and wind towers. Natural ventilation can be a cost-effective and energy-efficient way to regulate air in buildings, but it may not be suitable for all climates or building types.

Indoor air quality can also be improved by reducing the sources of pollutants. For example, using low-VOC building materials and cleaning products can reduce the amount of pollutants in the air. Additionally, reducing the use of tobacco products and minimizing indoor combustion sources can also improve indoor air quality.

Methods for air regulation in buildings

Here are some common methods for air regulation in buildings:

HVAC systems: Heating, ventilation, and air conditioning (HVAC) systems are used to regulate temperature, humidity, and air circulation in buildings. These systems can include air filters to remove contaminants from the air, as well as sensors to monitor and control temperature and humidity levels.

Natural ventilation: Natural ventilation can be used to regulate air flow in buildings by opening windows or using vents to allow fresh air in and stale air out. This can be particularly effective in mild weather conditions and can reduce the need for mechanical ventilation.

Exhaust systems: Exhaust systems are used to remove stale air and contaminants from indoor spaces. These systems can be installed in kitchens, bathrooms, and other areas where moisture and odors are produced.

Air sealing: Air sealing can be used to reduce air leaks in buildings, which can improve energy efficiency and indoor air quality. This involves sealing gaps and cracks in building envelopes (e.g., walls, roofs, windows, doors) to prevent the infiltration of outdoor air and the escape of indoor air.

Indoor plants: Indoor plants can be used to improve indoor air quality by removing pollutants and producing oxygen. This can be a cost-effective and aesthetically pleasing way to regulate air quality in buildings.

Humidifiers and dehumidifiers: Humidifiers and dehumidifiers can be used to regulate humidity levels in indoor spaces. This can help to reduce the growth of mold and other contaminants, as well as improve occupant comfort.

Overall, air regulation is an important aspect of building design and maintenance, and it can have significant impacts on occupant health, comfort, and energy consumption. A range of methods can be used to regulate air quality and temperature in buildings, and the choice of method will depend on factors such as the climate, building type, and occupant needs.

Equations Used to Understand Air Quality:

There are several equations that can be used to understand air quality in buildings. One common equation is the following:

Ventilation Rate = (Airflow Rate x 60) / Room Volume

The ventilation rate is the amount of air that is supplied to a room per unit time. It is calculated by multiplying the airflow rate by 60 (to convert from cubic meters per second to cubic meters per hour) and dividing by the room volume. This equation is useful for understanding the amount of fresh air that is being supplied to a room and can be used to determine whether the ventilation rate is sufficient to maintain indoor air quality.

Another equation used to understand air quality is the following:

$$\text{Concentration} = \frac{\text{Mass}}{\text{Volume}}$$

This equation is used to calculate the concentration of pollutants in the air. It is calculated by dividing the mass of a pollutant by the volume of air. This equation can be used to determine the concentration of various pollutants in the air, which is important for assessing indoor air quality.

Examples of Air Regulation in Buildings:

There are many examples of air regulation in buildings, and different strategies may be more suitable for different types of buildings and climates. One example is the use of HVAC systems in commercial buildings. These systems can be designed to provide heating, cooling, and ventilation to large spaces, and they can include air filters to remove pollutants from the air. Another example is the use of natural ventilation in residential buildings. In warmer climates, natural ventilation can be an effective way to cool buildings and provide fresh air. This can include the use of cross-ventilation, which involves opening windows on opposite sides of a room to allow air to flow through, as well as the use of shading devices to reduce solar heat gain.

3.7. Heat pump

Heat pumps are devices that transfer heat from one location to another, typically from a lower-temperature source to a higher-temperature sink. They are used for both heating and cooling applications and can be designed for use in residential, commercial, and industrial settings. In this essay, we will discuss heat pumps, including examples, design considerations, and equations used in their operation.

Heat pumps are a versatile and energy-efficient technology for heating and cooling buildings. They can be a cost-effective alternative to traditional heating and cooling systems, particularly in mild climates, and can help to reduce energy consumption and greenhouse gas emissions. A heat pump is a device that can be used to transfer heat from one location to another, typically for the purpose of heating or cooling a building. Heat pumps use a refrigeration cycle, similar to that used in air conditioning systems, to extract heat from a low-temperature source (such as outdoor air or groundwater) and transfer it to a high-temperature location (such as indoor air or a hot water tank).

Basic Operation of Heat Pumps:

Heat pumps work on the principle of the refrigeration cycle, which involves the compression and expansion of a refrigerant gas to transfer heat from one location to another. The refrigerant gas is compressed, which increases its temperature and pressure, and then flows through a condenser where it releases heat to the surroundings. The high-pressure, high-temperature gas then flows through an expansion valve, where it expands and cools, before entering an evaporator where it absorbs heat from the surroundings. The low-pressure, low-temperature gas then flows back to the compressor to repeat the cycle.

Heat pumps can operate in two modes: heating mode and cooling mode. In heating mode, heat is transferred from the surroundings to the building interior, while in cooling mode, heat is transferred from the building interior to the surroundings. This is achieved by reversing the direction of the refrigeration cycle, such that the evaporator becomes the condenser and vice versa.

Types of heat pumps:

There are several types of heat pumps, including air-source heat pumps, ground-source heat pumps (also known as geothermal heat pumps), and water-source heat pumps. Air-source heat pumps are the most common type and are typically used for residential and small commercial applications.

Efficiency: Heat pumps can be highly efficient, with some models achieving a coefficient of performance (COP) greater than 3.0. This means that for every unit of energy consumed by the heat pump, three or more units of heat are generated.

Operating principles: Heat pumps work by circulating a refrigerant (such as Freon or R-410A) through a closed loop of coils. In heating mode, the refrigerant absorbs heat from the outdoor air or ground and releases it indoors through a heat exchanger. In cooling mode, the process is reversed, with heat being extracted from indoor air and released outdoors.

Integration with other systems: Heat pumps can be integrated with other heating and cooling systems, such as radiant floor heating, to provide additional comfort and energy savings.

Environmental benefits: Heat pumps can reduce greenhouse gas emissions by using renewable energy sources (such as solar or wind power) to power the system. In addition, they can reduce the use of fossil fuels for heating and cooling, which can help to mitigate climate change.

Equations Used in Heat Pump Operation:

There are several equations that are used in the operation of heat pumps. One important equation is the Carnot efficiency equation, which gives the maximum efficiency of a heat pump operating between two temperature levels:

$$COPmax = (T1 / (T1 - T2))$$

Where T1 is the temperature of the heat source and T2 is the temperature of the heat sink. This equation can be used to determine the maximum possible efficiency of a heat pump system.

Another important equation is the heat balance equation, which relates the heat input and output of a heat pump system:

$$Qh = Qc + W$$

where Qh is the heat input to the heat pump, Qc is the heat output from the heat pump, and W is the work input to the heat pump. This equation can be used to determine the amount of heat that is transferred by the heat pump and the amount of work that is required to operate the system.

Design Considerations for Heat Pumps:

There are several design considerations to take into account when designing a heat pump system. One of the most important considerations is the selection of a suitable refrigerant. The refrigerant should have a high latent heat of vaporization and a low boiling point, as well as being non-toxic, non-flammable, and environmentally friendly. Common refrigerants used in heat pumps include R-410A, R-407C, and R-134a.

Another important consideration is the selection of suitable heat exchangers. Heat exchangers are used to transfer heat between the refrigerant and the surroundings. The size and design of the heat exchangers will depend on the specific application and the amount of heat that needs to be transferred. Common types of heat exchangers used in heat pumps include shell-and-tube, plate-and-frame, and spiral heat exchangers.

The efficiency of a heat pump system is also an important consideration. The coefficient of performance (COP) is a measure of the efficiency of a heat pump system and is defined as the ratio of the heat output to the work input. A higher COP indicates a more efficient system. The COP can be improved by using a larger temperature difference between the source and sink, by using a more efficient compressor, or by using a more efficient heat exchanger.

Advantages of Heat Pumps:

- **Energy Efficiency:** Heat pumps are highly energy-efficient and can provide significant cost savings compared to traditional heating and cooling systems. This is because they transfer heat rather than generate it, which requires less energy.
- **Versatility:** Heat pumps can be used for both heating and cooling applications, which makes them a versatile option for homes and buildings.
- Environmentally Friendly: Heat pumps use less energy and produce fewer greenhouse gas emissions than traditional heating and cooling systems, making them a more environmentally friendly option.
- Long Lifespan: Heat pumps have a longer lifespan than traditional heating and cooling systems, with an average lifespan of 15-20 years.

- Consistent Temperature: Heat pumps provide consistent temperatures throughout the home or building, without the fluctuations that can occur with traditional heating and cooling systems.

Disadvantages of Heat Pumps:

- Heat pumps can have a higher upfront cost than traditional heating and cooling systems, which can make them less accessible for some homeowners.
- Heat pumps are less effective in colder climates, as the efficiency of the system decreases as the temperature drops.
- Heat pumps require regular maintenance to ensure optimal performance, which can add to the overall cost of the system.
- Some heat pumps can be noisy, which can be a concern for homeowners who prefer a quiet living environment.
- Heat pumps require careful installation and sizing to ensure optimal performance, which can be a challenge for some homeowners and contractors.

Overall, while there are some disadvantages to heat pumps, their energy efficiency, versatility, and environmental benefits make them a popular choice for homeowners and building owners looking for a cost-effective and environmentally friendly heating and cooling solution.

3.8. Condensation

Condensation is the process by which water vapor in the air transforms into liquid water. This occurs when the temperature of a surface is cooler than the dew point temperature of the surrounding air. Dew point temperature is the temperature at which the air is saturated with water vapor and condensation can occur. When warm and moist air comes into contact with a cooler surface, such as a window or mirror, the air is cooled and cannot hold as much moisture. The excess moisture then condenses on the surface in the form of water droplets. This can be seen in the form of foggy windows, water droplets on walls, or even dew on grass in the morning. Condensation can be a problem in buildings, as it can lead to mold growth, water damage, and other issues. To prevent condensation, it is important to maintain proper ventilation and humidity levels in indoor spaces. This can be achieved through the use of dehumidifiers, air conditioning systems, and proper ventilation systems. In addition, proper insulation and sealing of building envelopes can help to prevent condensation by maintaining consistent indoor temperatures and preventing the infiltration of moist air from the outside. Properly designed and installed vapor barriers can also help to prevent moisture from entering the building envelope and causing condensation.

Condensation is the process of transforming a gas or vapor into a liquid state. This occurs when the temperature of the gas or vapor decreases, causing the molecules to lose energy and come together to form liquid droplets. Condensation can occur in a variety of settings, including the atmosphere, on surfaces, and in industrial processes. Overall, condensation is a natural process that occurs when warm and moist air comes into contact with a cooler surface. While it can be a problem in buildings, there are a variety of strategies that can be used to prevent and control condensation, including ventilation, insulation, and proper moisture management.

Types of Condensation:

Surface Condensation: This occurs when a surface that is cooler than the surrounding air or gas is exposed to a warm and moist environment. The moisture in the air or gas condenses on the surface, forming droplets. This type of condensation can occur on windows, mirrors, and other surfaces.

Cooling or Compression Condensation: This occurs when a gas or vapor is cooled or compressed, causing the molecules to lose energy and come together to form liquid droplets. This type of condensation is used in refrigeration and air conditioning systems to cool air.

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Examples of Condensation:

Dew: Dew is formed when water vapor in the air condenses on surfaces such as leaves, grass, and other objects during the night when the temperature drops. This occurs because the temperature of the surface is cooler than the surrounding air.

Clouds: Clouds are formed when moist air rises and cools, causing the water vapor in the air to condense into water droplets or ice crystals. This process is known as adiabatic cooling.

Fog: Fog is similar to clouds, but it occurs near the ground. It forms when moist air cools and the water vapor in the air condenses into tiny water droplets that remain suspended in the air.

Condensation in Industrial Processes: Condensation is used in many industrial processes, such as chemical manufacturing, to separate liquids from gases. For example, in petroleum refining, condensation is used to separate gasoline from natural gas.

Equations for Condensation:

The process of condensation can be described mathematically using several equations. The most common equation used to describe condensation is the Clausius-Clapeyron equation. This equation relates the vapor pressure of a substance to its temperature and enthalpy of vaporization. The Clausius-Clapeyron equation is as follows:

$$\ln(P2/P1) = -(\Delta Hvap/R)((1/T2)-(1/T1))$$

Where:

P1 and P2 are the vapor pressures of the substance at temperatures T1 and T2, respectively. ΔHvap is the enthalpy of vaporization of the substance. R is the gas constant. T1 and T2 are the temperatures at which the vapor pressures P1 and P2 are measured, respectively.

The Clausius-Clapeyron equation can be used to predict the conditions at which condensation will occur. If the temperature and pressure of a gas or vapor are known, the equation can be used to calculate the vapor pressure at a lower temperature by equation

$$(dP/dT) = \Delta Hvap / T\Delta V$$

(dP/dT) is the rate of change of vapor pressure with respect to temperature. ΔHvap is the enthalpy of vaporization (the amount of energy required to vaporize a unit mass of the substance). T is the temperature at which the phase transition occurs. ΔV is the difference in molar volumes between the vapor and liquid phases.

The Clausius-Clapeyron equation can be used to predict the vapor pressure of a substance at any temperature, as long as the enthalpy of vaporization and the difference in molar volumes between the vapor and liquid phases are known. The equation is particularly useful for understanding the behavior of substances with a high vapor pressure, such as volatile liquids and gases

3.9. Summary

The energy budget in an ecosystem is a balance sheet of the energy flows into and out of the ecosystem. Energy enters the ecosystem through photosynthesis and is passed along the food chain from primary producers to consumers. However, not all energy is transferred from one trophic level to another, as some is lost as heat through respiration, excretion, and other metabolic processes. This loss of energy results in a decrease in the available energy at each trophic level. The amount of energy lost between trophic levels can be calculated using the ecological efficiency, which is the ratio of energy at one trophic level to energy at the trophic level below it. Energy is also lost from the ecosystem through physical processes such as evaporation and runoff. Understanding the energy budget of an ecosystem, it is important to understand the overall productivity and sustainability of the ecosystem. By monitoring energy flows and identifying areas of energy loss, researchers and conservationists can work to improve the health and productivity of the ecosystem.

3.10. Terminal questions

Q.1: What is the heat and how it is circulated in nature.

Answer:---

Q.2: Discuss the Energy use and efficiency in building.

Answer:---

Q.3: Discuss the heat loss and its significance of calculations.

Answer:---

Q.4: What is the condensation? Discuss the various types of condensation.

Answer:---

Q.5: Calculation of energy gain in ecosystem.

Answer:--

Q.6: What is the equations used in the quantify the energy loss from natural ecosystem.

Answer:---

3.11. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.
5. Introduction to Energy and Climate , Developing a Sustainable Environment, Julie Kerr, Taylor & Francis eBooks

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Energy Resources and Climate Change

Block- 2

Energy Resources

UNIT -4

Concept of Energy

UNIT-5

Energy Flow Models

UNIT-6

Energy Policy

Rajarshi Tandon Open University, Prayagraj

PGEVS-107N

Energy Resources and Climate Change

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Introduction

This second block of Energy Resources and Climate Change, this consists of following three units:

Unit-4: this unit covers the concept of energy is types, sources, tools and time scale of fossil fuels production are discussed in this unit.

Unit-5: This unit describes the energy flow models in aquatic ecosystems and terrestrial ecosystem. The comparison of energy flow in different ecosystems also discussed. The three types of energy flow models such as single, Y shaped and Universal Model energy flow model is also discussed along with Lotka-Voltera model and Lindeman's trophic dynamic aspect.

Unit-6: This unit covers the energy the political choices in energy policy globally and in the Indian context (historical and contemporary case studies). The domestic and international energy policy, energy diplomacy and bilateral ties of India with her neighbor are also discussed briefly.

UNIT-4:–Concept of Energy

Contents

4.1. Introduction

The world energy comes from the Greek energia. Aristotle (384-322 BC) developed the concept of 'fire' as one of four basic 'elements' of nature first described by Empedocles (490-430 BC), the other three being earth, water and air. This view remained unchallenged for the next two thousand years. The largely apathetic and deeply religious 'scientists' of the Dark and Middle Ages did not seem to care to clarify it. The age of Enlightenment had to come eventually. The life is based upon conversion, utilization, storage and transfer of energy. The Sun is the primary source upon which almost all life depends.

This energy undergoes many changes affecting the planet in many ways and is enetually re-emitted as heat back into space. Energy is locked away as potential energy in fossil fuel buried underground once come from the sun. In the ensuing 150 years or so, the rapidly growing scientific community was successful in drawing a clear distinction between the more abstract concepts of force and energy and the less abstract concepts of heat and work. The period 1839-1849, clarified the relationship between heat and work, as two qualitatively different but quantitatively equivalent forms of energy. Energy is a driving force that brings order and structure to life. Energy is an elemental force of nature that powers our lives, and the universe and every thing in between.

Objectives:

After reading these units, learner will be able to know:

- the Energy and its Different Forms of Energy
- the source based conversion factors and units
- the types of Energy Resources
- the conventional and non-conventional sources of energy

4.2. Definition of Energy

The capacity for doing work. It may exist in potential, kinetic, thermal, electrical, chemical, nuclear, or other forms is known as energy. James Prescott Joule (1814-1889) established that the various forms of energy-mechanical, electrical and heat are basically the same and can be change one into another.

Scientists define energy as the ability to do work. Modern civilization is possible because people have learned how to change energy from one form to another and then use it to do work. It is a powerful and pervasive force that is hard to ignore and even harder to comprehend.

Energy is defined as the "**ability to do work, which is the ability to exert a force causing displacement of an object**." Despite this confusing definition, its meaning is very simple: energy is just the force that causes things to move. Energy is divided into two types: potential and kinetic. Energy is considers the process of energy-substitution and analyzes it as a process of complementary usage, hybridization and technological mixes.

Energy is **the capacity of a physical system to do work**. The common symbol for energy is the uppercase letter E. The standard unit is the joule, symbolized by J. One joule (1 J) is the energy resulting from the equivalent of one Newton (1 N) of force acting over one meter (1 m) of displacement.

4.2.1. Different Forms of Energy

Kinetic Energy and Potential Energy are the two main forms of energy which encompasses various other types of energy. Kinetic Energy and Potential Energy are collectively known as mechanical energy.

1. Kinetic Energy

Kinetic energy (KE) is defined as the energy possessed by a moving body by virtue of its motion. Work must be done on the object to change its kinetic energy. The kinetic energy is expressed in the form of an equation as K.E = ½mv^2 where 'm' denotes the mass of the object and 'v' denotes the velocity of the object. A running athlete, blowing wind, flying aircraft, etc. possesses kinetic energy.

2. Potential Energy

Potential Energy (P.E) is defined as the energy which is stored by an object due to its position, relative to the other objects. The potential energy is expressed in the form of an equation as P.E = m*g*h where 'm' denotes the mass of the object, 'g' denotes the acceleration due to gravity and 'h' denotes the height in meters. When we wind a toy car or stretch a rubber band, potential energy gets stored in the toy car and the rubber band due to the work done on it. The energy remains stored as potential energy if it is not used to cause a change in the velocity of the object.

3. Mechanical Energy

Mechanical energy is defined as the energy associated with the motion and the position of the object. It can possess energy in the form of either potential energy or kinetic energy or both. Hence, mechanical energy is expressed as the sum of kinetic energy and potential energy.

4. Chemical Energy

Chemical Energy is defined as the energy stored within the bonds of a chemical compound, i.e., the energy is stored between the atoms and molecules of the compound. It also refers to the ability of the chemical substances to undergo a chemical reaction to transform into other substances. The chemical energy is involved in the formation or destruction of chemical bonds, which is either absorbed or released from the chemical system.

5. Electrical Energy

Electrical Energy is defined as the energy that has been converted from electrical potential energy. An electrical circuit delivers this type of energy and it is a combination of electric current and electric potential. When the electrical potential energy is converted into another type of energy namely light, heat, or motion, it ceases to be electrical potential energy.

6. Nuclear Energy

Nuclear Energy, also known as atomic energy, is defined as the energy that is released as a result of processes in which atomic nuclei (i.e., the core of the atom) are affected. There are two methods by which nuclear energy can be released. One is known as nuclear fission and the other one is known as nuclear fusion.

4.2.2. Common Units of energy

- Barrel of oil
- Calorie
- Horsepower
- Joule (J)
- Kilowatt-hour (kWh)
- Kilowatt (kW)
- Megajoule (MJ)
- Megawatt (MW)

- The words “power” and “energy” are often used interchangeably. While energy is the ability to do work. Power is the rate at which energy is transferred, used, or transformed.
- Barrel is unit of measurement of volume. Generally, it is used to describe the production or consumption of crude oil by any entity. 1 barrel of oil (1 bbl) = 42 US gallon = 159 litres.

- Calorie is the approximate amount of energy needed to raise the temperature of one gram of water by one degree Celsius. This unit is used for measuring heat energy. One calorie is equal to 4.184 joules. It is often used instead of joules when dealing with the energy released from food.
- Horsepower is a unit for measuring the rate of work (or power) equivalent to 33,000 foot-pounds per minute or 746 watts. The mechanical horsepower, it is known as imperial horsepower. It is exactly 550 foot-pounds per second. It is approximately equivalent to 745.7 watts.
- Joule is a standard International System of Units of energy; 1055 Joules is equal to 1 BTU.
- Kilowatt-hour is a unit of energy equal to one kW applied per hour; for running a one kW equipment for one hour would dissipate one kWh of electrical energy as heat. The kilowatt-hour (symbolized kWh) is a unit of energy equivalent to one kilowatt (1 kW) of power expended for one hour (1 h) of time. 1 kWh = One thousand watt hours.
    - Kilowatt is one thousand watts of electricity.
    - One million Joules.
    - One Million Watts; a modern coal plant will have a capacity of about 1,000 MW.
- 1 unit of electricity = 1 kWh. The electricity used is generally charged for in “unit of electricity’. Killowatt-hours is the product of watts x time (one killowatt = 1000 watts). A two killowatt heater switched on for three hours will have used six killowatt-hours of electricity.
- The volt is the International System of Units (SI) measure of electric potential or electromotive force. A potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance.

4.3. Energy Units

Many sorts of units are used in energy discussions. They fall into two broad categories: (a) those whose definition is not related to a particular fuel, which we here term "basic" units; and (b) those whose definition is related to idealize properties of a specific fuel are termed "source-based" units. These units, along with special topics related to electricity, are discussed in succeeding sections. Table 1 gives conversion factors between units, as well as the energy content of specific fuels.

Basic Units

Joule (J)

This is the basic energy unit of the metric system, or in a later more comprehensive formulation, it is the International System of Units (SI). It is ultimately defined in terms of the meter, kilogram, and second.

Calorie (cal)

Historically the calorie was defined in terms of the heating of water. Thus, in a traditional definition, one calorie is the amount of heat required to raise the temperature of 1 gram of water by 1°C, from 14.5 °C to 15.5 °C. (This is sometimes referred to as the 15 °C calorie, and differs slightly from the "calorie" measured for other temperature intervals.) More recently the calorie has been defined in terms of the joule; the equivalence between the calorie and joule is historically known as the mechanical equivalent of heat.

Several definitions of the calorie are now in common use, including (2):

Thermo chemical calorie	1 cal = 4.184 J (exact)
15 °C calorie	1 cal = 4.1858 J
International Table calorie	1 cal = 4.1868 J (exact)
mean calorie	1 cal = 4.1900 J

The International Table (IT) calorie has been adopted in the publications of the Energy Information Administration of the U.S. Department of Energy (DOE/EIA) (3) and of the International Energy Agency of the Organization for Economic Co-operation and Development (OECD/IEA) (4). In view of the importance of these publications, it is reasonable to view the IT calorie as being the preferred unit for discussions of energy production and use, but there is no universally adopted practice (see also the discussion of Btu, below).

Sometimes a capitalized version, Calorie, is used to denote the kilocalorie (kcal). In discussing food, the "calorie," capitalized or not, is always the kilocalorie.

British thermal unit (Btu).

This is the English system analog of the calorie. For specific heat capacities to be the same, whether expressed in Btu/lb-°F or in cal/gm-°C:

1 Btu = 251.9958 cal.

As for the calorie, there is a family of "Btu's" that is relatively in common use, including:

Thermo chemical Btu 1 Btu = 1054.35 J

59 °F (15 °C) Btu 1 Btu = 1054.80 J

International Table Btu 1 Btu = 1055.06 J

mean Btu 1 Btu = 1055.87 J

Again, the IT unit is the one used in DOE/EIA publications.

Kilowatt-hour (kWh).

The kilowatt-hour is a standard unit of electricity production and consumption. By definition, noting that 1 kilowatt = 1000 watts:

1 kWh = 3.6 x 10 6 J (exact).

The relationship between the kWh and the Btu depends upon which "Btu" is used. It is common, although not universal, to use the equivalence:

1 kWh = 3412 Btu.

This corresponds to the International Table Btu. [More precisely, 1 kWh = 3412.14 Btu (IT).]

Large-scale units.

In describing national or global energy budgets, it is in common practice to use large-scale units based upon the joule, Btu, and kWh:

Exajoule (EJ):

1 EJ = 1018 J

Quadrillion Btu(quad):

1 quad = 1015 Btu = 1.055 EJ

Terawatt-year (TWyr):

1 TWyr = 8.76 x 1012 kWh = 31.54 EJ = 29.89 quad

4.4. Source based conversion factors and units

In discussing the production and use of energy it is often convenient to speak in terms of the bulk amount of fuel, e.g. a barrel of oil or a ton of coal. These terms are sometimes used not only to denote a volume or mass, but also to represent an amount of energy. While useful in putting a primary focus on the fuel of interest, there is an intrinsic imprecision in such an approach because "oil" and "coal" embrace a variety of products, with different energy contents per unit mass. The differences can be large.

Given the wide variations in the actual heat content of fuels, especially oil and coal, it is common to introduce a nominal energy equivalent that reflects a typical energy content of the given fuel, but is decoupled from the variations that occur in actual fuels. The energy equivalent can be considered to be an alternate energy unit, precisely related to units such as the joule, calorie, or Btu.

Conversion factors for oil.

The heat content of crude oil from different countries varies from about 5.6 million Btu (MBtu) per barrel to about 6.3 MBtu. The heat content of typical petroleum products varies even more. A nominal conversion factor is sometimes used for a barrel of crude oil, which is close to its actual average energy content:

1 barrel of oil equivalent = 5.80 MBtu.

With this definition, a correspondence can be established between millions of barrels of oil per day (Mbd) and quads per year:

1 Mbd = 0.0058 x 365 = 2.12 quad/yr.

Which is sometimes rounded off to: 1 Mbd = 2 quad/yr?

Energy equivalence for oil can also be specified in terms of energy per metric ton (tonne). The number of barrels of crude oil per tonne varies widely, depending upon the source. In 1993, the EIA has reported values varying from well under 7 barrels/tonne for some countries of origin to over 8 barrels/tonne for others. For the United States, the average was 7.33 barrels/tonne. This average, together with the nominal equivalence of 5.8 MBtu/bbl, corresponds to heat content for crude oil of 42.5 MBtu/tonne.

There are differing definitions in the literature of a tonne of oil equivalent (toe). In OECD/IEA publications is a set equal to 10.0 kcal (IT), while in other publications it is set equal to 10.7 x 106 kcal (thermo chemical) . These choices correspond, respectively, to:

1 toe = 1.00 x 1010 cal (IT) = 41.868 GJ = 39.68 MBtu (IT) and

1 toe = 1.07 x 1010 cal (thermochemical) = 44.769 GJ = 42.46 MBtu (thermochemical).

In OECD/IEA tabulations, the megatonne of oil equivalent (Mtoe), equal to 4.1868 x 1016 J, are used as the general unit to describe the energy content of all fuels. A corresponding larger unit, the gigatonne of oil equivalent (Gtoe) can be related to the exajoule and quad:

1 Gtoe = 41.868 EJ = 39.68 quad.

Conversion factors for coal.

Amounts of coal are described both in short tons and metric tons. Heat contents vary widely among countries, averaging less than 10 MBtu/ton for some regions and up to about 30 MBtu/ton for others, where low heat content corresponds to a large lignite fraction. For the United States in 1995, the average was 20.9 MBtu/ton.

In a fairly widely used specification of a nominal value, the energy content of 1 tonne of coal equivalent is set equal to 7 x 109 calories. Then, at a level of precision that makes the particular choice of "calorie" irrelevant:

1 tonne of coal (equiv) = 29.3 GJ = 27.8 MBtu

1 ton of coal (equiv) = 26.6 GJ = 25.2 MBtu.

Conversion factors for natural gas.

Natural gas is made up largely, but not entirely, of methane (CH_4) and its energy content is more uniform than that of coal. For the large majority of sources the gross heat content of dry natural gas lies between 900 Btu/ft^3 and 1100 Btu/ft^3.

There is no widely used equivalent unit of energy specifically based on natural gas, although the heat content of natural gas is often approximated by the rounded value of 1000 Btu/ft^3. In discussions of natural gas production and consumption it is also common to use the unit therm, where

1 therm = 100,000 Btu.

Electricity sales.

Electricity sales differ from net generation due to transmission losses. In standard tabulations, such as those of the DOE/EIA, there may be further differences due to imports, exports, time lags between generation and billing, and the inclusion in utility sales of amounts of electricity purchased by utilities from non-utility producers for resale. In 1993, for example, the ratio of U.S. utility sales to net utility generation was 0.99. Transmission and distribution losses amounted to about 8%, but this was largely balanced by purchases from non-utility electricity producers and, secondarily, imports (3).

Efficiency for fossil fuel and nuclear sources

At 100% efficiency, the conversion from heat to electricity is at a rate of 3412 Btu per kWh. Actual generation efficiencies, limited by the Second Law of Thermodynamics and design practicalities, fall short of this. More specifically, for U.S. power plants during recent years the average heat input per kWh of net generation was in the neighborhood of 10,300 Btu/kWh for fossil-fuel steam plants and of 10,700 Btu/kWh for nuclear plants, corresponding to thermal conversion efficiencies of 33% and 32%, respectively. [It is expected that future plants, especially those based on gas turbine systems, often will have higher efficiencies, in some cases exceeding 50%.]

Primary energy and end-use energy

In considering energy consumption for electricity generation, a separation is sometimes made between the electrical energy consumed at the point of use (converted from electricity sales at the rate of 3412 Btu/kWh) and the energy lost to heat in electricity generation and transmission. The end-use energy and the energy losses are then individually tabulated, with the losses roughly twice as great as the end-use energy. However, this separation creates a possibly misleading asymmetry in comparisons among modes of energy use, because end-use losses are neglected for fossil fuels used directly and these losses sometimes are substantial.

Energy equivalent for non-fossil fuel sources

To facilitate comparisons between different energy sources, a conversion factor is assigned to non-fossil fuel sources which relates electricity generated to a nominal primary energy. For nuclear energy, this is done on the basis of the heat content of the steam produced. A similar approach can be used for geothermal plants.

For the various renewable energy sources

The primary energy cannot be readily established and often is irrelevant. Instead, a "primary energy" is assigned by adopting a standard conversion factor---equivalent to adopting a nominal efficiency, where 100% efficiency corresponds to 3412 Btu per kWh. In DOE/EIA publications, the nominal efficiency for renewable energy sources (hydroelectric, biomass, wind, photovoltaic, and solar thermal) is taken to be the same as the efficiency of fossil-fuel steam electric plants, namely 33.2%. [More precisely, the conversion factor is set at 10,272 Btu/kWh.] In OECD/IEA publications, on the other hand, the efficiency is taken to be 100% for hydroelectric, wind, and direct solar sources. For geothermal sources it is taken to be 10% (4). Thus, compared to DOE/EIA publications, the OECD/IEA publications underestimate the primary energy consumed for hydroelectric power and overestimate the primary energy consumed for geothermal power.

Gigawatt-year (GWyr). Large individual plants have capacities in the neighborhood of 1 GW of electrical output (GWe). This makes the gigawatt-year (GWyr) a natural unit to use in discussions of total electricity production. By definition:

1 GWyr = 8.76 x 109 kWh.

4.5. Types of Energy Resources

Energy Resource

Non-Renewable Resource

Renewable Resource (Non-Conventional

Conventional	**Non-conventional**
These resources are exhaustible.	These resources are inexhaustible.
These resources cause pollution as they emit smoke and ash.	These resources are usually pollution-free.
These resources are very expensive to be maintained, stored and transmitted.	These resources are less expensive for local use and can easily be maintained.
Examples- coal, natural gas, petroleum, and water power.	Examples- solar, biomass, wind, biogas, and tidal, geothermal.

Renewable	**Non Renewable**
The resources that can be replenished through rapid natural cycles are known as renewable resource.	The resources that cannot be replenished through natural processes are known as non-renewable resources.
These resources are able to increase their abundance through reproduction and utilization of simple substances. Examples of renewable resources are plants, (crops and forests), and animals who are being replaced from time to time because they have the power of reproducing and maintain life cycles.	These are available in limited amounts, which cannot be increased. These resources include fossil fuels (petrol, coal etc.), metals (iron, copper, gold, silver, lead, zinc etc.), minerals and salts (carbonates, phosphates, nitrates etc.)
Some examples of renewable resources	Once a non-renewable resource is consumed, it

though they do not have life cycle but can be recycled are wood and wood-products, pulp products, natural rubber, fibers (e.g. cotton, jute, animal wool, silk and synthetic fibers) and leather.	is gone forever. Then we have to find a substitute for it or do without it.
In addition to these resources, water and soil are also classified as renewable resources.	Non-renewable resources can further be divided into two categories: re-cycleable, non-re cycleable
Solar energy although having a finite life, as a special case, is considered as a renewable resource in as much as solar stocks are inexhaustible on the human scale	**Re-cycleable-** collected after they are used and can be recycled. Eg. Asbestos, Clay, Mica. **Non-recycleable-** cannot be recycled in any way. Eg. Fossil Fuels and Uranium.
Disadvantage: Unreasonable supply, Usually produced in small quantities, Often very difficult to store, Currently per unit cost of energy is more compared to other types.	**Disadvantage:** Highly polluting, Available only in few places, High running cost, Limited supply and will one day get exhausted.

Conventional and Non-conventional Sources of Energy

In basic terms, "conventional and non-conventional" sources of energy give an idea about how it is easier to reach the resource at present and how feasible it is in terms of economic viability. There are a lot of natural resources present around us. Some are present beneath the Earth (fossil fuels, geothermal energy), some are on the Earth (ocean, river), some are above the Earth (wind) and some are present far away from the Earth (The sun). But for the past many years, we are using some particular resources (like petro, diesel, and gas) and more advanced mechanisms are available to extract energy from these sources. Therefore, these sources of energy are known as **conventional sources of energy**. These sources are very limited in nature. On the other hand, some sources of energy are available for a very long time and can provide an unlimited amount of energy. Unfortunately, we do not have enough advanced technology to extract energy from these sources. These sources of energy are non-conventional sources of energy.

4.6. Natural sources of energy

The resources, which are locked in the dead organic materials beneath and far away from the Earth, found naturally are known as natural sources of energy. The natural sources of energy are divided into two categories,

- Conventional sources of energy
- Non-conventional sources of energy

4.6.1. Conventional sources of energy

The energy sources that are present for a long time found naturally on or beneath the Earth and take a long time to produce or replenish are known as conventional sources of energy. Generally, these are also non-renewable energy sources. The conventional sources of energy are again divided into two categories, commercial and non-commercial energy sources.

Commercial energy sources: To get energy from these kinds of sources, we need to pay for it.

The consumption price depends on various factors like demand and supply, availability, feasibility etc. A few examples are,

(a) Electricity: It is the most common and essential form of energy which we use in our daily life. It runs many home appliances like fridges, bulbs, and washing machines etc, also used in commercial buildings and in production units. Electricity is produced by various commercial energy sources in power plants like nuclear power plants, hydroelectric power plants, and thermal power plants.

(b) Coal: It is a type of fossil fuel which is present beneath the surface of the Earth and was formed by decomposed organic materials due to the high compression and temperature due to Earth’s layers. It takes millions of years to form coal which we use. Therefore it is a non-renewable energy resource.

(c) Natural gas and oil: These are also obtained from fossil fuels and are present beneath the surface of the Earth and formed from decomposed organic materials. They are at the high compression from and temperature of the Earth’s layers. Natural gas and oil also take a very long time to produce but can be used instantly therefore these are also known as non-renewable energy resources.

Non-commercial energy sources:

The energy resources which are generally available are free to use. Examples are fire woods, cow dung, and straw. Firewood's are obtained from the trees and plants. Dung is obtained from animal wastes and straw is obtained from the crop plants like wheat crops, rice crops etc.

4.6.2. Non-conventional sources of energy

The natural resources that can produce useful energy continuously for a long period of time and are available again and again for use even after it is exhausted are known as non-conventional sources of energy or renewable resources of energy. Some types of non-conventional sources of energy are; sunlight, wind, water flow, and ocean.

(a) Solar energy: The energy produced by the Sun is referred to as solar energy. It is formed due to nuclear fission and fusion inside the Sun. This energy travels in the form of radiation (electromagnetic waves). This energy is collected by some photovoltaic cell panels which absorb the solar energy and convert it into electricity that can be used for home appliances. Solar heating panels are used to heat the water in the solar heater.

(b) Wind: When we talk about wind energy then it means that the wind speed should be high enough to produce a considerable amount of useful work. This kind of wind energy is usually available near the coastal regions or near the mountains where high wind flow is available at a constant rate. Big turbines, called **wind turbines** are installed at such sites to tap this wind energy which drives these turbines and as result, electricity is generated.

(c) Tidal energy: We know the tides are created in the ocean due to the rotation of the Earth and the attraction between Earth and the moon. Tides are nothing but the rise and fall of the water level in the ocean. We can observe it easily on the shores. The tidal energy is captured by forming narrow dams at the narrow entrances of rivers. During high tides and low tides, the motion of the water column is used to rotate the turbines that produce electricity.

(d) Biomass energy: Biomass energy is extracted from biological materials where biological materials are formed from living organisms and plants. In the biomass power plant, biomass is burnt into a combustor in order to produce heat which will be further converted into mechanical energy in order to generate electricity. Biomass can also be converted into other forms of energy like fuels used in transportation, biodiesel or methane gas depending on the requirements.

(e) Geothermal energy: As we know that the temperature increases as we move inside the Earth's layers. This high temperature is the thermal energy source. Potential sources can be hot springs and volcanoes which contain a very high amount of heat. This kind of energy is known as geothermal energy. This energy can be extracted and can be used to generate electricity. In Himachal Pradesh and Ladakh, geothermal power plants are located.

(f) Hydro energy: This energy is generally available in flowing rivers. A dam is formed to store the water of the river at some convenient location. This stored water contains the potential energy which can be converted into kinetic energy by giving a narrow passage to the flow. Thus we get a water stream with high-speed that drives large turbines to produce electricity.

Renewable and non-renewable resources

A ***resource*** is a source or supply from which a benefit is produced and that has some utility. ***Natural resources*** are materials or things that people use from the earth. Resources can broadly be classified upon their availability. They are classified into renewable and non-renewable resources. They can also be classified as actual and potential on the basis of the level of development and use, on the basis of origin they can be classified as biotic and abiotic, and on the basis of their distribution, as ubiquitous and localized (private, community-owned, natural and international resources). An item becomes a resource with time and developing technology. The benefits of resource utilization may include increased wealth, proper functioning of a system, or enhanced well-being. From a human perspective, a natural resource is anything obtained from the environment to satisfy human needs and wants. From a broader biological or ecological perspective, a resource satisfies the needs of a living organism.

The concept of resources has been developed across many established areas of work, in economics, biology and ecology, computer science, management, and human resources for example - linked to the concepts of competition, sustainability, conservation, and stewardship. In application within human society, commercial or non-commercial factors require resource allocation through resource management.

Renewable natural resources

They are called renewable because they can grow again or never run out. Let's look more closely at renewable natural resources. Trees are a good example. If cut down, they can regrow from seeds and sprouts. Animals are another example. Baby animals are born and grow up. They replace older animals that die.

Trees are one of the most useful renewable natural resources. We use trees to produce almost 8,000 different things, like cardboard box. Wood is used to make most of these products. Tree wood is in our homes, furniture, and paper and on and on. Tree chemicals are also used to produce things like rayon cloth, food, medicine, and rubber.

Air and water are renewable natural resources too. They don't regrow like trees nor have babies like animals. But, they are always being renewed. They move in cycles. They go from one place to another, and often back where they started, again and again. This is a good thing, because all living things need air and water to survive. There is one other type of renewable natural resource. It includes sources of power like sun and wind energy. These are never ending. Finally, renewable resources can regrow or be replaced within a person's lifespan.

Nutrients are chemicals that living things need. They are renewable natural resources. They move round and round in cycles and never run out. When an animal like this cow eats a plant, it takes in nutrients. The nutrients are used in the animal's body and then many come out as waste, which returns the nutrients to the soil. When the animal dies, nutrients will return to the soil as well. Plants take up the nutrients in the soil and continue the cycle.

Nonrenewable natural resources

These are things that can run out or be used up and usually come from the ground. There are fixed amounts of these resources. They are not living things, and they are sometimes hard to find. They don't regrow and they are not replaced or renewed. They include the fossil fuels we burn for energy (natural gas, coal, and oil). Minerals, used for making metals, are also non-renewable natural resources. Non-renewable natural resources are things that take longer than a person's lifespan to be replaced. In fact, they can take millions of years to form.

Fossil fuels such as oil, coal, and gas will not last forever. They are non-renewable. People are trying hard to find new fuels that are clean and will provide the power we need. Wind, solar, and hydrogen power are renewable resources that offer hope for the future.

***Take care of natural resources*:**

People use both types of natural resources to produce the things they need or want. Our homes, clothing, plastics, and foods are all made from natural resources. All natural resources should be used wisely. We must *conserve* natural resources. Conserve means not use up, spoil, or waste things. This is especially true for the non-renewable resources. However, even some renewable natural resources can run out if they are all killed or overused. We must also protect our natural resources from pollution. Pollution occurs when people put harmful chemicals and other things into nature. Oil spilled in water, toxic chemicals in the air, or garbage dumped on the side of the road are examples of this problem. Also we can reduce, reuse, and recycle! For example, turn off the lights when we are not in a room. This will reduce the use of fossil fuel used to make electricity. Ride our bicycle and walk more, to reduce the amount of gasoline used to transport us. We can reuse things like plastic jugs, jars, paper, and bags, etc. Each time we reuse something, and conserve the natural resources that would have been used to make new ones. Items that can be easily recycled include: glass, some plastics, paper, cardboard, aluminum, and steel. Some plastics and metals are hard to recycle. They are often made from mixtures of materials. Mixtures can be hard to separate. Try to buy and use things that we can recycle.

4.7. Natural resources and associated problems

Manifold increase in population is causing an increase of demand of our natural resources. If this pace continued there will be a time when the natural resources will be depleted and future generation will be deprived of them. As per ***Brundtland commission*** report, entitled '***Our Common future'*** published in 1987, natural resources are not inexhaustible and *development process should be aimed to meet the needs of the present generation without compromising the ability of future generations to meet their own needs*.

There are many causes of depletion of natural resources –

Uneven distribution of resources – natural resources are unevenly distributed around the world; a country may be rich in one kind of resource and poor in other kinds of resources. For example, South Africa contains most of the world's gold and platinum but has little of silver. North America is rich in molybdenum; Malaysia and Indonesia are rich in tin, tungsten and manganese. Petroleum is very rich in Gulf countries and may be poorly represented or even lacking in another country.

USA, Russia, China, Australia, etc. have a wide diversity of natural resources and these had been efficiently used for the development. Whereas, Africa and Asia, although rich in natural resources, were exploited by foreign rulers for many years and much of their mineral and forest wealth has been depleted. Due to lack of money and technologies, the countries of Africa and Asia are far behind to develop and use them optimally to bring about the progress in economy.

Population growth

Rapid increasing population has caused an increasing demand for resources, e.g., to feed grow more crops. The forested areas are being converted into agricultural lands. The need of huge quantity of food crops resulted in the intensive farming methods that soon deplete the soil of its nutrients. Addition of fertilizers to boost the crop production and use of synthetic pesticides to control pests, destroy the soil quality in the long run. Large quantities of water used in agricultural fields for irrigation and fulfilling the needs of man for drinking, cooking and other domestic purposes. A large amount of wood is used as fuel and foliage is used as fodder for animals. Forested areas have been converted into settlement. Transport and communication network also depletes natural habitats and natural resources.

Industrial development – without proper environmental assessment rapid industrialization consumes huge amount of minerals, burns large quantities of fossil fuel, uses large amount of water and consumes plenty of energy. To promote industrial estate results clearing of clear forest areas and loss of natural habitats. For high consumption chief electricity industries, it requires setting up of hydroelectric projects across the rivers and streams in the upper course. Construction of dams for water results to submerge natural forests and uprooting of wildlife and tribal communities.

Economic development-for fulfilling of our demand over exploitation of natural resources is causing a great shortage and non-availability of natural resources. Hence prices of resources are increasing tremendously resulting the adverse affects on economic conditions of many countries. There are large hike of resources and mineral oil. Intensive agricultural practices are causing depletion of groundwater resulting the lowering of water table. Deforestation, poaching and animal trade is causing threat to biodiversity of our country. Loss of natural forests and non-scientific agricultural practices is causing desertification.

Therefore it becomes necessary to use the natural resources in such a way that they can also be use for future generation and are not lost. In other sense allocation of resources has to be done in such a manner so that they are well managed and conserved i.e. to maintain its sustainability and equitable availability. Resource conservation means its prevention from loss, waste or degradation so that it lasts indefinitely, e.g. manage and conserve the natural resources, wildlife, minerals and fossil fuel, etc. so that they are not exhausted.

4.8. Energy tools and techniques of energy conservation

Conservation of electrical energy is a vital area, which is being regarded as one of the global objectives. Along with economic scheduling in generation of electricity and use of modem equipments in transmission and distribution network, it is also important to optimize the energy requirement of electric loads. It is said that energy saved is energy generated. Improving the efficiency of electrical equipment is now recognized in many countries as a less costly means than construction of new power plants for meeting some of the increased demand for electricity services. In today's energy scenario, industries are the major consumers of electric energy produced in any country. Electrical motors, being the most widely used energy converters in any industry, even a small percentage of energy saving is considered to be a big deal in existing industrial drive applications.

4.9. Methods of Energy Conservation

In India, about 60 % of the generated electricity is consumed by 3 - phase squirrel-cage Induction motors installed in industrial, agricultural and other applications. It is estimated that, every one percent reduction in energy consumption by this electric drive would save around Rs.500 crore per annum. Several measures can be adopted for reducing energy losses in

Induction motors and improving energy conservation. The recommended ways to achieve this are:

- By design modifications
- By constructional modifications
- By efficient operation

Origin and time scale of fossil fuels production

Fossil Fuels:

Fossils are the remains of creatures that lived long ago. So, fossils include organic matter buried beneath layers of rocks. A fuel is a source of energy. Without fossil fuels, most people could not drive their cars. They could not turn on their lights or heat their homes. This is because most of the energy needed to do these things comes from fossil fuels. The energy in fossil fuels originally came from the Sun. Plants use the energy in sunlight to make their own food. The energy in plants passes to the animals that eat the plants. Some energy remains in plants and animals that die and become fossil fuels. Burning the fossil fuels releases the energy for humans to use. Fossil fuels include coal, oil, and natural gas.

Sedimentary rock:

The rocks that form layers at Earth's surface are sedimentary rocks. A sedimentary rock is made of bits of other rocks. Processes such as **weathering** break down rocks at Earth's surface. These bits of broken rock are called sediments. Sediments form layers at the bottoms of valleys and seas. New layers increase the pressure on older layers. This pressure compacts the sediments. (During compaction, bits of rock are pressed tightly together.) Over time, water flows through the compacted sediments. Most of the water on Earth contains dissolved minerals. Some of these minerals stick to the sediments. Eventually, enough minerals stick to form a kind of cement. The cement holds together all the bits of rock to form new rock. Not all sedimentary rocks form in this way.

Involvement of Sedimentary rock in the formation of Fossil fuels:

The effects of pressure and temperature can change organic matter into fossil fuels. This does not happen quickly. The transformation takes millions of years. Coal forms from dead plants that sink to the bottoms of swamps. The organic matter is buried under sediments and slowly transformed into peat. If the peat is buried under more sediment, it can become coal. There are several kinds of coal. Coal that has experienced greater pressure contains more energy. Some people consider coal to be a type of sedimentary rock. The other kinds of fossil fuels, oil and natural gas, are not rocks. They formed from microscopic animals that lived in ancient seas. When these tiny creatures died, they were buried beneath layers of sediments. The sediments became sedimentary rocks. Over millions of years, pressure from the rocks changed some of the organic matter into oil. Organic matter can also become natural gas.

Petroleum Engineering:

Oil is not found in underground lakes filled with black liquid. Instead, the rocks in an oil reservoir have tiny holes called pores. Pressure from the layers of rock above the reservoir squeezes drops of oil into the pores. Petroleum engineers look for ways to remove oil from underground rocks. They test the ground to determine the best places to drill. They build pumps to force the oil to the surface. However, these methods remove only a quarter of the oil in any reservoir. How can people get the remaining oil? That's a problem that petroleum engineers are still working on.

Gasoline:

Petroleum is a mix of chemicals. By breaking apart these chemicals, people can turn petroleum into a wide range of products. (This process is called refining. Before it has been refined, petroleum is sometimes called crude oil.) One such product is gasoline. When gasoline is burned, it expands very quickly. This expansion releases lots of energy in the form of explosions. A gasoline engine allows people to create and control these explosions. The energy can then be used to propel a car forward. Americans use hundreds of millions of gallons of gasoline each day. Nearly one-fifth of all the energy used in the United States comes from gasoline.

It is very important for people to use less coal, oil, and natural gas. Removing fossil fuels from the ground pollutes the environment. So does burning them. But there is an even simpler reason for people to find other sources of energy. Fossil fuels are non renewable resources. This means that we use them much more quickly than nature makes them. Remember: coal, oil, and natural gas take millions of years to form.

Characteristics of Fossil Fuels

- forms from organic matter buried beneath sediments
- changed by high pressures and temperatures
- exists mostly as a solid
- exists mostly as a liquid
- exists mostly as a gas
- forms mostly from plant matter
- forms mostly from microscopic animals
- releases energy when burned
- pollutes the environment when burned
- nonrenewable resource

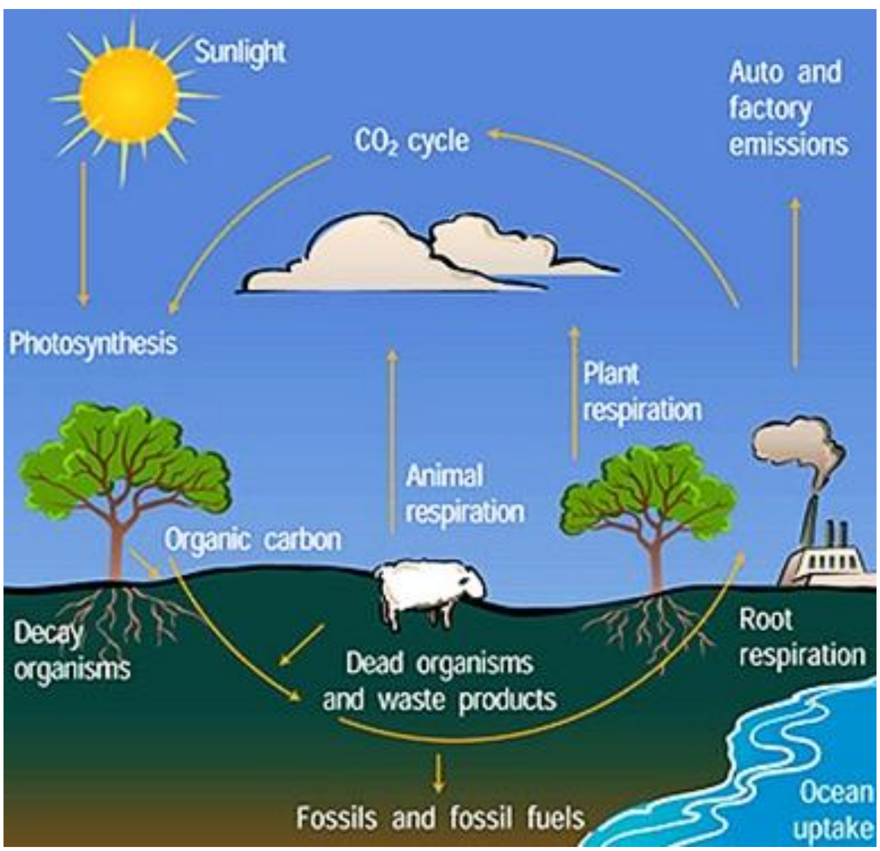

Figure shows the Energy Cycle

4.10. Summary

The world is looking for alternate energy sources that can overcome the limitations of fossil fuels. Now a day's renewable energy plays a very significant role. It gave a chance to us to reduce carbon emissions, clean the air and prevent global warming of planet earth. India has one of the biggest reserves of coal in the world. However, petroleum resources are meager in comparison to the major oil producing nations of the world. For securing the energy security in future India has no option but to venture in to nuclear energy as well as renewable energy resources. Importance of renewable (non-conventional) energy sources was recognized in the country in the early 1970s. Today, India has large programme for renewable energy. The activities cover all major renewable energy sources, such as biomass (biogas), solar, wind, ocean, small hydro power plants and other emerging technologies. Biomass energy, where solar energy is utilized indirectly, has been the major source of energy to human beings throughout the history of civilization. Ocean tides, produced by gravitational force of sun and moon, contain enormous amount of energy. The high tide and low tide refer to the rise and fall, respectively of the water in the oceans. The natural heat from the interior of earth can usefully be converted into energy is known as geothermal energy.

4.11. Terminal questions

Q.1. What do you thing about energy and its utility? Discuss briefly.

Q.2. **Answer:---**

Q.3. What are the energy resources? Discuss about different sources of energy resources of India.

Answer:---

Q.4. Discuss the different types of energy resources used in India.

Answer:---

Q.5. Discuss the conventional and non conventional energy resources used in India.

Answer:---

Q.6. Discussed about the energy tools and techniques of energy conservation.

Answer:---

4.12. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non conventional Energy Resources, D.S. Chauhan, New Age International
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey, "Renewable Energy Power for a Sustainable Future, Boyle, Oxford University Press.
5. Introduction to Energy and Climate , Developing a Sustainable Environment, Julie Kerr, Taylor & Francis eBooks

Unit-5: Energy Flow Model in Ecosystem

Contents

5.1. Introduction

The energy flow model is a conceptual framework used to understand and analyze the movement of energy through different components of a system or ecosystem. It provides a way to study how energy enters, flows through, and exits a particular system, such as an ecosystem, a food chain, or even a human-made energy system. The energy flow model is based on the fundamental principle of energy conservation, which states that energy cannot be created or destroyed; it can only be transferred or transformed from one form to another. In the context of the energy flow model, energy is typically measured in terms of its flow rate or quantity passing through each component of the system. The energy flow model is based on the fundamental principle of energy conservation, which states that energy cannot be created or destroyed; it can only be transferred or transformed from one form to another. In the context of the energy flow model, energy is typically measured in terms of its flow rate or quantity passing through each component of the system. The energy flow model helps quantify the transfer and transformation of energy at each trophic level, accounting for energy loss through metabolic processes, heat dissipation, and waste production. It allows scientists to study the efficiency of energy transfer between different organisms within an ecosystem and to analyze the consequences of disruptions or changes in energy flow on the overall functioning of the system. The energy flow model provides a valuable framework for studying and analyzing the movement of energy within natural and human-made systems. It helps us to understand the complex interplay between energy inputs, transformations, and outputs, and informs decisions and actions aimed at improving energy efficiency and sustainability. Energy flow is the flow of energy through living things within an ecosystem. All living organisms can be organized into producers and consumers, and those producers and consumers can further be organized into a food chain. Each of the levels within the food chain is a trophic level.

Objectives

- To discuss energy flow models and its application in ecosystem
- To discuss basic energy flow model and its characteristics
- To discuss the terrestrial and aquatic energy flow models
- To discuss Lindeman's trophic dynamic aspect and its applications

5.2. Basic energy flow model

The basic energy flow model illustrates the movement of energy through a simple system, such as an ecosystem or a food chain. It outlines the flow of energy from its source to different components within the system

Energy Source: The energy flow model starts with an external source of energy, often the sun in natural ecosystems. The sun provides radiant energy in the form of sunlight.

Producers: The energy from the sun is captured by autotrophic organisms, such as plants or algae, through the process of photosynthesis. For example the Grasses in a grassland ecosystem convert sunlight, carbon dioxide (CO_2), and water (H_2O) into glucose ($C_6H_{12}O_6$) and oxygen (O_2) through photosynthesis. Thus it converts solar energy into chemical energy in the form of carbohydrates. The general chemical equation for photosynthesis is:

$$6CO_2 + 6H_2O + sunlight \rightarrow C_6H_{12}O_6 + 6O_2$$

Primary Consumers: Herbivores or primary consumers obtain energy by consuming producers. They derive their energy from the carbohydrates and other organic compounds produced by plants. It consumes plant material, such as leaves, fruits, or seeds, to obtain energy. They extract the chemical energy stored in the organic compounds produced by primary producers. For example: A rabbit feeding on grass obtains energy from the stored glucose in the plant material.

Secondary Consumers: Secondary consumers are carnivores or omnivores that feed on primary consumers.They obtain energy by consuming the flesh of other organisms. For example: A snake preying on the rabbit consumes the stored energy in the rabbit's body, utilizing the organic compounds and converting them into its own energy.

Tertiary Consumers: Tertiary consumers are predators that feed on secondary consumers. They acquire energy from consuming other carnivores or omnivores. A hawk preying on the snake acquires energy from the snake's body by consuming it is the example of tertiary consumer.

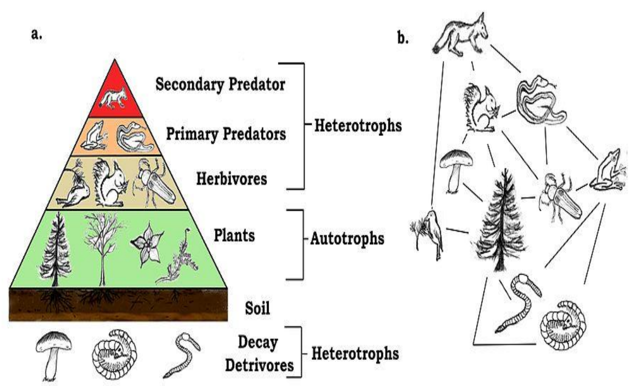

Fig.5.1: Producer and consumers

Decomposers: Decomposers break down organic matter, including dead organisms, feces, and plant litter. They release energy through the process of decomposition, returning nutrients to the ecosystem. Like Bacteria and fungi decompose the remains of dead plants and animals, breaking down complex organic compounds into simpler molecules and releasing energy in the process.

Energy Loss: At each trophic level, there is a loss of energy due to metabolic processes, heat dissipation, and waste production. This energy loss occurs during digestion, respiration, and other metabolic activities.

Energy Flow and Cycling: Energy flows through the system, with energy being transferred from one trophic level to another. Some of the energy is stored and used for growth and reproduction, while the rest is lost as heat. The energy that is not utilized by organisms eventually returns to the environment and becomes available for new energy cycles.

It is important to note that the basic energy flow model is a simplified representation of energy transfer within a system where transfer of energy from one trophic level to another within an ecosystem, with energy being passed along the food chain. It also highlights the importance of decomposers in recycling nutrients and energy back into the ecosystem. In reality, ecosystems and food chains are more complex, with multiple interconnected pathways and feedback loops. Nonetheless, the basic energy flow model provides a useful starting point for understanding the fundamental principles of energy transfer and the interconnectedness of organisms within a system.

How Organisms Acquire Energy in a Food Web

All living things require energy in one form or another since energy is required by most, complex, metabolic pathways (often in the form of ATP); life itself is an energy-driven process. Living organisms would not be able to assemble macromolecules (proteins, lipids, nucleic acids, and complex carbohydrates) from their monomeric subunits without a constant energy input. It is important to understand how organisms acquire energy and how that energy is passed from one organism to another through food webs and their constituent food chains. Food webs illustrate how energy flows directionally through ecosystems, including how efficiently organisms acquire it, use it, and how much remains for use by other organisms of the food web. Energy is acquired by living things in three ways: photosynthesis, chemosynthesis, and the consumption and digestion of other living or previously-living organisms by heterotrophs.

Photosynthetic and chemosynthetic organisms are grouped into a category known as autotrophs: organisms capable of synthesizing their own food (more specifically, capable of using inorganic carbon as a carbon source). Photosynthetic autotrophs (photoautotrophs) use sunlight as an energy source, whereas chemosynthetic autotrophs (chemoautotrophs) use inorganic molecules as an energy source. Autotrophs act as producers and are critical for all ecosystems. Without these organisms, energy would not be available to other living organisms and life itself would not be possible. Photoautotrophs, such as plants, algae, and photosynthetic bacteria, serve as the energy source for a majority of the world's ecosystems. These ecosystems are often described by grazing food webs. Photoautotrophs harness the solar energy of the sun by converting it to chemical energy in the form of ATP (and NADP). The energy stored in ATP is used to synthesize complex organic molecules, such as glucose.

Chemoautotrophs are primarily bacteria that are found in rare ecosystems where sunlight is not available, such as in those associated with dark caves or hydrothermal vents at the bottom of the ocean. Many chemoautotrophs in hydrothermal vents use hydrogen sulfide (H_2S), which is released from the vents, as a source of chemical energy. This allows chemoautotrophs to synthesize complex organic molecules, such as glucose, for their own energy and in turn supplies energy to the rest of the ecosystem.

Heterotrophs function as consumers in the food chain; they obtain energy in the form of organic carbon by eating autotrophs or other heterotrophs. They break down complex organic compounds produced by autotrophs into simpler compounds, releasing energy by oxidizing carbon and hydrogen atoms into carbon dioxide and water, respectively. Unlike autotrophs, heterotrophs are unable to synthesize their own food. If they cannot eat other organisms, they will die.

Productivity within Trophic Levels

Productivity, measured by gross and net primary productivity, is defined as the amount of energy that is incorporated into a biomass.

Productivity within an ecosystem can be defined as the percentage of energy entering the ecosystem incorporated into biomass in a particular trophic level. Biomass is the total mass in a unit area (at the time of measurement) of living or previously-living organisms within a trophic level. Ecosystems have characteristic amounts of biomass at each trophic level.

The productivity of the primary producers is especially important in any ecosystem because these organisms bring energy to other living organisms by photoautotrophy or chemoautotrophy. **Photoautotrophy** is the process by which an organism (such as a green plant) synthesizes its own food from inorganic material using light as a source of energy; **chemoautotrophy**, on the other hand, is the process by which simple organisms (such as bacteria or archaea) derive energy from chemical processes rather than photosynthesis. **The rate at which photosynthetic primary producers incorporate energy from the sun is called gross primary productivity (G.P.P.)**.

Because all organisms need to use some of this energy for their own functions (such as respiration and resulting metabolic heat loss), scientists often refer to the **net primary productivity (N.P.P.)** of an ecosystem. Net primary productivity is the energy that remains in the primary producers after accounting for the organisms' respiration and heat loss. The net productivity is then available to the primary consumers at the next trophic level.

Transfer of Energy between Trophic Levels

Energy is lost as it is transferred between trophic levels; the efficiency of this energy transfer is measured by **TLTE** and **NPE.**

Ecological efficiency: the transfer of energy between trophic levels

Large amounts of energy are lost from the ecosystem between one trophic level and the next level as energy flows, from the primary producers through the various trophic levels of consumers and decomposers. The main reason for this loss is the second law of thermodynamics, which states that whenever energy is converted from one form to another, there is a tendency toward disorder (entropy) in the system. In biologic systems, this means a great deal of energy is lost as metabolic heat when the organisms from one trophic level are consumed by the next level. The measurement of energy transfer efficiency between two successive trophic levels is termed the **trophic level transfer efficiency** (TLTE) and is defined by the formula:

$$\text{TLTE} = \frac{\text{Energy transferred to next level}}{\text{Energy received during transfer}} \times 100$$

The 10% Law of Energy Flow

In general, only about 10% of energy is transferred from one trophic level to the next, and this number can vary from 5-20% depending on the ecosystem. This means that 90% of obtained energy is lost at each trophic level, greatly affecting the maximum number of possible levels in the ecosystem. For example, if an ecosystem received 600,000 Kcal of solar energy from the sun, primary producers would pass on only 60,000 Kcal to herbivores, which would pass only 6,000 Kcal to secondary consumers, 600 Kcal to tertiary consumers and 60 Kcal to quaternary consumers at the top of the food chain. An apex predator like a wolf—needing an average of 2000 Kcal per day—would need to consume a very high quantity of secondary or tertiary consumers to meet its calorie quota per day (**Fig**.2.7).

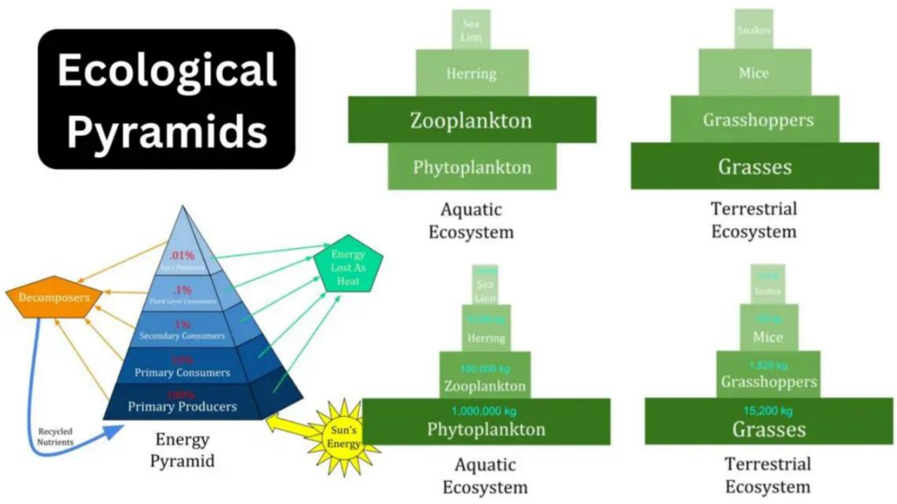

Fig.2.7 : Ecological Pyramid

Net production efficiency

Another main parameter that is important in characterizing energy flow within an ecosystem is the net production efficiency. Net production efficiency (NPE) allows ecologists to quantify how efficiently organisms of a particular trophic level incorporate the energy they receive into biomass. It is calculated using the following formula:

$$\text{N.P.E.} = \frac{\text{Net primary productivity}}{\text{G.P.P.}} \times 100$$

Net consumer productivity is the energy content available to the organisms of the next trophic level. Assimilation is the biomass (energy content generated per unit area) of the present trophic level after accounting for the energy lost due to incomplete ingestion of food, energy used for respiration, and energy lost as waste. Incomplete ingestion refers to the fact that some consumers eat only a part of their food. For example, when a lion kills an antelope, it will eat everything except the hide and bones. The lion is missing the energy-rich bone marrow inside the bone, so the lion does not make use of all the calories its prey could provide.

Thus, NPE measures how efficiently each trophic level uses and incorporates the energy from its food into biomass to fuel the next trophic level. In general, cold-blooded animals (ectotherms), such as invertebrates, fish, amphibians, and reptiles, use less of the energy they obtain for respiration and heat than warm-blooded animals (endotherms), such as birds and mammals. The extra heat generated in endotherms, although an advantage in terms of the activity of these organisms in colder environments is a major disadvantage in terms of NPE. Therefore, many endotherms have to eat more often than ectotherms to obtain the energy they need for survival. In general, NPE for ectotherms is an order of magnitude (10x) higher than for endotherms. For example, the NPE for a caterpillar eating leaves has been measured at 18 percent, whereas the NPE for a squirrel eating acorns may be as low as 1.6 percent.

The inefficiency of energy use by warm-blooded animals has broad implications for the world's food supply. It is widely accepted that the meat industry uses large amounts of crops to feed livestock. Because the NPE is low, much of the energy from animal feed is lost. For example, it costs about $0.01 to produce 1000 dietary calories (kcal) of corn or soybeans, but approximately $0.19 to produce a similar number of calories growing cattle for beef consumption. The same energy content of milk from cattle is also costly, at approximately $0.16 per 1000 kcal. Much of this difference is due to the low NPE of cattle. Thus, there has been a growing movement worldwide to promote the consumption of non-meat and non-dairy foods so that less energy is wasted feeding animals for the meat industry.

5.3. Single flow energy model in ecosystem

In the context of an ecosystem, a single flow energy model refers to a simplified representation of energy flow within a specific trophic level or pathway. It focuses on tracking the energy transfer from primary producers (plants or algae) to primary consumers (herbivores) or from primary consumers to secondary consumers. The single or linear channel energy flow model is one of the first published models pioneered by H. T. Odum in 1956. As can be seen in Fig. 5.2, this model depicts a community boundary and, in addition to light and heat flows, it also includes import, export and storage of organic matter.

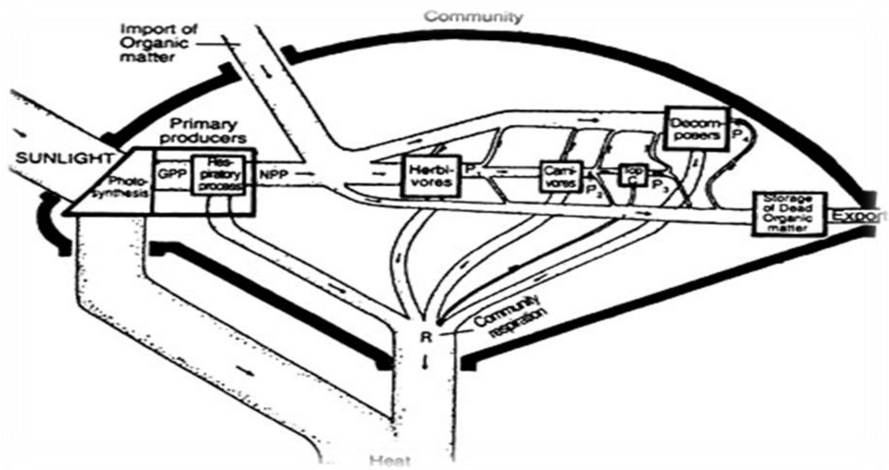

Fig.5.2: Single or linear channel energy flow diagram (P_1, P_2, P_3 and P_4 secondary production of the indicated level (H. T. Odum, 1956)

Decomposer organisms are placed in a separate box as a means of partially separating the grazing and detritus food chains. Decomposers are actually a mixed group in terms of energy levels and their importance in this energy flow model is overlooked. This model will suffice as long as only the imports and exports are considered.

Characteristics of single flow energy model

- The single flow energy model simplifies the complex energy dynamics within an ecosystem by focusing on a specific trophic level or pathway.
- It provides a basic understanding of energy transfer from one group of organisms to another within a simplified context.
- In this model, energy flows in a unidirectional manner from the primary producers (plants or algae) to the consumers (herbivores) within the trophic level being considered.
- It illustrates the transfer of energy from one set of organisms to another as they consume and utilize the energy stored in organic matter.
- The model incorporates the concept of trophic efficiency, which represents the efficiency with which energy is transferred from one trophic level to the next.
- Trophic efficiency accounts for energy losses due to metabolic processes, growth, and heat production.
- It is typically estimated to be around 10% in ecological systems, meaning that approximately 10% of energy is transferred from one trophic level to the next.

- The single flow energy model allows for the quantification of energy transfer within the trophic level being considered.
- It provides a numerical estimate of the amount of energy available to consumers based on the energy captured by primary producers and the trophic efficiency.
- The model has a limited scope as it focuses on a specific trophic level or pathway and does not account for the complexities of multiple trophic interactions, feedback loops, or energy flows between different trophic levels.
- The single flow energy model does not consider the role of decomposers, detritivores, and the breakdown of organic matter.
- It simplifies the energy flow by excluding the energy recycling processes associated with the decomposition of dead organisms and organic waste.

Limitation of single flow energy

- The single flow energy model provides a simplified representation of energy flow within a specific trophic level.
- It overlooks the intricate complexities of interactions between different trophic levels, feedback loops, and the interconnectedness of energy flows in a diverse ecosystem.
- The model does not account for the multiple trophic interactions that occur in ecosystems.
- The single flow energy model typically disregards spatial and temporal variations in energy flow.
- Energy dynamics can differ across different habitats within an ecosystem and can change over time due to seasonal variations, migrations, or disturbances.
- The model assumes a constant trophic efficiency, usually estimated at around 10%, which represents the fraction of energy transferred from one trophic level to the next.
- The single flow energy model does not consider the role of decomposers, detritivores, and the breakdown of organic matter.
  - The single flow energy model is not suitable for complex ecosystems with multiple trophic levels, diverse species interactions, and intricate food webs.
  - It cannot fully capture the energy dynamics and trophic interactions that occur in such ecosystems.

5.4. Y-Shaped Energy Flow Model:

In the Y-shaped energy flow model, energy from a single source is divided into two or more pathways, resembling the shape of the letter "Y." Each pathway represents a different route or destination for energy flow (Fig.5.3). The model recognizes that energy can be distributed and utilized in various ways within an ecosystem or energy system. There is no specific equation associated with the Y-shaped energy flow model. Instead, it represents the concept of energy divergence and the allocation of energy across multiple pathways or destinations. The Y shaped energy model is more practical working model than the single channel model mainly because:

a) It relates to the basic stratified structure of ecosystem;
b) The direct consumption of living plants and dead organic matter are usually separated in both time and space; and
c) The macro consumers and micro consumers differ greatly in size-metabolism relations and in the techniques required for studying them.

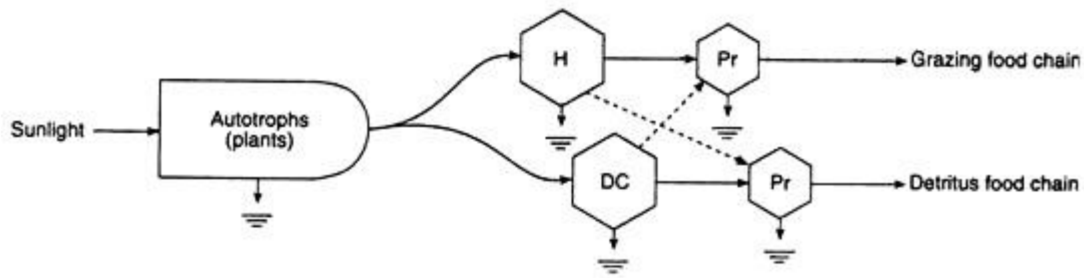

Fig.5.3: Y-shaped energy flow model, it shows linkage between grazing and detritus food chain where H= herbivores, DC= detritus consumer, Pr = predators

In an ecosystem, primary producers (plants or algae) capture solar energy through photosynthesis. This energy is then divided into different pathways. One pathway represents the energy flow through herbivores (primary consumers) that consume plants directly. Another pathway represents the energy flow through decomposers (detritivores) that break down organic matter and release energy for microbial processes. These pathways diverge from the primary producers, forming a Y-shaped energy flow model.

Characteristics of Y shaped energy flow model

- Energy from a single source is divided into multiple pathways or destinations.

- The model recognizes that energy can flow through different routes or channels within an ecosystem or energy system.
- Energy is distributed and utilized in various ways, allowing for different allocations across the pathways.
- The model visually resembles the shape of the letter "Y," symbolizing the branching or divergence of energy flow.
- It accounts for the flexibility of energy distribution and utilization, accommodating varying needs and demands within the system.
- The model acknowledges that energy flow within the system can change over time due to shifts in demand, availability, or other factors.
- The Y-shaped energy flow model highlights the diverse pathways and destinations that energy can take within a system, reflecting the complexity of energy distribution.

Limitation of y shaped energy flow model

1 The Y-shaped energy flow model simplifies the complex and interconnected nature of energy flow within ecosystems or energy systems. It represents energy distribution as a dichotomy, disregarding the potential for multiple or more intricate pathways.

2 The model does not provide a quantitative measurement or equation to quantify the energy flow in each pathway. It merely illustrates the concept of divergence and allocation without explicitly accounting for the amount or proportion of energy in each pathway.

3 The Y-shaped energy flow model typically represents energy flow at a specific point in time and does not capture the dynamics and changes that may occur over time. It does not consider temporal variations or the potential for energy redistribution in response to shifts in demand or availability.

4 The model focuses primarily on the distribution and allocation of energy, overlooking other important factors such as nutrient cycling, material flows, or ecological interactions. It provides a narrow perspective on energy dynamics within a system.

5 The model does not account for feedback loops between pathways or the potential for energy to be recycled or re-enter a different pathway. It disregards the potential for energy flow to be interconnected or influenced by interactions between different parts of the system.

5.5. Universal Model energy flow model

The universal model is applicable to any living component, which may be plant, animal, microorganism, individual, population or trophic group.

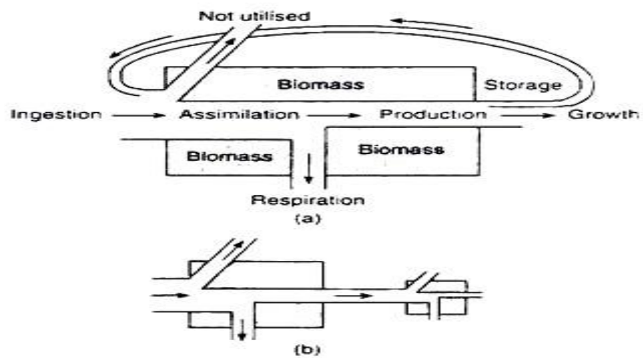

Fig.5.4: Universal model of energy flow a) Energy flow in one trophic level, b) A link between trophic levels in food chain

The shaded box (Fig.5.4) represents the living, standing crop biomass (generally measured as some kind of weight, such as dry weight, wet weight etc.) of the component which should be expressed in calories, so that its relation with rates of energy flow can be established. The total energy input or intake or ingestion varies. For strict autotrophs, it is light, while, for strict heterotrophs, it is organic food. A key feature of the model is the separation of assimilated energy (A) into the production (P) and respiration (R) components. R is the energy that is lost as heat (maintenance energy) and P is the portion transformed to new or different organic matter and is the part that is available to the next trophic level.

5.6. Energy flow models in aquatic ecosystems

Energy flow models in aquatic ecosystems follow similar principles as those in terrestrial ecosystems but take into account the specific dynamics and components of water-based environments.

Producers in streams are phytoplankton. These include algae, diatoms and certain types of bacteria. Green plants in the streams such as milfoil and elodea and floating plants such as water cress are also producers in the stream ecosystem much of the energy base of the stream, however, comes from the plant material outside the water along the stream banks. When this plant material falls into the stream it becomes organic debris called detritus and is used as an energy source for many of the aquatic organisms.

Primary consumers are also known as Herbivores. These are organisms that eat the producers. Some are microscopic and are called Zooplankton. These include animals like cope pods, ostracods, daphnia and rotifers. Most of the zooplankton are Filter Feeders and use special adaptations to bring water to themselves so they can filter out the organic material.

Secondary consumers (and higher order too) are the Carnivores. Some are predators and include insect larvae (dragonflies, dobsonflies, beetle larvae), and crayfish as well as surface insects (water striders) and fishing spiders. Scavengers are consumers that eat dead and decaying organic matter (the detritus and other organic matter).

Scavengers in the aquatic ecosystem include the aquatic worms and leaches, sowugs, scuds, crayfish, turtles and some fishes. Parasites are also found in the aquatic ecosystem, most notably the leeches. These segmented worms dine on the body fluids of other animals and are either blood suckers of various vertebrates or actual predators of small invertebrates. The number and types of producers, consumer and decomposer differ in various ecosystem resulting thatflow of energy also differs.

- **Marine Food Chain:** In a marine ecosystem, the energy flow starts with primary producers, such as phytoplankton or seaweed, which use sunlight and nutrients to produce organic matter through photosynthesis. These primary producers serve as the energy source for herbivorous organisms, such as zooplankton or small fish, which consume the primary producers. The energy then transfers to secondary consumers, such as larger fish or marine mammals, which feed on the herbivores. Tertiary consumers, such as apex predators like sharks or killer whales, consume the secondary consumers. Decomposers, such as bacteria and fungi, break down dead organisms, releasing energy back into the ecosystem.
- **Estuarine Food Web:** Estuaries are dynamic ecosystems where freshwater meets the ocean. The energy flow in estuarine systems involves a complex web of interactions among various organisms. Primary producers, such as algae or seagrass, convert sunlight and nutrients into organic matter. Herbivorous organisms, such as small invertebrates or fish, feed on the primary producers. The energy is then transferred to secondary consumers, which may include larger fish, birds, or marine mammals. Estuaries also support detritus-based food

webs, where decomposers play a significant role in breaking down organic matter and releasing energy.

- **Deep-Sea Food Web:** In the deep-sea ecosystem, where sunlight does not penetrate, the energy flow relies on alternative energy sources. The primary producers in this ecosystem are chemosynthetic bacteria or archaea, which use chemical energy from hydrothermal vents or methane seeps to produce organic matter. These bacteria form the basis of the food web. Organisms such as tube worms, mussels, or clams consume the chemosynthetic bacteria. Predatory organisms, including deep-sea fish or cephalopods, feed on these primary consumers. Decomposers break down dead organisms and recycle the energy within the deep-sea ecosystem.
- **Coral Reef Food Web:** Coral reef ecosystems are highly diverse and productive. The energy flow in coral reefs starts with the symbiotic relationship between corals and algae. Corals provide shelter for photosynthetic algae, known as zooxanthellae, which provide the corals with nutrients through photosynthesis. The energy is then transferred to herbivorous fish, such as parrotfish or surgeonfish, which graze on the algae. Secondary and tertiary consumers, including carnivorous fish or marine turtles, feed on the herbivores. Decomposers play a role in recycling nutrients and energy within the reef ecosystem.
- They demonstrate the interconnectedness of different organisms and the various pathways through which energy is transferred and cycled within water-based environments.

5.7.Energy flow model in territorial ecosystem

In a terrestrial ecosystem, particularly in a territorial ecosystem, the energy flow model involves the movement of energy through different trophic levels and the interactions among organisms within a defined area.

Producers: The energy flow starts with primary producers, such as plants, trees, or other photosynthetic organisms. These autotrophic organisms capture solar energy and convert it into chemical energy through photosynthesis. They produce organic compounds, such as carbohydrates, which serve as a source of energy for other organisms.

Herbivores: Herbivores, also known as primary consumers, are organisms that feed directly on producers. They derive their energy by consuming plant matter. Examples include insects, small mammals, or grazing animals like deer or rabbits.

Carnivores: Carnivores are secondary consumers that obtain energy by consuming herbivores. They are predators that feed on other animals. Carnivores can be further divided into different levels based on their position in the food chain. For instance, primary carnivores consume herbivores, while secondary carnivores consume primary carnivores.

Tertiary Consumers: Tertiary consumers are at the top of the food chain and are typically apex predators. They feed on other carnivores and have fewer predators themselves. Examples of tertiary consumers include large predators like lions, tigers, or wolves.

Decomposers: Decomposers, such as bacteria, fungi, and detritivores, play a crucial role in the energy flow model by breaking down dead organic matter and recycling nutrients. They obtain energy by decomposing dead plants, animals, and waste materials, releasing nutrients back into the ecosystem.

Energy Loss and Cycling: At each trophic level, there is a loss of energy due to metabolic processes, heat production, and waste. Only a portion of the energy is transferred from one trophic level to the next, with the rest being lost as heat or unavailable for consumption. Energy that is not used by organisms is eventually returned to the environment through waste and decomposition processes, becoming available for new energy cycles.

It's important to note that territorial ecosystems encompass a specific area with distinct boundaries, and the energy flow within these ecosystems may be influenced by factors such as resource availability, competition, and territorial interactions among organisms. The energy flow model helps to understand the transfer of energy and the interdependencies among different organisms within a territorial ecosystem, providing insights into its functioning and stability.

5.8. Compression of energy flow in different ecosystem

The compression of energy flow refers to the reduction or restriction of energy transfer between trophic levels in an ecosystem. It occurs when energy is lost or diverted at various stages, resulting in limited energy availability for higher trophic levels. However, much variation in the flow of energy is found within each type of ecosystem, creating a challenge in identifying variation between ecosystem types. In a general sense, the flow of energy is a function of primary productivity with temperature, water availability, and light availability. For example, among aquatic ecosystems, higher rates of production are usually found in large rivers and shallow lakes than in deep lakes and clear headwater streams. Among terrestrial ecosystems, marshes, swamps, and tropical rainforests have the highest primary production rates, whereas tundra and alpine ecosystems have the lowest. The relationships between primary production and environmental conditions have helped account for variation within ecosystem types, allowing ecologists to demonstrate that energy flows more efficiently through aquatic ecosystems than terrestrial ecosystems due to the various bottom-up and top-down controls in play.

Bottom-up

The strength of bottom-up controls on energy flow is determined by the nutritional quality, size, and growth rates of primary producers in an ecosystem. Photosynthetic material is typically rich in nitrogen (N) and phosphorus (P) and supplements the high herbivore demand for N and P across all ecosystems. Aquatic primary production is dominated by small, single-celled phytoplankton that are mostly composed of photosynthetic material, providing an efficient source of these nutrients for herbivores. In contrast, multi-cellular terrestrial plants contain many large supporting cellulose structures of high carbon but low nutrient value. Because of this structural difference, aquatic primary producers have less biomass per photosynthetic tissue stored within the aquatic ecosystem than in the forests and grasslands of terrestrial ecosystems. This low biomass relative to photosynthetic material in aquatic ecosystems allows for a more efficient turnover rate compared to terrestrial ecosystems.

Top-down

Top-down mechanisms exert greater control on aquatic primary producers due to the roll of consumers within an aquatic food web. Among consumers, herbivores can mediate the impacts of trophic cascades by bridging the flow of energy from primary producers to predators in higher trophic levels. Across ecosystems, there is a consistent association between herbivore growth and producer nutritional quality. However, in aquatic ecosystems, primary producers are consumed by herbivores at a rate four times greater than in terrestrial ecosystems. Although this topic is highly debated. Researchers have attributed the distinction in herbivore control to several theories, including producer to consumer size ratios and herbivore selectivity

Modeling of top-down controls on primary producers suggests that the greatest control on the flow of energy occurs when the size ratio of consumer to primary producer is the highest. The size distribution of organisms found within a single trophic level in aquatic systems is much narrower than that of terrestrial systems. The energy flow in different ecosystem are mentioned as follows

Desert Ecosystem: Deserts are characterized by extreme aridity and limited plant growth. The energy flow in desert ecosystems is compressed due to the scarcity of primary producers. The lack of water and nutrients restricts plant growth, resulting in low biomass and limited energy available for herbivores. As a consequence, the number of herbivores and subsequent carnivores in the food chain is relatively low compared to other ecosystems.

Arctic Tundra Ecosystem: The Arctic tundra experiences harsh environmental conditions, including long winters and low temperatures. These conditions restrict plant growth and limit the availability of primary producers. Consequently, the energy flow in the Arctic tundra ecosystem is compressed. The short growing season and sparse vegetation result in reduced energy transfer to herbivores, leading to a limited number of consumers and predators in the ecosystem.

Tropical Rainforest Canopy: In tropical rainforests, a significant portion of energy flow is compressed within the upper canopy layers. The dense vegetation and complex vertical structure of the rainforest result in reduced light availability at the forest floor. As a result, the majority of primary production occurs in the upper canopy layers where sunlight is abundant. This leads to a compression of energy flow, as a significant amount of energy is captured and utilized by plants and other organisms in the upper canopy, limiting energy transfer to lower layers and reducing the availability of resources for organisms at lower trophic levels.

Deep-Sea Ecosystem: In the deep-sea ecosystem, where sunlight does not penetrate, the compression of energy flow occurs due to limited primary production. Deep-sea organisms rely on alternative energy sources, such as chemosynthesis or detritus-based food webs. However, these energy sources are generally limited compared to the energy available from photosynthesis in surface ecosystems. Consequently, the energy flow is compressed, and the number of organisms and trophic levels in the deep-sea ecosystem is relatively lower compared to shallow water ecosystems.

5.9. Lindeman tropic dynamic aspect

The Lindeman trophic dynamic aspect, also known as the Lindeman efficiency hypothesis or Lindeman's trophic pyramid, is a concept that describes the energy transfer and efficiency between trophic levels in an ecosystem. It provides insights into the flow of energy and the efficiency of energy transfer within a food chain or food web. Lindeman proposed that energy transfer between trophic levels is typically around 10% efficient. The Lindeman trophic dynamic aspect can be mathematically represented using the following equation:

Energy available to higher trophic level = Energy available to lower trophic level * Trophic efficiency.

The trophic efficiency refers to the efficiency with which energy is transferred from one trophic level to the next. It is commonly estimated to be around 10% but can vary depending on the ecosystem and specific interactions. The trophic efficiency takes into account factors such as energy loss through respiration, excretion, and incomplete digestion, as well as energy used for growth and reproduction.

Grassland Ecosystem: In a grassland ecosystem, primary producers, such as grasses, convert solar energy into chemical energy through photosynthesis. Herbivores, such as rabbits or zebras, consume the grasses to obtain energy. The trophic efficiency between the primary producers and herbivores is typically around 10%. This means that only around 10% of the energy stored in the grasses is transferred to the herbivores. Similarly, when carnivores, such as lions or cheetahs, consume the herbivores, the trophic efficiency is again around 10%.

Aquatic Food Chain: In an aquatic ecosystem, phytoplankton serves as primary producers, converting solar energy into chemical energy. Zooplankton, such as small crustaceans, feed on the phytoplankton. The trophic efficiency between phytoplankton and zooplankton is approximately 10%. When small fish consume the zooplankton, the trophic efficiency is once again around 10%. This efficiency continues to decrease as energy is transferred to higher trophic levels.

Forest Ecosystem: In a forest ecosystem, trees and other plants are the primary producers, capturing solar energy through photosynthesis. Herbivores, such as deer or insects, consume the plants. The trophic efficiency between primary producers and herbivores is estimated to be around 10%. When carnivores, like wolves or bears, feed on the herbivores, the trophic efficiency is again around 10%.

These examples demonstrate the general pattern of energy transfer efficiency between trophic levels as proposed by Lindeman. While the exact values may vary, the concept of the Lindeman trophic dynamic aspect provides a framework for understanding the overall efficiency of energy flow within ecosystems.

5.10.Lotka Voltera Model

The Lotka-Volterra model, also known as the predator-prey model, is a mathematical model that describes the dynamics of interactions between two species in an ecosystem: a predator and its prey. It was developed independently by Alfred J. Lotka and Vito Volterra in the early 20th century. The Lotka-Volterra model consists of a set of coupled differential equations that describe the population changes over time for both the predator and prey species. The model assumes certain simplifications and assumptions, including:

Prey Growth: The prey population grows exponentially in the absence of predators, assuming an unlimited food supply and other favorable conditions.

Predator-Prey Interaction: The predator population depends on the availability of prey as a food source. The rate of change of predator population is proportional to the product of prey and predator population sizes.

Population Interactions: The prey population decreases as a result of predation, while the predator population increases with successful predation on the prey.

Time Delays: The model assumes instant population responses to changes in predator-prey interactions without considering time lags in population dynamics.

The Lotka-Volterra model can be expressed using the following equations:

$dP/dt = \alpha P - \beta PV$

$dV/dt = \delta PV - \gamma V$

Where:

P: Prey population size

V: Predator population size

α: Prey growth rate (without predation)

β: Predation rate coefficient

δ: Conversion efficiency of prey to predators

γ: Mortality rate of predators

The model demonstrates how the interaction between predator and prey populations can lead to cyclic or oscillatory patterns of population abundance. When prey populations are abundant, predator populations increase due to increased food availability. As predator populations grow, they exert more predation pressure, leading to a decline in prey populations. As prey populations decline, predator populations are eventually affected by food scarcity and begin to decrease. This cycle repeats as predator and prey populations oscillate.

It's important to note that the Lotka-Volterra model is a simplified representation of predator-prey dynamics and does not capture all complexities of real ecosystems. Factors such as environmental variations, other predator or prey species, and spatial considerations are not accounted for in the basic model. Nonetheless, the model provides a useful framework for understanding the interactions and dynamics between predator and prey populations.

Let's consider an example of a predator-prey relationship between foxes (predators) and rabbits (prey) in a forest ecosystem:

Prey Growth Equation:

The prey (rabbits) population, P, grows exponentially in the absence of predation, assuming favorable conditions and unlimited resources. The equation $dP/dt = \alpha P$ represents the growth of the rabbit population.

Predation Equation:

The predator (foxes) population, V, depends on the availability of prey as a food source. The rate of change of predator population is proportional to the product of the prey and predator population sizes. The equation $dV/dt = \delta PV$ represents the population growth of foxes based on their predation on rabbits.

Now let's see how the equations work in the context of the example:

Prey Growth: Suppose the rabbit population experiences exponential growth with a growth rate $\alpha = 0.2$. This means that without predation pressure from foxes, the rabbit population would increase by 20% per unit of time.

Predation: The fox population, on the other hand, depends on the availability of rabbits as their food source. Suppose the predation rate coefficient β is 0.1, indicating that each fox captures and consumes 10% of the rabbit population per unit of time. The conversion efficiency δ is 0.3, meaning that 30% of the consumed rabbits are effectively converted into new fox individuals.

With these parameter values, the Lotka-Volterra equations can be used to simulate the population dynamics of rabbits and foxes over time. The model predicts cyclic fluctuations in the population sizes of both species; with peaks and a trough alternating as the predator-prey interaction unfolds.

It's important to note that real ecosystems are more complex than this simplified model, as they involve various factors such as environmental influences, additional predator or prey species, and spatial considerations. Nonetheless, the Lotka-Volterra model provides a fundamental framework for understanding predator-prey interactions and population dynamics in ecological systems.

5.11. Summary

The energy flow model in an ecosystem describes how energy is transferred and transformed among different organisms within a food chain or food web. The flow of energy in ecosystems is vitally important to the thriving of life on Earth. Nearly all of the energy in Earth's ecosystems originates within the Sun. Once this solar energy reaches Earth, it is distributed among ecosystems in an extremely complex manner. The energy flow model begins with sunlight, which serves as the primary source of energy for most ecosystems. Plants, algae, and some bacteria capture sunlight through photosynthesis, converting it into chemical energy in the form of organic compounds. Producers, such as plants and algae, utilize the energy from sunlight to produce organic matter through photosynthesis. This process is known as primary production and forms the base of the energy pyramid. Herbivores, also known as primary consumers, feed on producers, consuming the organic matter produced by plants and algae. They obtain energy by digesting and metabolizing the organic compounds in their food. Secondary consumers are carnivores that feed on herbivores, while tertiary consumers are carnivores that feed on other carnivores. These consumers obtain energy by consuming other organisms, transferring and assimilating the energy stored in the organic compounds of their prey. Decomposers, such as bacteria and fungi, break down dead organic matter, releasing energy through the process of decomposition. Detritivores, such as earthworms and scavengers, feed on decaying organic matter, further facilitating its decomposition and energy release. At each trophic level, energy is transferred from one organism to another, but a significant amount of energy is lost as heat during these transfers. As a result, the amount of available energy decreases as we move up the trophic levels, forming an energy pyramid. Understanding the energy flow model in an ecosystem helps us recognize the interconnectedness of organisms and their dependence on energy from the sun. It emphasizes the role of producers in capturing and converting solar energy into a usable form and highlights the importance of maintaining balanced food chains and webs for the overall health and sustainability of ecosystems.

5.12. Terminal questions

1. What is energy flow model in ecosystem? Write the universal energy flow models with examples.

Answer: ---

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2. Write the energy flow models in aquatic ecosystems and its characteristics.

Answer: ---

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3. Discuss the energy flow models terrestrial ecosystem with examples.

Answer: ---

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4. Write the comparison of energy flow in different ecosystems.

Answer: ---

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5. What is the Lindeman's trophic dynamic aspect? Discuss briefly.

Answer: --

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6. Explain Lotka Voltera Model in ecosystem.

Answer: --

5.13. Further suggested Readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011

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

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

4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey, "Renewable Energy Power for a Sustainable Future, Boyle, Oxford University Press.

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

Unit-6: Energy policy

Contents

6.1. Introduction

The energy policy of India is to increase the locally produced energy is India and reduce energy poverty with more focus on developing alternative sources of energy, particularly nuclear, solar and wind energy. Net energy import dependency of India was 40.9% in 2021-22. Given India growing energy demands and limited domestic oil and gas reserves, the country has ambitious plans to expand its renewal and most work out nuclear power programme. The energy policy of India is characterized by tradeoffs between four major drivers, A rapidly growing economy with a need for dependable and reliable supply of electricity, gas and petroleum products, increasing household income with a need for an affordable and adequate supply of electricity and clean cooking fuels limited domestic reserves of fossil fuels and the need to import coal and well and indoor urban and regional environment impacts necessitating the need fuel and cleaner technology

India's energy policy refers to the set of principles, goals, and strategies formulated by the Indian government to address the country's energy needs, ensure energy security, promote sustainable development, and mitigate the environmental impact of energy production and consumption. India is the world's third-largest consumer of energy, and with its growing economy and population, ensuring access to reliable and affordable energy sources is a key priority for the government. India aims to diversify its energy sources and reduce dependence on imports to ensure a stable and secure energy supply. The country has been working to enhance domestic production of conventional energy resources like coal, oil, and natural gas, while also focusing on increasing renewable energy generation. The government is committed to providing universal access to affordable and reliable energy services, particularly to the rural and underprivileged sections of society. Initiatives like the Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) aim to provide electricity connections to all households in the country. Improving energy efficiency across all sectors is a crucial aspect of India's energy policy. The government has implemented various programs and standards to promote energy-efficient technologies and practices in industries, buildings, and transportation, thereby reducing energy demand and carbon emissions. Recognizing the environmental and climate change challenges associated with conventional energy sources, India has made significant efforts to promote renewable energy generation. The government has set ambitious targets for renewable energy capacity, particularly in solar and wind power, and introduced supportive policies such as incentives, subsidies, and favorable regulatory frameworks. India emphasizes energy conservation and demand-side management as effective means to reduce energy consumption. Initiatives like the National Mission for Enhanced Energy Efficiency (NMEEE) focus on promoting energy conservation measures and demand-side management practices across different sectors. India acknowledges the importance of environmental sustainability in its energy policy. The government is committed to reducing greenhouse gas emissions and mitigating the environmental impact of energy production and consumption. It has ratified the Paris Agreement and is actively working towards achieving its commitments under the agreement. The Indian government has established various institutions, regulatory bodies, and programs such as the Ministry of Power, Ministry of New and Renewable Energy, Bureau of Energy Efficiency, and National Solar Mission, among others. These entities work collaboratively to develop and implement policies, set targets, provide incentives, and monitor the progress of India's energy sector. India's energy policy seeks to balance economic growth, energy security, and environmental sustainability by adopting a diversified energy mix, promoting renewable energy, enhancing energy efficiency, and ensuring equitable energy access for all.

Objectives

- To discuss history of Indian energy policy.
- To discuss political choices on energy policy.
- To discuss the domestic and international energy policy.
- To discuss bilateral ties of India with other country.

6.2. Political choice in energy policy global

Political choices in energy policy vary across countries, reflecting their unique circumstances, resources, priorities, and political ideologies. Here are a few examples of political choices in energy policy at the global level:

6.2.1. Germany's Energiewende:

Germany's energy policy, known as Energiewende (Energy Transition), is a prominent example of a political choice to shift away from nuclear power and fossil fuels towards renewable energy sources. The policy was driven by concerns over nuclear safety and climate change. Germany has set ambitious targets for renewable energy deployment, implemented feed-in tariffs and subsidies to incentivize renewable energy generation, and introduced energy efficiency measures. Germany's Energiewende, or energy transition, is guided by a comprehensive set of policies and initiatives aimed at transforming the country's energy system towards renewable energy sources and increased energy efficiency. These policies have been implemented at both the federal and state levels.

- **Renewable Energy Act (Erneuerbare-Energien-Gesetz or EEG):** The EEG is a central piece of legislation that provides a feed-in tariff system for renewable energy producers. It guarantees fixed, long-term payments for renewable energy fed into the grid, providing a stable investment framework. The EEG has been revised multiple times to adjust support levels and adapt to changing market conditions.
- **Energy Efficiency Measures:** Germany has implemented various policies to promote energy efficiency across sectors. This includes energy efficiency standards for buildings, incentives for energy-efficient renovations, and the promotion of energy-efficient appliances. The National Action Plan on Energy Efficiency provides a roadmap for improving energy efficiency and reducing energy consumption.
- **Grid Expansion and Integration:** As renewable energy capacity increases, ensuring the effective integration of intermittent sources like wind and solar into the grid becomes crucial. Germany has implemented policies to expand and upgrade the power grid, including the development of a decentralized and flexible grid infrastructure. This includes measures to facilitate the integration of renewable energy sources and the implementation of smart grid technologies.
- **Energy Research and Development:** Germany has committed significant resources to research and development (R&D) activities in the energy sector. Funding programs support the development of new technologies, such as advanced solar panels, energy storage systems, and grid optimization solutions. The aim is to foster innovation, improve energy efficiency, and reduce the costs of renewable energy technologies
- **Carbon Pricing:** Germany has implemented a carbon pricing mechanism to reduce greenhouse gas emissions and incentivize the transition to low-carbon technologies. The pricing mechanism, known as the European Union Emissions Trading System (EU ETS),

sets a cap on greenhouse gas emissions and requires companies to purchase emission allowances. This creates economic incentives for emissions reduction and supports the deployment of renewable energy sources.

- **Phasing Out Nuclear Power:** In the wake of the Fukushima nuclear disaster in 2011, Germany made a decision to phase out nuclear power plants. The policy aims to shut down all remaining nuclear power plants by the end of 2022 and replace their energy generation with renewable sources.

6.2.2. United States' Shale Gas Revolution:

In the United States, there has been a political choice to promote the development of domestic shale gas resources. This policy has led to a significant increase in natural gas production, driven by technological advancements in hydraulic fracturing (fracking).. The policies related to the shale gas revolution in the United States have been shaped by a combination of federal, state, and local regulations. The government has supported this choice through regulatory measures that streamline the permitting process for shale gas development and by advocating for energy independence and economic benefits.

- **Regulatory Framework:** The U.S. Environmental Protection Agency (EPA) has been responsible for developing and implementing regulations related to shale gas production. The EPA has issued rules to address environmental concerns associated with fracking, such as well construction, wastewater management, and air emissions. Additionally, states have their own regulations governing shale gas development, which can vary in stringency.
- **Federal Government Support:** The U.S. government has generally been supportive of the shale gas revolution due to its potential economic benefits, energy security implications, and the belief that natural gas is a cleaner-burning fossil fuel compared to coal. Federal agencies, such as the Department of Energy, have provided research funding and supported initiatives to promote shale gas development.
- **State-Level Policies:** States play a significant role in regulating shale gas production. Some states with substantial shale gas resources, such as Pennsylvania, Texas, and North Dakota, have implemented policies to encourage the industry's growth. These

policies include streamlining permitting processes, offering tax incentives, and investing in infrastructure development.

- ❖ **Environmental Concerns:** The shale gas revolution has raised concerns about environmental impacts, including water contamination, methane emissions, and land disturbance. Environmental advocacy groups have called for stricter regulations and greater oversight to address these issues. Some states and localities have enacted more stringent regulations or even imposed bans or moratoriums on fracking.
- ❖ **International Implications:** The shale gas revolution in the United States has had significant geopolitical and economic implications. The increased domestic natural gas production has reduced U.S. reliance on imported energy and contributed to lower energy prices. It has also led to discussions about the potential for exporting liquefied natural gas (LNG) to other countries.

6.2.3. France's Nuclear Dominance:

France has made a political choice to rely heavily on nuclear power for its electricity generation. The country's energy policy is characterized by a significant investment in nuclear energy infrastructure and research. Nuclear power provides a large share of France's electricity, and the government views it as a means to ensure energy security, reduce greenhouse gas emissions, and support technological innovation in the nuclear sector. It is supported by a comprehensive policy framework and specific initiatives.

- ❖ **Nuclear Power Generation:** France operates a significant number of nuclear power plants, making it one of the world's largest producers of nuclear energy. As of my knowledge cutoff in September 2021, France has 56 nuclear reactors in operation, spread across 18 nuclear power plants. These reactors contribute a substantial portion of the country's electricity generation.
- ❖ **Energy Transition Law:** France's Energy Transition Law, adopted in 2015, sets the country's long-term energy policy objectives. While the law aims to reduce the share of nuclear power in the energy mix, it acknowledges the need for a gradual and orderly transition. The law targets reducing the share of nuclear power in electricity production from around 70% to 50% by 2035, with a concurrent increase in the share of renewable energy sources.

- **Nuclear Safety Regulations**: France has strict regulations in place to ensure the safety and security of its nuclear power plants. The French Nuclear Safety Authority (Autorité de Sûreté Nucléaire, ASN) is responsible for regulating and overseeing the safety of nuclear installations. It conducts regular inspections, sets safety standards, and enforces compliance with safety requirements.
- **EDF's Role**: Électricité de France (EDF), a state-owned utility, plays a crucial role in France's nuclear power sector. EDF operates the majority of nuclear power plants in the country and is responsible for their maintenance, safety, and electricity production. EDF's operations are guided by government policies and regulations.
- **International Cooperation:** France actively participates in international collaborations related to nuclear energy. It is a member of the International Atomic Energy Agency (IAEA) and has bilateral agreements with several countries for cooperation in nuclear research, development, and safety.
- **Nuclear Waste Management:** France has implemented a comprehensive strategy for the management of nuclear waste. This includes the storage and disposal of radioactive waste in specialized facilities. The country operates a deep geological repository called the Centre de 'Enfouissement des Déchets Radioactifs (CEA), which is responsible for long-term disposal of high-level radioactive waste.

6.2.4. Denmark's Renewable Energy Leadership:

Denmark has pursued a political choice to become a global leader in renewable energy. The country has set ambitious targets for renewable energy production and has implemented supportive policies and financial incentives to encourage the development of wind power and other renewable sources. Denmark's energy policy is driven by the goal of achieving energy independence, reducing carbon emissions, and creating a sustainable and green economy. he country has implemented ambitious policies and initiatives to promote renewable energy generation and has achieved remarkable success in this area. The key policies and data related to Denmark's renewable energy leadership are as:

- **Renewable Energy Targets:** Denmark has set ambitious targets for renewable energy generation. The country aims to have 100% of its electricity consumption sourced from renewable energy by 2030. Furthermore, Denmark has set a goal to be entirely free of fossil fuels by 2050, including in the heating and transportation sectors.

- **Wind Power Generation:** Denmark has been a pioneer in wind energy and is a world leader in wind power capacity per capita. The country has a significant number of onshore and offshore wind farms. As of 2021, Denmark had a total installed wind power capacity of over 6.7 GW, which accounted for approximately 48% of its electricity consumption.
- **Feed-in Tariffs and Subsidies**: Denmark has implemented feed-in tariff systems and subsidies to incentivize renewable energy production. These policies provide guaranteed payments to renewable energy producers, creating a stable investment environment. They have played a crucial role in attracting private investments and driving the growth of wind power in Denmark.
- Energy Agreement 2018: In 2018, Denmark reached a broad political agreement called the Energy Agreement. The agreement outlines specific measures and targets to accelerate the country's transition to renewable energy. It includes provisions for increased wind power capacity, energy efficiency improvements, and investments in research and development for new renewable technologies.
- Energy Islands: Denmark has unveiled plans to develop energy islands, which will serve as hubs for large-scale offshore wind farms. These islands will act as renewable energy hubs, integrating wind power generation, energy storage, and interconnection infrastructure. The first energy island, known as "Bornholm Energy Island," is expected to be operational by 2030.
- Green Financing and Investments: Denmark has been at the forefront of green financing and sustainable investments. The country has established green investment funds and initiatives to support renewable energy projects and sustainable technologies. Additionally, Danish pension funds and institutional investors have actively allocated funds towards renewable energy and sustainable development globally.

6.2.5. Saudi Arabia's Diversification Efforts:

In recent years, Saudi Arabia has made political choices to diversify its energy mix and reduce dependence on oil exports. The government has launched the Saudi Vision 2030 plan, which aims to promote economic diversification and reduce the country's reliance on oil revenue. The plan includes the development of renewable energy projects, such as solar and wind, and investments in other sectors like tourism and technology. Saudi Arabia has been actively pursuing economic diversification efforts to reduce its dependence on oil revenues and foster long-term sustainable growth. These efforts are guided by a comprehensive policy framework and specific initiatives.

Vision 2030: Saudi Arabia's Vision 2030 is a strategic roadmap that outlines the country's long-term economic and social goals. It aims to transform the Saudi economy by diversifying revenue sources, reducing dependence on oil, and developing non-oil sectors. Vision 2030 focuses on sectors such as tourism, entertainment, manufacturing, logistics, and renewable energy.

- **National Transformation Program (NTP):** The NTP is an operational framework that supports the implementation of Vision 2030. It sets specific targets, milestones, and initiatives to achieve the diversification objectives. The program includes initiatives to attract foreign investment, promote entrepreneurship, develop key industries, enhance the business environment, and improve education and training.
- **Saudi Arabian General Investment Authority (SAGIA):** SAGIA plays a crucial role in attracting foreign direct investment (FDI) and supporting economic diversification. It has implemented various initiatives to streamline investment procedures, improve the business environment, and provide incentives for investors in non-oil sectors. SAGIA has targeted priority sectors such as tourism, entertainment, healthcare, information technology, and renewable energy.
- **Renewable Energy:** Saudi Arabia has prioritized the development of renewable energy sources as part of its diversification efforts. The country has set ambitious targets to increase the share of renewable energy in its energy mix. The Saudi government has launched several initiatives and programs, including competitive bidding processes, to attract investments in renewable energy projects such as solar and wind power.
- **Public Investment Fund (PIF):** The PIF is Saudi Arabia's sovereign wealth fund and has been actively involved in supporting economic diversification. It has undertaken major investment initiatives domestically and internationally, focusing on sectors aligned with the diversification strategy. The PIF has made substantial investments in technology companies, infrastructure projects, renewable energy, and entertainment ventures.

The political choices in energy policy can vary significantly, influenced by a country's specific circumstances, goals, and available resources. They highlight the diversity of approaches taken by different nations to address energy challenges, promote sustainability, and achieve their respective energy objectives.

6.3. Political choice in energy policy in India

In the Indian context, political choices in energy policy have evolved over time, reflecting the country's unique energy challenges, developmental needs, and environmental concerns.

India's energy policy has gone through various phases since its independence in 1947. Initially, the focus was on attaining energy self-sufficiency through domestic coal production and hydroelectric projects. However, with the 1973 oil crisis, India faced a severe energy shortage and embarked on a policy of diversification, including the development of nuclear power and exploration of oil and gas resources. In recent decades, there has been a growing emphasis on renewable energy, energy efficiency, and sustainable development.

In recent years, India has made significant political choices to promote renewable energy. The government launched the National Solar Mission in 2010, with the goal of achieving 100 GW of solar power capacity by 2022. This initiative has led to a rapid increase in solar installations and a decline in solar tariffs, making India one of the leading solar markets globally. Additionally, wind power has been a focus, with India becoming the fourth-largest wind power producer in the world.

The political choice to ensure energy access and rural electrification has been a priority for the Indian government. The Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) was launched in 2017 to provide electricity connections to all rural and urban households. This initiative aims to bridge the energy access gap and improve the quality of life for millions of people.

India's energy policy has historically relied heavily on coal due to its abundant reserves. However, recognizing the environmental impact of coal-based power generation, the government has introduced policies to promote cleaner coal technologies and gradually transition towards cleaner energy sources. This includes the promotion of supercritical and ultra-supercritical coal-fired power plants with lower emissions, as well as the introduction of policies encouraging the retirement of old and inefficient coal plants. The political choices made by the Indian government to address energy access, sustainability, and developmental goals. The choices range from promoting renewable energy and rural electrification to ensuring the viability of the power sector. These decisions reflect the complex energy landscape in India, where the government seeks to balance economic growth, energy security, and environmental concerns.

Case Study:

Ujwal DISCOM Assurance Yojana (UDAY) is a case study that demonstrates a political choice aimed at addressing the financial health of state electricity distribution companies (DISCOMs) in India. Launched in 2015, UDAY aimed to improve the operational and financial efficiency of DISCOMs through measures such as reducing aggregate technical and commercial losses, tariff reforms, and reducing the burden of DISCOM debt. The program aimed to ensure sustainable and reliable power supply, enhance energy access, and promote financial viability in the power sector.

6.4. Indian Domestic energy policy

Indian domestic energy policy encompasses a range of measures and initiatives implemented by the government to address the country's energy needs, promote energy security, enhance energy access, and encourage sustainable development. The examples of Indian domestic energy policy as follows:

6.4.1. National Solar Mission:

The National Solar Mission, launched in 2010, is a key policy initiative to promote solar energy in India. The mission aims to achieve 100 GW of solar power capacity by 2022 through various strategies such as providing financial incentives, setting up solar parks, encouraging rooftop solar installations, and promoting research and development in solar technologies. This policy has led to significant growth in solar power installations and a decline in solar tariffs. The solar energy as a key component of its renewable energy strategy to reduce greenhouse gas emissions and combat climate change. Thus India has implemented various policies and initiatives to accelerate solar deployment and has achieved significant progress in this area such as:

- **Solar Capacity Growth:** India has witnessed rapid growth in solar energy capacity in recent years. As of my knowledge cutoff in September 2021, India had a cumulative installed solar power capacity of over 40 gigawatts (GW). This includes both utility-scale solar projects and rooftop solar installations.

- **International Solar Alliance (ISA):** India co-founded the International Solar Alliance, a global alliance of countries focused on promoting solar energy deployment. The ISA aims to mobilize resources, share best practices, and facilitate the deployment of solar projects worldwide, particularly in solar-rich countries.
- **Solar Parks and Ultra Mega Solar Projects:** India has established solar parks and ultra mega solar projects to attract investment and streamline the development of large-scale solar power plants. These projects provide the necessary infrastructure, such as land and transmission facilities, to accelerate solar deployment. Examples include the Rewa Ultra Mega Solar Park in Madhya Pradesh and the Pavagada Solar Park in Karnataka.
- **Solar Rooftop Initiatives:** India has implemented programs to encourage the adoption of solar rooftop systems. These initiatives aim to harness solar energy potential in residential, commercial, and industrial buildings. The government offers subsidies, incentives, and net metering arrangements to promote solar rooftop installations. For instance, the Jawaharlal Nehru National Solar Mission supports rooftop solar projects through various schemes.
- **Solar Auctions and Tariffs:** India has adopted a competitive auction-based system for solar project allocation. These auctions help drive down solar tariffs, making solar power increasingly cost-competitive. The Solar Energy Corporation of India (SECI) and various state distribution companies conduct regular solar auctions to award projects to developers. These auctions have resulted in record-low solar tariffs, contributing to the growth of the sector.
- **Off-Grid Solar Solutions:** India has also focused on deploying off-grid solar solutions to provide electricity access to remote and rural areas. Initiatives like the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and the Saubhagya scheme aim to electrify off-grid households through the installation of solar home systems and mini-grids. These efforts reduce reliance on fossil fuel-based energy sources and contribute to emissions reduction.

6.4.2. National Wind Energy Mission:

The National Wind Energy Mission was launched in 2014 with the objective of enhancing wind energy capacity in India. The mission focuses on developing wind resources, creating a conducive policy environment, attracting investments, and promoting research and development in wind power technologies. It aims to achieve a wind power capacity of 60 GW by 2022. This policy has contributed to India becoming one of the largest wind power producers globally. The country has implemented various policies and initiatives to promote wind power development, leading to substantial growth in wind energy capacity. The key examples related to India's national wind energy mission are followings:

- **Wind Energy Capacity:** As of my knowledge cutoff in September 2021, India had a cumulative installed wind power capacity of over 40 gigawatts (GW), making it one of the largest wind energy markets in the world. This capacity includes both onshore and offshore wind power projects.
- **National Wind Energy Mission:** The National Wind Energy Mission was launched as part of the larger renewable energy strategy of the Indian government. The mission aims to achieve a total installed wind power capacity of 60 GW by 2022, with a further target of 140 GW by 2030. The mission encompasses policy support, capacity building, research and development, and investment facilitation.
- **Competitive Bidding:** India has shifted from a feed-in tariff system to competitive bidding for wind power project allocation. Under this mechanism, wind power projects are allocated through auctions, which have contributed to a significant reduction in wind power tariffs. This competitive process has attracted private investment and encouraged cost optimization in the sector.
- **Wind Resource Assessment:** The Indian government has conducted comprehensive wind resource assessment studies across various states to identify high-potential areas for wind power development. These studies provide critical data on wind speed, direction, and other factors that aid in selecting suitable locations for wind farms.
- **Policy and Regulatory Support:** The government has implemented supportive policies and regulations to encourage wind energy deployment. This includes providing fiscal incentives, allowing open access for wind power transmission, and streamlining the approval processes for wind projects. The Ministry of New and Renewable Energy (MNRE) plays a central role in formulating and implementing policies for wind power development.
- **Wind-Solar Hybrid Projects:** To optimize land utilization and grid integration, India has also promoted wind-solar hybrid projects. These projects combine wind and solar energy

generation at the same site, allowing for complementary power generation and increased capacity utilization. The government has provided specific policy support and financial incentives for such hybrid projects.

6.4.3. Ujwal DISCOM Assurance Yojana (UDAY):

The Ujwal DISCOM Assurance Yojana (UDAY) was an important initiative launched by the Government of India in November 2015 to address the financial distress and operational inefficiencies of power distribution companies (DISCOMs) in the country. The program aimed to improve the financial health of DISCOMs, reduce their debt burden, enhance operational efficiency, and ensure affordable and reliable power supply. The key features related to the UDAY program are such as:

- ❖ **Operational and Technical Improvements:** UDAY aimed to bring about operational and technical improvements in DISCOMs. It included measures to reduce transmission and distribution losses, improve metering and billing efficiency, and enhance power infrastructure. DISCOMs were required to implement measures to achieve prescribed targets for these parameters.
- ❖ **Tariff Reforms:** The program emphasized the need for tariff reforms to ensure a sustainable and viable power sector. DISCOMs were encouraged to revise electricity tariffs regularly, taking into account factors like cost of supply, aggregate technical and commercial (AT&C) losses, and operational efficiencies. Timely revision of tariffs aimed to bridge the revenue-cost gap and improve financial viability.
- ❖ **Renewable Energy Integration:** UDAY aimed to promote the integration of renewable energy sources into the power mix. It encouraged DISCOMs to meet their renewable purchase obligations (RPOs) and facilitate the integration of renewable energy projects into the grid.
- ❖ **Financial Restructuring:** UDAY focused on the financial restructuring of DISCOMs by taking over a significant portion of their debt. Under the program, states were encouraged to issue bonds to take over 75% of the DISCOMs' outstanding debt as of September 30, 2015. The remaining 25% of the debt was re-priced or issued as state-guaranteed DISCOM bonds.
- ❖ **Debt Servicing Assistance:** The UDAY program provided support to DISCOMs in servicing their restructured debt. States were expected to take over future losses of

DISCOMs and ensure a gradual reduction in aggregate technical and commercial losses.

6.4.4. Energy Conservation Building Code (ECBC):

The Energy Conservation Building Code (ECBC) is a set of norms and guidelines developed by the Bureau of Energy Efficiency (BEE), under the Ministry of Power, Government of India. The ECBC is designed to establish minimum energy efficiency standards for commercial buildings and promote energy conservation in the construction and operation of buildings. So the ECBC sets standards for energy performance, including lighting, HVAC (heating, ventilation, and air conditioning), building envelope, and renewable energy integration. It applies to commercial buildings with a connected load of 100 kW or more. The ECBC aims to reduce energy consumption and greenhouse gas emissions in the building sector. The key feature of Energy Conservation Building Code is such as

1. It applies to commercial buildings with a connected load of 100 kilowatts (kW) or more, or a contract demand of 120 kilovolt-amperes (kVA) or more.
2. It covers aspects related to building envelope design, lighting, heating, ventilation, air conditioning (HVAC), electrical systems, and renewable energy integration.
3. It sets energy performance requirements for various building components and systems.
4. It provides multiple compliance pathways for building designers and owners to meet the energy performance requirements.
5. It encourages the use of energy simulation software to evaluate the energy performance of building designs.
6. It also emphasizes the importance of building commissioning, which involves verifying and optimizing the performance of building systems to ensure they operate efficiently. Commissioning helps identify and address any issues that may impact energy efficiency during the construction and operational phases.
7. It requires buildings to obtain an ECBC compliance certificate, which signifies that the building meets the prescribed energy efficiency standards.
8. The ECBC aims to promote energy-efficient building design and operation, reduce energy consumption, and mitigate the environmental impact of buildings.

6.4.5. Pradhan Mantri Ujjwala Yojana (PMUY):

PMUY is a government initiative launched in 2016 to provide free LPG (liquefied petroleum gas) connections to households below the poverty line. The aim is to promote clean cooking fuels, improve indoor air quality, reduce health hazards associated with traditional cooking methods, and empower women. This policy has significantly increased LPG penetration in rural areas and improved access to clean cooking fuel.

These examples highlight some of the key domestic energy policies in India, focusing on renewable energy promotion, energy efficiency in buildings, electricity sector reforms, and access to clean cooking fuels. The government continues to develop and implement policies to address the energy challenges of the country, reduce dependence on fossil fuels, and transition to a more sustainable energy future. Some key features and objectives of the Pradhan Mantri Ujjwala Yojana:

- **Eligibility:** The scheme targets women from below-poverty-line households who do not have access to clean cooking fuel. The eligibility is determined based on the Socio-Economic Caste Census (SECC) data.
- **Free LPG Connections:** Under PMUY, eligible households receive a financial assistance of Rs. 1,600 (as of my knowledge cutoff in September 2021) to cover the cost of a new LPG connection, which includes a gas cylinder, regulator, and hose. The initial installation charges are waived off, ensuring that the beneficiary receives the connection without any upfront payment.
- **Identification and Enrollment:** The identification and enrollment of eligible beneficiaries are carried out through a comprehensive and transparent process, often in collaboration with state governments, local authorities, and public sector oil marketing companies (OMCs). Beneficiaries are identified through the SECC database, and their applications are verified and processed by the respective OMCs.
- **Public Awareness and Outreach:** PMUY includes a significant emphasis on creating awareness about the health and environmental benefits of using clean cooking fuel. Public awareness campaigns and outreach programs are conducted to educate beneficiaries and promote behavior change towards adopting LPG as a cooking fuel.
- **Support for Ongoing LPG Refills:** PMUY provides options for beneficiaries to avail interest-free loan facilities for the purchase of subsequent LPG refills. This ensures continued access to clean cooking fuel beyond the initial free connection.

- **Monitoring and Evaluation:** The implementation of PMUY involves regular monitoring and evaluation to ensure effective delivery and assess the impact of the scheme. Monitoring mechanisms are put in place to track the number of beneficiaries, LPG connections provided, and refills availed, and overall program performance.

The Pradhan Mantri Ujjwala Yojana has had a significant impact since its launch, reaching millions of households and improving access to clean cooking fuel. It has contributed to reducing the reliance on traditional cooking fuels like biomass and kerosene, thereby reducing indoor air pollution and associated health hazards. The scheme has also empowered women by providing them with a safer and cleaner cooking environment, allowing them to focus on other aspects of their lives.

6.5. International energy policy

International energy policies are formulated by countries and international organizations to address global energy challenges, promote cooperation, and ensure sustainable and secure energy systems. In addition, the International energy policies also address climate change, sustainable development, renewable energy promotion, energy access, and energy cooperation. They demonstrate the global commitment and collaborative efforts to tackle energy challenges and transition to more sustainable and resilient energy systems. The some examples of international energy policies:

6.5.1. Paris Agreement:

The Paris Agreement, adopted in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), is an international treaty that sets the framework for global efforts to combat climate change. The agreement aims to limit global temperature rise to well below 2 degrees Celsius above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 degrees Celsius. It calls for countries to develop and communicate their nationally determined contributions (NDCs) outlining their efforts to reduce greenhouse gas emissions and enhance climate resilience.

6.5.2. Sustainable Development Goals (SDGs):

The Sustainable Development Goals, adopted by the United Nations in 2015, encompass a set of 17 goals to address social, economic, and environmental challenges worldwide. Goal 7 focuses specifically on ensuring access to affordable, reliable, sustainable, and modern energy for all. The SDGs emphasize the importance of clean energy, energy efficiency, and universal energy access as crucial components of sustainable development.

6.5.3. International Renewable Energy Agency (IRENA):

IRENA is an intergovernmental organization dedicated to promoting the widespread adoption and sustainable use of renewable energy globally. It supports countries in their transition to a renewable energy future by providing technical assistance, policy advice, capacity building, and facilitating knowledge sharing and collaboration. IRENA's work contributes to the development and implementation of international energy policies that promote renewable energy deployment and integration.

6.5.4. International Energy Agency (IEA):

The IEA is an autonomous agency established under the framework of the Organisation for Economic Co-operation and Development (OECD). It works to promote energy security, economic growth, and environmental sustainability. The IEA conducts energy policy analysis, provides energy market insights, and offers recommendations to its member countries and other stakeholders. The agency also coordinates emergency response measures, promotes energy technology cooperation, and supports global efforts to address climate change.

6.5.5. Energy Charter Treaty (ECT):

The Energy Charter Treaty is an international agreement aimed at promoting energy cooperation and investment protection. It establishes a framework for the promotion and protection of energy-related investments, trade, transit, and energy efficiency. The treaty encourages dialogue and cooperation among its member countries to enhance energy security, foster market-oriented energy sectors, and support sustainable development.

6.6. Current challenge on international energy policy

One of the current challenges in international energy policy is the need to accelerate the global transition to clean and renewable energy sources to mitigate climate change, but it phase following challenges such as:

- **Decarbonization Targets:** Many countries have set ambitious decarbonization targets to reduce greenhouse gas emissions and limit global temperature rise. However, achieving these targets requires significant policy and investment efforts, as well as technological advancements, to shift away from fossil fuels and scale up renewable energy sources.
- **Energy Access and Equity**: Ensuring universal access to affordable and reliable energy remains a challenge, particularly in developing countries. Balancing energy access with sustainability objectives requires innovative approaches to provide clean energy solutions to underserved populations while reducing reliance on fossil fuels.
- **Energy Security and Resilience:** As countries transition to renewable energy sources, ensuring energy security and resilience becomes crucial. The intermittent nature of some renewables, such as solar and wind power, presents challenges for grid stability and reliability. Policy frameworks need to address issues related to grid integration, storage technologies, and system flexibility to maintain a reliable energy supply.
- **Investment and Financing:** The transition to clean energy requires substantial investments in renewable energy infrastructure, energy efficiency, and research and development. Mobilizing adequate investment and attracting private sector financing at scale remains a challenge, particularly for developing countries that may face financial constraints and investment risks.
- **Energy Governance and Cooperation:** Effective energy governance and international cooperation are essential for addressing global energy challenges. Cooperation is needed to share best practices, technologies, and knowledge, and to establish mechanisms for collective action on issues such as carbon pricing, energy trade, and energy efficiency standards.
- **Just Transition and Social Impacts:** Transitioning to a low-carbon economy can have social and economic implications, including potential job displacement in certain industries and regions. Ensuring a just transition that takes into account the social impact on affected communities, supports job creation in clean energy sectors, and provides support for reskilling and retraining is crucial.

Addressing these challenges requires strong political will, international collaboration, and effective policy frameworks that integrate climate goals, energy access, and sustainability objectives. Continued efforts to enhance international cooperation, technology transfer, capacity building, and financial support are necessary to accelerate the global transition to a sustainable energy future.

6.7. Diplomatic and bilateral ties for energy of India

India has engaged in diplomatic and bilateral ties with its neighboring countries in the context of energy cooperation. These relationships aim to enhance energy security, promote cross-border energy trade, and foster regional energy integration. The India's diplomatic and bilateral ties for energy with its neighbors are followings:

Bhutan:

India has a close energy partnership with Bhutan, primarily focused on hydropower. Under bilateral agreements, India supports the development of hydropower projects in Bhutan and imports surplus electricity generated from these projects. This cooperation benefits Bhutan economically and helps meet India's energy demand. The largest joint venture between the two countries is the Chukha and Tala hydropower projects, with a combined capacity of over 2,300 MW.

Nepal:

India and Nepal have long-standing energy cooperation, centered around hydropower development. India provides technical and financial assistance to Nepal for the development of its hydropower potential. Several projects, such as the Upper Tamakoshi and Arun-III hydropower projects have been implemented with Indian support. India also imports electricity from Nepal during surplus periods, contributing to Nepal's economic growth and energy export earnings.

Bangladesh:

India and Bangladesh have strengthened their energy ties in recent years. Cross-border transmission lines have been established to facilitate the import of electricity from Bangladesh to India and vice versa. The countries have signed agreements for the supply of natural gas from Bangladesh to India, which will help meet India's energy needs and enhance regional energy security. Joint ventures and investments in the energy sector are also being explored.

Sri Lanka:

India and Sri Lanka have collaborated in various areas of energy, including renewable energy, petroleum, and natural gas. India has supported Sri Lanka in developing renewable energy projects, such as solar and wind, through grants and concessional financing. The countries have also explored possibilities for cooperation in the oil and gas sector, including joint exploration and development of offshore hydrocarbon resources.

Myanmar:

India and Myanmar have pursued energy cooperation, particularly in the oil and gas sector. Indian companies have invested in exploration and production projects in Myanmar, contributing to both countries' energy security. Plans for the construction of oil and gas pipelines connecting India and Myanmar have been discussed to facilitate cross-border energy trade.

These examples highlight India's efforts to engage in energy cooperation with its neighboring countries, leveraging shared resources and promoting regional energy integration. Through diplomatic and bilateral ties, these collaborations aim to enhance energy access, improve energy security, and foster economic development in the region.

6.8. Bilateral ties for energy of India with other countries

The India has diverse bilateral ties with other countries in the energy sector. This ties encompass a wide range of energy resources, technologies, and trade, aiming to enhance energy security, including fossil fuels, renewable energy, energy trade, and technology collaboration and promote sustainable development. The bilateral ties of India's with other country are listed as:

United Arab Emirates (UAE):

India has a significant energy partnership with the UAE, which is one of India's major suppliers of crude oil and natural gas. Indian companies have invested in UAE's upstream and downstream oil and gas sectors. The countries have also explored opportunities for collaboration in renewable energy, including solar and wind power projects. Additionally, the UAE's sovereign wealth funds have made investments in India's renewable energy sector.

Russia:

India has a longstanding energy relationship with Russia, primarily in the area of oil and gas. Indian companies have invested in oil and gas exploration projects in Russia, and the countries have engaged in energy trade, including crude oil imports. Cooperation in the nuclear energy sector is also significant, with the construction of the Kudankulam Nuclear Power Plant in India, which involves Russian technology and expertise.

United States:

India and the United States have been expanding their energy cooperation in recent years. The countries have signed several agreements on energy security, clean energy, and energy technology collaboration. The United States has become a significant supplier of crude oil and liquefied natural gas (LNG) to India. Collaboration in areas such as renewable energy, energy efficiency, and smart grid technologies has also been emphasized.

Israel:

India and Israel have been developing energy cooperation, particularly in the areas of renewable energy and energy efficiency. The countries have signed agreements to promote collaboration in research, development, and deployment of clean technologies. Cooperation in the field of solar energy, including the establishment of solar parks, has been a focus.

6.9. Energy conservation policy in India

Energy conservation policies in India aim to promote sustainable development, reduce dependence on fossil fuels, and mitigate climate change. The government has implemented several measures to encourage energy efficiency and conservation across various sectors.

Energy Conservation Act, 2001: This act provides a legal framework for energy efficiency and conservation measures in India. It establishes the Bureau of Energy Efficiency (BEE) as the central agency responsible for promoting and implementing energy conservation activities.

- **National Mission on Enhanced Energy Efficiency (NMEEE):** The NMEEE includes several initiatives and programs to improve energy efficiency in industries, buildings, appliances, and municipal sectors. Some notable examples under this mission are:
    - **Perform, Achieve, and Trade (PAT) scheme:** This scheme mandates specific energy efficiency targets for energy-intensive industries and enables trading of energy-saving certificates.

- ❖ **Energy Conservation Building Code (ECBC):** The ECBC sets energy performance standards for commercial buildings and encourages the adoption of energy-efficient design and technologies.
- ❖ **Standards and Labelling Program:** This program sets energy efficiency standards for appliances and labeling requirements, enabling consumers to make informed choices.

- **National Solar Mission:** Launched in 2010, this mission aims to promote the use of solar energy in India. It includes the installation of utility-scale solar power plants, rooftop solar systems, and solar water heating systems. By increasing the share of solar power in the energy mix, India reduces reliance on fossil fuels and mitigates greenhouse gas emissions.
- **UJALA (Unnat Jyoti by Affordable LEDs for All):** This program promotes the adoption of energy-efficient LED bulbs to replace traditional incandescent bulbs. It has resulted in significant energy savings and reduced electricity bills for consumers.
- **Energy Efficiency Services Limited (EESL):** EESL is a public sector energy service company that implements energy efficiency projects across various sectors. It has implemented initiatives such as the Street Lighting National Program, which aims to replace conventional street lights with energy-efficient LED lights.
- **Smart Grid Mission:** The Smart Grid Mission focuses on modernizing the electricity grid infrastructure to improve efficiency, reliability, and grid management. It includes initiatives like advanced metering infrastructure, distribution automation, and demand response mechanisms.

These policies and initiatives have resulted in tangible energy savings and reduced greenhouse gas emissions in India. For example, under the PAT scheme, several industries have achieved significant energy savings. The UJALA program has distributed millions of LED bulbs, leading to substantial electricity savings. The solar power capacity in India has witnessed remarkable growth, contributing to renewable energy generation. These efforts demonstrate India's commitment to energy conservation and a sustainable future.

6.10. Energy conservation act 2001

The Energy Conservation Act, 2001 is an important legislation in India that focuses on promoting energy efficiency and conservation practices. It provides the foundation for several energy efficiency programs and initiatives in India. It has led to the implementation of schemes like the Perform, Achieve, and Trade (PAT) scheme, which sets specific energy efficiency targets for energy-intensive industries. It has also facilitated the adoption of energy labeling programs and the promotion of energy-efficient technologies across different sectors, contributing to energy savings and environmental sustainability. The key features and provisions of the Energy Conservation Act, 2001 are such as:

- **Objective:** The act aims to provide a legal framework for energy efficiency measures, promote energy conservation, and reduce energy consumption to ensure sustainable development.
- **Bureau of Energy Efficiency (BEE):** The act establishes the Bureau of Energy Efficiency as the central agency responsible for coordinating, promoting, and implementing energy conservation efforts across various sectors in India.
- **Energy Conservation Building Code (ECBC):** The act provides for the development and implementation of the Energy Conservation Building Code. ECBC sets minimum energy performance standards for commercial buildings and encourages the use of energy-efficient design, technologies, and materials.
- **Energy Audits and Conservation Measures:** The act mandates designated consumers, such as industries and establishments with high energy consumption, to conduct regular energy audits and implement energy conservation measures. These audits help identify energy-saving opportunities and facilitate the adoption of energy-efficient practices.
- **Energy Managers and Energy Auditors:** The act introduces the concept of energy managers and energy auditors. These professionals are certified by BEE and play a crucial role in energy management, conducting energy audits, and implementing energy conservation measures in designated establishments.
- **Standards and Labeling:** The act empowers the central government to prescribe energy performance standards and labeling requirements for appliances and equipment. This facilitates the identification of energy-efficient products and enables consumers to make informed choices.
- **Energy Conservation Fund:** The act establishes the Energy Conservation Fund to finance and support energy efficiency and conservation projects, research and development activities, and public awareness programs.

- **Penalties and Enforcement:** The act specifies penalties for non-compliance with energy conservation measures, including fines and imprisonment. It provides for the appointment of designated officials to enforce the provisions of the act.

6.11. Summary

India's energy policy focuses on energy security, renewable energy development, energy efficiency, and cleaner fossil fuels. The policy aims to achieve 450 GW of renewable energy capacity by 2030 and promotes electric mobility. It aims to increase domestic coal production, ensure LPG access for households, and diversify crude oil imports. The government promotes market reforms, private investments, and energy conservation measures. India is committed to climate change mitigation and sustainable development. Global energy policies are driven by the need for energy security, decarburization, and sustainable development. Renewable energy is gaining prominence, with countries adopting targets and policies to promote renewable energy deployment. The energy efficiency measures and energy conservation programs are being implemented worldwide. Both India and the world are focusing on diversifying energy sources, reducing reliance on fossil fuels, promoting renewable energy, improving energy efficiency, and addressing climate change challenges. The policies aim to ensure sustainable and secure energy systems for economic growth and environmental sustainability.

6.12. Terminal questions

Q.1. What is energy policy? Discuss energy conservation policy of Indian.

Answer: --

Q.2. Write the energy policies of Germany and its ties with India.

Answer: --

Q.3. Discuss about the Political choice in energy policy global on global level.

Answer: --

Q.4. What is the Domestic energy policy? Discuss the National Solar Mission in brief.

Answer: ---

Q.5. Write the current challenge on international energy policy.

Answer: ---

Q.6. Discuss the diplomatic and bilateral ties for energy of India.

Answer: ---

6.13. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.
5. Introduction to Energy and Climate , Developing a Sustainable Environment, Julie Kerr, Taylor & Francis eBooks

Block-3 **PGEVS-107N**

Rajarshi Tandon Open University, Prayagraj

Energy Resources and Climate Change

Block- 3

Climate Change and Global Warming

UNIT -7

Introduction to Climate Change

UNIT-8

Mansoon

UNIT-9

Green House Effects and Global Warming

Rajarshi Tandon Open University, Prayagraj

PGEVS-107N

Energy Resources and Climate Change

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Introduction

This third block of Energy Resources and Climate Change, this consists of following three units:

Unit-7: this unit covers the definition, scope and facts of climate change. The earth energy budget, composition and thermal structure of atmosphere, origin and types of wind, wind speed & direction also discussed. The brief discussion of weather and climate, temperature, pressure, precipitation and humidity is also mentioned here briefly.

Unit-8: This unit describes the definition of monsoon, winter and summer. The rainy season, monsoon, cyclones of the Indian region is also discussed. In addition the origin and effects on mansoon of El-Nino and La Nina also discussed. The and IOD and their impacts also mentioned here in briefly.

Unit-9: This unit covers the causes and effects, sources and sinks of greenhouse gases. And also covers the urban heat islands; ozone layer depletion and recovery, issues and remedies; ground level ozone and air pollution; global dimming, carbon footprint briefly.

Unit-7: Introduction to Climate Change

Contents

7.1. Introduction

Climate change is one of the most pressing issues facing our planet today. It refers to the long-term changes in the Earth's climate system, primarily due to human activities, such as burning fossil fuels, deforestation, and industrial processes. Fossil fuel coal and gas by for the largest contributor to climate change. Their contribution produces blanket around the planet and trap sun heat. Carbon dioxide released due to deforestation and land clearing also trap sun's heat. The global climate change is predicted to lead to extreme temperatures, severs drought as well as heavy storms and periodic flooding.

The impacts of climate change are already being felt across the world, from rising sea levels to more frequent and intense natural disasters. In this article, we will provide an introduction to climate change, its causes, impacts, and potential solutions. The Earth's energy budget is the balance between the amount of energy that comes into the Earth from the sun and the amount that is reflected back into space or absorbed by the Earth's surface and atmosphere. The energy budget plays a critical role in determining the Earth's weather and climate. Weather refers to the day-to-day changes in atmospheric conditions in a specific location, while climate refers to the long-term patterns of atmospheric conditions over a large region or the entire planet. The greenhouse effect plays a crucial role in the Earth's climate, and human activities have led to an increase in greenhouse gas concentrations, causing anthropogenic climate change.

Objectives:

- To discuss climate change and its effects on nature
- To discuss earth heat budget and its effects on nature
- To discuss atmospheric temperature and pressure
- To discuss the humidity and its roles in precipitation

7.2. Climate Change

Definition

Long-term changes in temperature and weather patterns are referred to as climate change. These changes could be caused by natural processes, such oscillations in the solar cycle. But since the 1800s, human activities primarily the combustion of fossil fuels like coal, oil, and gas have been the primary and increasing temperatures. Carbon dioxide and methane are two examples of greenhouse gas emissions that are contributing to climate change.

Fossil fuel combustion produces greenhouse gas emissions which serves as a blanket around the planet, trapping heat from the sun are produced, for instance, while burning coal or gasoline to heat a building.

Scope:

The argument over climate change was rather one-sided and focused on the growing understanding of certain gases in the atmosphere which may produce a greenhouse effect, and which could subsequently result in some degree of global warming. The history of the industrial revolution and the expanding understanding of the greenhouse effect, however, were subsequently combined to show that humanity has been steadily increasing concentration of greenhouse gases for more than a century, mostly in the form of carbon dioxide (CO_2).

Climate Change Facts:

- As of July 2021, the amount of carbon dioxide (CO_2) in our atmosphere is at its highest level (416 ppm) in recorded human history.
- The second-hottest year according to NOAA was 2020, when average worldwide temperatures were 1.76 degrees F (0.98 degrees C) greater than the 20th century norm.
- Deforestation accounts for 11% of all human-caused global greenhouse gas emissions; this percentage is similar to the emissions by all of the passenger cars
- Tropical forests are very good at storing carbon, making up at least a third of the mitigation measures required to avert the worst-case scenarios of climate change. Barely 3% of all climate money goes towards natural solutions.
- Currently, 11% of the world's population is at risk from the effects of climate change, including sea level rise, droughts, floods, heat waves, and extreme weather conditions.
- Coastal mangroves make up just 0.7% of the world's forests, but they can store up to 10 times as much carbon per hectare as tropical forests. Every year, we lose 800,000 hectares of mangrove vegetation. Mangroves may vanish in the next century if we keep losing them at this rate. With this loss, coastal populations lose a crucial weather buffer and massive volumes of carbon dioxide released into the atmosphere.
- Recent years have seen the highest average global temperatures ever. If we don't take action to reduce emissions the heatwaves, droughts, and natural disasters will happen more frequently and with greater severity. We must keep the increase in global temperature to 1.5°C in order to avoid the worst effects. Yet, there has already been a 1.2 degree increase in global warming.

- With merely a 2°C rise in temperature, the 99% of coral reefs will be gone. The 30% of marine life lives on coral reefs; they are also important centres for biodiversity. The health of the Ocean will suffer greatly as a result of their demise.
- Fish contribute 20% of animal protein to roughly 3 billion people; plants provide over 80% of the human diet; and as much as 80% of people living in rural regions in developing nations rely on traditional plant-based remedies for primary healthcare. Climate change is a major factor in the current threat to extinction of about 1 million plants and animals, along with other types of habitat loss.
- The present migratory crisis is exacerbated by climate change. The effects of climate change are now putting many communities, especially a disproportionately high number of indigenous peoples, children, and women, in grave danger. (Source). For instance, 30 million people were driven from their homes due to climatic disasters in 2020, which is three times the number of people displaced by war and violence.
- The window of opportunity is to stop the worst effects of the climate crisis is rapidly closing. To maintain the 1.5-degree target, emissions must be reduced by 45% by 2030. Yet, worldwide CO_2 emissions from energy increased by 6% in the previous year.

7.3. Earths Energy Budget

We must take into account processes at three levels. In order to comprehend of the major heating Earth's climate system which maintains the energy balance, the surface of the planet, the top edge from which sunlight enters the atmosphere, where sunlight enters the system; and the atmosphere in between should be taken into account. The amount of incoming and emitted energy, or net flow, must be equal at each level. The energy balance of the planet is intricate and involves numerous ongoing activities.

Part 1: Incoming Solar Radiation:

Our planet and its atmosphere are continually being flooded with solar energy as it travels through space. Either the energy is reflected or absorbed. It reaches the top of the atmosphere. Clouds, atmospheric constituents, or brilliant land surfaces like sea ice and snow reflect about 30% of the solar energy that enters the upper atmosphere back to space. The climatic system of Earth is unaffected by this energy. Around 23% of the sun's energy is absorbed by water vapour, dust, and ozone in the atmosphere, whereas 47% of it passes through the atmosphere and is absorbed by the Earth's surface. The Earth system so absorbs roughly 70% of the total solar energy that is received.

- 23 units – reflected by the clouds and atmosphere
- 7 units – reflected by the Earth’s surface
- 19 units – absorbed by the atmosphere (ozone, aerosols, dust)
- 4 units – absorbed by clouds
- 47 units – absorbed by the Earth surfaces (primarily ocean)

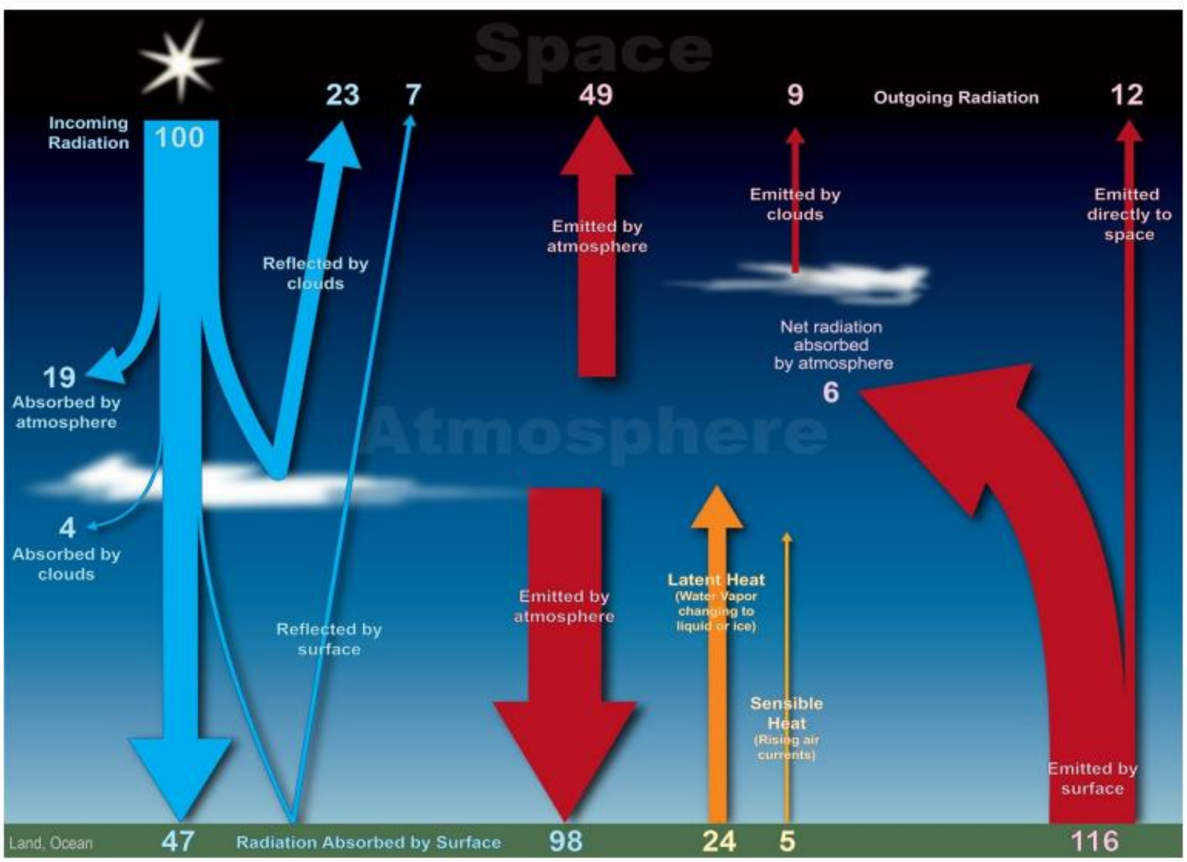
Part 2: Surface Energy Budget

A approximately 30% of the sun's rays are reflected back to space by atmospheric particles or brilliant ground surfaces, leaving approximately 70% of the sun's energy to be absorbed by the atmosphere (23%) and Earth's surface (47%) including the ocean. The 47% of solar energy which is the ocean and land surfaces absorbed must be transferred and transformed by surface processes back into the atmosphere and finally into space for the energy budget at the Earth's surface to balance. Three main processes allow energy to escape the surface: evaporation, convection, and thermal infrared (IR) energy emission. Evaporation and sublimation remove around 24% of the solar energy that enters the atmosphere from the surface. As a result of absorbing incoming solar energy, liquid water molecules transform into gas molecules. The water vapours molecules' haphazard movements, travel through the atmosphere, and carry the latent heat energy that was required to evaporate the water. The latent heat is released to the surrounding environment when the water vapour molecules condense back into clouds. The main sources of energy for the atmospheric heat engine are evaporation from tropical oceans and the subsequent release of latent heat. Convection causes an additional 5% of the sun's energy to escape the surface. Direct sunlight warming of the earth causes air to become warm and buoyant. Since the atmosphere is often warmer at the surface and colder above the warm air rises under these circumstances, transferring heat away from the surface. Finally, atoms and molecules on the surface radiate heat, which accounts for a net loss of 18% of the solar energy that enters the surface. The Earth's surface radiates heat upward to the atmosphere at a rate of 116%, while the atmosphere reflects heat downward to the ground at a rate of 98%, creating this net upward emission.

- 24 Units – Latent heat: energy that is used in evaporation, transpiration, and condensation
- 5 Units – Sensible heat: energy that becomes convection
- 12 Units – Emitted from Earth directly back to space
- 6 Units – Net radiation amount absorbed by atmosphere

7.4. The Atmosphere's Energy Budget

The flow of energy into the atmosphere must be matched by an equal flow of energy out of the atmosphere and back into space, just as the incoming and outgoing energy at the Earth's surface must balance. At the top of the atmosphere, measurements by satellites reveal that the atmosphere emits thermal infrared radiation equal to 58% of the incoming solar energy. The atmosphere must be absorbing that much energy if it is radiating this much. What source does that energy have? Remember from Part 1 that 23% of the solar energy entering the earth is directly absorbed by clouds, aerosols, water vapour, and ozone.



The evaporation and convection transfer another 24 and 5% of incoming solar energy from the surface to the atmosphere, which then moves the energy back to space. These three processes transfer the equivalent of 52% of the incoming solar energy to the atmosphere. The total inflow of energy must match the outgoing thermal infrared observed at the top of the atmosphere. The remaining energy (6%) comes from the portion that was absorbed by the atmosphere and not re-emitted back to Earth.

A. 49 emitted by the atmosphere

B. 9 emitted by clouds

Why is it important for us to study the energy budget?

The energy that the sun sends to Earth and the energy that Earth sends back into space must always is in balance for the Earth-atmosphere system to function properly. The Earth's temperature will eventually rise or fall in order to bring the energy budget back into balance if the Earth system is altered by either natural occurrences, like volcanoes, or human activity.

Internal changes in the system brought on by atmospheric and oceanic circulations affect Earth's energy budget and will make it difficult to pinpoint exactly how the system is adapting at any particular time. Observations of the Earth's energy budget over a variety of time scales, from monthly to multi-decadal, are required to advance our understanding.

The atmospheric and oceanic circulations are driven by the global distribution of the difference between incoming and departing radiant energy. The tropics have an excess of radiant energy because more energy is absorbed than is released. The opposite is true at high latitudes. The general circulation of the atmosphere and oceans moves heat from the tropics to the poles in order to correct this latitudinal imbalance in radiant energy. Hence weather and ocean circulation patterns would be directly impacted by a change in the geographical distribution of radiant energy.

The energy required to evaporate water at the surface, which in turn controls how much precipitation can fall over the globe, is provided by the radiation balance at the Earth's surface.

7.5. Composition of the Atmosphere:

The atmosphere can be divided into two layers the heterosphere and the homosphere. The heterosphere is the outermost sphere of the atmosphere, where the gases are distributed on distinct layers according to their atomic weight and gravitational pull. The lightest elements that make up the outer layer are hydrogen and helium. The heavier elements at the base are nitrogen and oxygen.

The layer that lies between the Earth's surface and heterosphere is the homosphere. The gases in this layer are uniformly mixed. The ozone layer that extends from 12 to 31 miles lies in this layer. The ozone layer is a very important layer, as it helps to protect life on the Earth from the harmful effects of the sun's ultraviolet rays.

The three major gases that make up the atmosphere are called constant gases. These constant gases are nitrogen, oxygen, and argon. Nitrogen in the atmosphere makes up about 78% of the total composition of the atmosphere. It is one of the building blocks of life, as it is the major component of protein. Oxygen makes up about 21%, and is absolutely necessary for plant and animal respiration. Without oxygen, fire cannot burn. Plants release free oxygen in the atmosphere by photosynthesis. Argon makes up only 0.934% of the atmosphere, and is a colourless, odourless, inert gas.

The other trace gases are called variable gases. These variable gases include methane, hydrogen, helium, neon, krypton, carbon dioxide, and a form of oxygen known as ozone. The following is a list of gases with their percent volume that make up the atmosphere. The atmosphere is the reason that we have so many seasons and weather conditions. It forms a thick blanket around the Earth that helps protect those on the surface from harmful sunrays, cosmic radiation, and heat.

Table: 1 Composition of the Atmosphere:

Composition of Atmosphere	Chemical Formula	Percent Volume
Nitrogen	N_2	78.08%
Oxygen	O_2	20.95%
Water (variable gas)	H_2	0 to 4%
Argon	Ar	0.934%
Carbon dioxide (variable gas)	CO_2	0.0360%
Neon	Ne	0.0018%
Helium	He	0.0005%
Methane (variable gas)	CH_4	0.00017%
Hydrogen	H_2	0.00005%
Nitrous Oxide (variable gas)	N_2O	0.00003%
Ozone (variable gas)	O_3	0.00004%

7.6. Thermal Structure of the Atmosphere

Atmospheric layers are characterized by **variations in temperature** resulting primarily from the absorption of solar radiation; visible light at the surface, near ultraviolet radiation in the middle atmosphere, and far ultraviolet radiation in the upper atmosphere.

Troposphere

The troposphere is the atmospheric **layer closest to the planet** and contains the largest percentage (around 80%) of the mass of the total atmosphere.

Temperature and water vapor content in the troposphere **decrease rapidly with altitude.**

- Water vapor plays a major role in regulating air temperature because it absorbs solar energy and thermal radiation from the planet's surface.
- The troposphere contains **99 % of the water vapor** in the atmosphere.
- Water vapor concentrations vary with latitude. They are greatest above the tropics, where they may be as high as 3 %, and decrease toward the polar regions.
- **All weather phenomena** occur within the troposphere, although turbulence may extend into the lower portion of the stratosphere.
- Troposphere means "**region of mixing**" and is so named because of vigorous convective air currents within the layer.
- The upper boundary of the layer, known as the **tropopause**, ranges in height from **5 miles (8 km) near the poles up to 11 miles (18 km) above the equator.** Its height also varies with the seasons; highest in the summer and lowest in the winter.

Stratosphere

- The stratosphere is the second major strata of air in the atmosphere.
- It extends above the tropopause to an altitude of about 30 miles (50 km) above the planet's surface.
- The air temperature in the stratosphere remains relatively constant up to an altitude of 15 miles (25 km).
- Then it increases gradually to up to the stratopause.
- Because the **air temperature** in the stratosphere **increases with altitude**, it does not cause convection and has a stabilizing effect on atmospheric conditions in the region.

- **Ozone** plays the major role in regulating the **thermal regime of the stratosphere**, as water vapor content within the layer is very low.
- **Temperature increases with ozone concentration**.
- Solar energy is converted to kinetic energy when ozone molecules absorb ultraviolet radiation, resulting in heating of the stratosphere.
- The ozone layer is centered at an altitude between 10-15 miles (15-25 km).
- Approximately **90 % of the ozone in the atmosphere resides in the stratosphere**.
- Ozone concentration in this region is about 10 parts per million by volume (ppmv) as compared to approximately 0.04 ppmv in the troposphere.
- **Ozone absorbs the bulk of solar ultraviolet radiation** in wavelengths from 290 nm – 320 nm (UV-B radiation). These **wavelengths are harmful** to life because they can be absorbed by the nucleic acid in cells.
- Increased penetration of ultraviolet radiation to the planet's surface would damage plant life and have harmful environmental consequences.
- Appreciably large amounts of solar ultraviolet radiation would result in a host of biological effects, such as a dramatic increase in cancers.

Mesosphere

- The mesosphere a layer extending from approximately **30 to 50 miles (50 to 85 km)** above the surface is characterized by **decreasing temperatures.**
- The **coldest temperatures** in Earth's atmosphere occur at the **top of this layer**, the mesopause, especially in the summer near the pole.
- The mesosphere has sometimes jocularly been referred to as the "ignorosphere" because it had been probably the least studied of the atmospheric layers.
- The stratosphere and mesosphere together are sometimes referred to as the **middle atmosphere.**

Thermosphere

- The thermosphere is located above the mesosphere.
- The temperature in the thermosphere **generally increases with altitude** reaching 600 to 3000 F (600-2000 K) depending on solar activity.

- This increase in temperature is due to the absorption of intense solar radiation by the limited amount of remaining molecular oxygen.
- At this extreme altitude gas molecules are widely separated.
- Above 60 miles (100 km) from Earth's surface the chemical composition of air becomes strongly dependent on altitude and the atmosphere becomes enriched with lighter gases (atomic oxygen, helium and hydrogen).
- Also at 60 miles (100 km) altitude, Earth's atmosphere becomes too thin to support aircraft and vehicles need to travel at orbital velocities to stay aloft.
- This demarcation between aeronautics and astronautics is known as **the Karman Line.**
- Above about 100 miles (160 km) altitude the major atmospheric component becomes atomic oxygen.
- At very high altitudes, the residual gases begin to stratify according to molecular mass, because of gravitational separation.

Exosphere

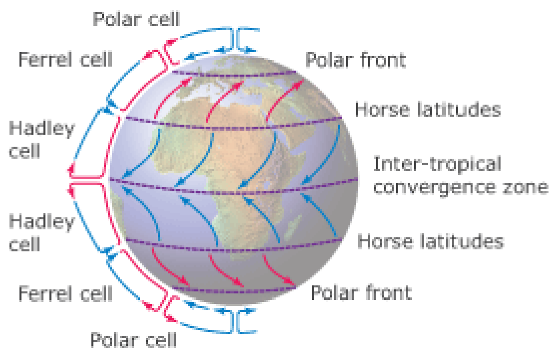
- The exosphere is the most distant atmospheric region from Earth's surface.
- In the exosphere, an upward travelling molecule can escape to space (if it is moving fast enough) or be pulled back to Earth by gravity (if it isn't) with little probability of colliding with another molecule.
- The altitude of its lower boundary, known as the **thermopause or exobase,** ranges from about 150 to 300 miles (250-500 km) depending on solar activity.
- The upper boundary can be defined theoretically by the altitude (about 120,000 miles, half the distance to the Moon) at which the influence of solar radiation pressure on atomic hydrogen velocities exceeds that of the Earth's gravitational pull.
- The exosphere observable from space as the **geocorona** is seen to extend to at least 60,000 miles from the surface of the Earth.
- The exosphere is **a transitional zone** between Earth's atmosphere and interplanetary space.

7.7. Wind

Origin

Wind entirely caused by the effects of the sun which. Delivers 175 million watts of energy to the earth perhour this energy heats the planet's surface, most intensively at the equator, which causes air to rise. This rising air creates an area of low pressure at the surface into which cooler air is sucked, and it is this flow of air is called "wind".

In reality atmospheric circulation is much more complicated and, after rising at the equator air travels pole wards. As it travels the air cools and eventually descends to the earth's surface at about 30° latitude (north and south), from where it returns once again to the equator (a closed loop known as a Hadley Cell).



Similar cells exist between 30° and 60° latitude (the Ferrel Cells) and between 60° latitude and each of the poles (the Polar Cells). Within these cells, the flow of air is further impacted by the rotation of the earth or the "Coriolis Effect". This effect creates a sideways force which causes air to circulate anticlockwise around areas of low pressure in the northern hemisphere and clockwise in the southern hemisphere. While these mechanisms are responsible for the creation of winds at a global level, those at the level of an individual wind farm are also impacted by more local effects. The most significant of these are:

Influence	Effect
Cost	During the day, the earth heats up more quickly than the sea. This causes air to rise over the land and in turn air to be "sucked in" from over the sea – an effect known as a sea breeze. During the night, the earth cools down more quickly than the sea and the effect is reversed. Overall, average wind speeds on the coast can be ~0.5 m/sec higher than those just a few kilometres inland.
Land	Wind speeds up as it travels over hills and other topographical features, increasing the amount of energy available to be exploited. This is not all

	good however as it also creates turbulence which is not usually experienced in flatter landscapes.

Due to a combination of its latitude (at the boundary of the Ferrel and Polar Cells) and the lack of landmass in the prevailing south-westerly wind direction, the UK is fortunate to have much higher wind speeds than those in continental Europe. Indeed Renewable UK has estimated that the UK has some 40% of the Europe's total wind resource. Despite this the UK currently has only 4% of Europe's total wind capacity and it is for these reasons that wind power in particular is expected to play such an important role in meeting the country's renewable energy targets.

7.7.1. Types of Winds

A. Primary or Planetary wind-

The wind that flows throughout the year in a particular direction is called Primary or planetary wind. This type of wind is also known as prevailing wind. The primary wind has also different types which are known as trade winds, westerlies and easterlies....

Trade Winds

- The trade winds are the winds that blow from subtropical high-pressure areas to the equatorial low-pressure belt.
- As a result, they are restricted to a portion of the earth's surface between 30°N and 30°S.
- In the northern hemisphere, they flow as the north-eastern trades, while in the southern hemisphere, they flow as the south-eastern trades.
- The Coriolis force and **Farrel's law** are used to explain the deflection in their predicted north-south orientation.
- In their origin areas (subtropical high-pressure band), trade winds are descending and stable, but as they approach the equator, they grow humid and warmer after collecting up moisture along the route.
- At the equator, trade winds from two hemispheres meet, and due to convergence, they ascend, causing heavy rainfall.
- Eastern trade winds, which are connected with cool ocean currents, are drier and more stable than western trade winds.

Westerlies

- Winds moving from subtropical high-pressure belts to sub-polar low-pressure belts are known as the westerlies.
- In the northern hemisphere, they blow from the south-west to the north-east, while in the southern hemisphere, they blow from the north-west to the south-east.
- Because of the huge expanse of ocean, the westerlies in the southern hemisphere are stronger and more persistent, whereas those in the northern hemisphere are irregular due to uneven relief of vast landmasses.
- Between 40° and 65° South latitudes, the westerlies flourish. For sailors, these latitudes are known as the Roaring Forties, Furious Fifties, and Shrieking Sixties.
- The westerlies' poleward edge is relatively variable. Seasonal and short-term changes are common. Wet spells and weather unpredictability are caused by these winds.

Polar Easterlies

- Polar easterlies are dry, cold winds that blow from the north-east to the south-west in the Northern Hemisphere and from the south-east to the north-west in the Southern Hemisphere.
- They blow from the subpolar lows' polar high-pressure regions.

B. Secondary or periodic wind- The wind that changes its direction in different seasons is called secondary or periodic wind. It is also known as seasonal winds. It generally occurs in several locations throughout the world. Monsoon wind is a recognizable secondary wind.

- Periodic winds: **Land and sea breeze**, **mountain, and valley breeze**.

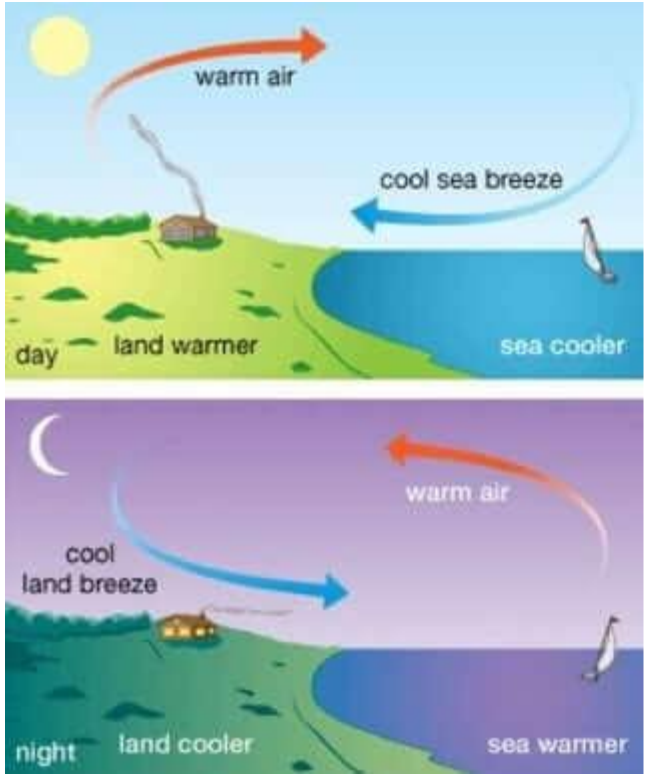
Monsoons

- Monsoons were traditionally explained as **land and sea breezes on a large scale.** Thus, they were considered a **convectional circulation on a giant scale.**
- The monsoons are characterized by **seasonal reversal** of wind direction.
- During summer, the trade winds of the southern hemisphere are pulled northwards by an apparent northward movement of the sun and by an intense low-pressure core in the north-west of the Indian subcontinent.
- While crossing the equator, these winds get deflected to their right under the effect of Coriolis force.

- These winds now approach the Asian landmass as south-west monsoons. Since they travel a long distance over a vast expanse of water, by the time they reach the south-western coast of India, they are over-saturated with moisture and cause heavy rainfall in India and neighboring countries.
- During winter, these conditions are reversed and a high-pressure core is created to the north of the Indian subcontinent. **Divergent winds** are produced by this **anticyclonic movement** which travels southwards towards the equator. This movement is enhanced by the apparent southward movement of the sun. These are north-east or winter monsoons which are responsible for some precipitation along the east coast of India.
- The monsoon winds flow over India, Pakistan, Bangladesh, Myanmar (Burma), Sri Lanka, the Arabian Sea, Bay of Bengal, southeastern Asia, **northern Australia, China** and
- Outside India, in the eastern Asiatic countries, such as China and Japan, the **winter monsoon is stronger** than the summer monsoon. (We will study about monsoons in detail while studying Indian Climate).

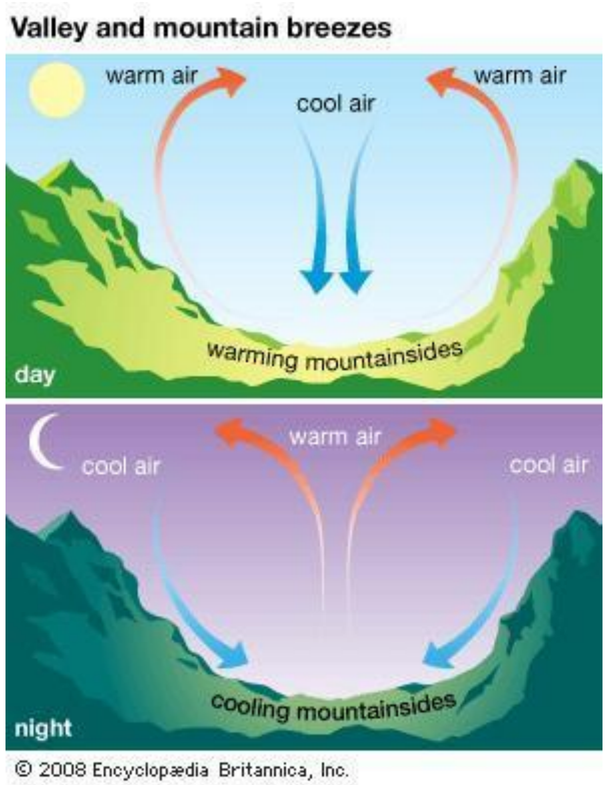
Land Breeze and Sea Breeze

- The land and sea absorb and transfer heat differently. During the day the land heats up faster and becomes warmer than the sea. Therefore, over the land, the air raises giving rise to a low-pressure area, whereas the sea is relatively cool and the pressure oversea is relatively high. Thus, the pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze. At the night the reversal of condition takes place. The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence land breeze results.



Valley Breeze and Mountain Breeze

- In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the valley breeze. During the night the slopes get cooled and the dense air descends into the valley as the mountain wind. The cool air, of the high plateaus and ice fields draining into the valley, is called Katabatic wind.
- Another type of warm wind (Katabatic wind) occurs on the leeward side of the mountain ranges. The moisture in these winds, while crossing the mountain ranges condenses and precipitates. When it descends down the leeward side of the slope the dry air gets warmed up by the adiabatic process. This dry air may melt the snow in a short time.



C. Tertiary and Local Wind- The wind that blows only during a particular period of the day or a year in a small area is called tertiary or local wind. This type of wind is below due to the difference in temperature and air pressure of a particular location. There are different types of tertiary or local wind which are hot, cold, ice-filled, dust, and rich. Loo is a type of hot and driving tertiary wind which flows in the Northern plains of India....

Table of Major Local Wind Systems

Brick fielder	Very hot north-east summer wind that blows dust and sand across Australia.
Chinook	Warm, dry wind of the Rocky Mountains, USA. Welcomed by cattlemen because it can remove snow cover very quickly. Named after a local Indian tribe.
Foehn	Warm, dry European wind that flows down the side of mountains.
Haboob	The Arabic name for a violent wind which raises sandstorms, especially in North Africa.

Levanter	Pleasant, moist east wind that brings mild weather to the Mediterranean.
Mistral	Violent, dry, cold, north-west wind that blows along the coasts of Spain and France.
Sirocco	The hot, dry South wind that blows across North Africa from the Sahara. Becomes very hot and sticky as it reaches the sea.
Elephanta	Malabar coast; South easterly wind; Marks end of southwest monsoon
Nor' easter	Northeast USA; Strong storm winds from the northeast
Nor 'wester	East coast of New Zealand; Warm dry winds
Santa-Ana winds	Southern California Strong, extremely dry winds; Responsible for frequent wildfires
Shamal	Persian Gulf; Strong North-westerly wind; Causes large sandstorms in Iraq
Calima	Sahara to Canary Islands (west African coast); Carries dust from the Sahara

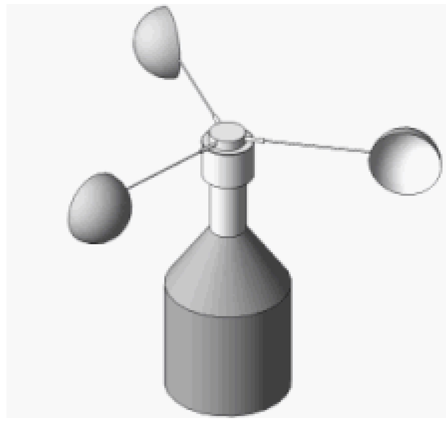
7.7.2. Wind Speed

In meteorology, wind speed, or wind flow speed, is a fundamental atmospheric quantity caused by air moving from high to low pressure, usually due to changes in temperature. Wind speed is now commonly measured with an anemometer. Wind speed affects weather forecasting, aviation and maritime operations, construction projects, growth and metabolism rate of many plant species, and has countless other implications The wind direction is usually almost parallel to isobars (and not perpendicular, as one might expect), due to Earth's rotation.

Units

Metres per second (m/s) is the SI unit for velocity and the unit recommended by the World Meteorological Organization for reporting wind speeds, and is amongst others used in weather forecasts in the Nordic countries. Since 2010 the International Civil Aviation

Organization (ICAO) also recommends meters per second for reporting wind speed when approaching runways, replacing their former recommendation of using kilometres per hour (km/h). An anemometer is one of the tools used to measure wind speed.



Factors affecting wind speed:

Wind speed is affected by a number of factors and situations, operating on varying scales (from micro to macro scales). These include the pressure gradient, Rossby waves and jet streams, and local weather conditions. There are also links to be found between wind speed and wind direction, notably with the pressure gradient and terrain conditions.

Pressure gradient is a term to describe the difference in air pressure between two points in the atmosphere or on the surface of the Earth. It is vital to wind speed, because the greater the difference in pressure, the faster the wind flows (from the high to low pressure) to balance out the variation. The pressure gradient, when combined with the Coriolis effect and friction, also influences wind direction.

Rossby waves are strong winds in the upper troposphere. These operate on a global scale and move from West to East (hence being known as Westerlies). The Rossby waves have a different wind speed from what we experience in the lower troposphere.

Local weather conditions play a key role in influencing wind speed. The formation of hurricanes, monsoons and cyclones and freak weather conditions can drastically affect the flow of velocity of the wind.

Beaufort Wind Scale Force	Wind (Knots)	Classification
0	≤1	Calm
1	1 - 3	Light Air
2	4 - 6	Light Breeze
3	7 - 10	Gentle Breeze
4	11 - 16	Moderate Breeze
5	17 - 21	Fresh Breeze
6	22 - 27	Strong Breeze
7	28 - 33	Near Gale
8	24 - 40	Gale
9	41 - 47	Strong Gale
10	48 - 55	Storm
11	56 - 63	Violent Storm
12	64 +	Hurricane

7.7.3. Wind Direction:

Wind direction is generally reported by the direction from which the wind originates. For example, a north or northerly wind blows from the north to the south. Wind direction is usually reported in cardinal (or compass) direction, or in degrees. Consequently, a wind blowing from the north has a wind direction referred to as 0° (360°); a wind blowing from the east has a wind direction referred to as 90°, etc.

Weather forecasts typically give the direction of the wind along with its speed, for example a "northerly wind at 15 km/h" is a wind blowing *from* the north at a speed of 15 km/h. If wind gusts are present, their speed may also be reported.

Measurement techniques

A variety of instruments can be used to measure wind direction, such as the windsock and wind vane. Both of this instrument's work by moving to minimize air resistance. The way a weather vane is pointed by prevailing winds indicates the direction from which the wind is blowing. The larger opening of a windsock faces the direction that the wind is blowing from; its tail, however, the smaller opening, points in the same direction as the wind is blowing.

7.8. Weather

Definition

Weather is the daily atmospheric conditions of a specific place. The study of weather is necessary to understand its effects on the everyday life and activities of humans. The atmospheric conditions like the brightness of sun, wind, visibility, humidity, cloudiness, temperature, etc. measure the weather of a particular day and time.

Weather can change within minutes, or hours, or even as per seasons. These changes mostly happen in the closest atmospheric layer to the ground called the troposphere. Nowadays, due to satellite observation, weather prediction has become easy.

The effects of weather change:

Many crops farmed around the world will be affected by weather changes. Wheat and rice thrive in hot regions, whereas maize and sugarcane prefer cooler conditions. Changes in rainfall patterns will have an impact on the growth of plants and crops. The impact of changing weather on plant development could lead to food shortages in some regions. Brazil, sections of Africa, Southeast Asia, and China will be the hardest hit, with many people facing starvation.

7.9. Climate

Definition

Climate is the atmospheric condition of a particular location over a long-term period. The average summation of the atmospheric elements of a place is considered as the climate of that particular region. These atmospheric elements include temperature, solar radiation, precipitation, humidity, wind, and atmospheric pressure. Depending on these elements and their variants, respective centres of a specific zone maintain climate records. These records, like the amount of rainfall, the hottest day, the coldest day, etc. are helpful in forecasting the upcoming climate which is done by analyzing previously accumulated data. Based on the observation of these atmospheric elements' records of above 30 years, is deduced.

7.9.1. The Causes of climate change:

Many natural processes have contributed to this, including fluctuations in the sun, volcanic eruptions, variances in Earth's orbit, and CO_2 concentration. Warming has often taken thousands or millions of years to occur. However, research indicates that the current climate is changing at a faster rate than previously, based on geological data.

Since the Industrial Revolution, human activity has raised greenhouse gas levels in the atmosphere, resulting in higher heat absorption and higher surface temperatures. Air pollutants in the atmosphere affect climate through scattering and absorbing solar and infrared energy, as well as changing cloud microphysical and chemical properties. Finally, changes in land use, such as deforestation, have affected the amount of sunlight reflected back into space.

Difference between Weather and Climate in Points:

Even though both weather and climate include some similar atmospheric elements, there are some prominent differences between these two. Here are some differences between weather and climate in tabular form-

Sr. No.	Weather	Climate
1.	The day-to-day information of atmospheric changes of a particular area at a specific time is called weather.	Climate is the statistical information of the average weather condition of a specific region for more than 30 years.

2.	The weather of a place includes the short-term atmospheric condition. Also, these atmospheric conditions can change within a short period like minutes, hours, days, etc.	The climate of a country or zone includes the long-term average atmospheric conditions. Thus, the climate is the average weather information observed over decades.
3.	The atmospheric elements of weather are air pressure, humidity, wind, temperature, rain, cloudiness, storms, snow, precipitation, etc. These conditions can affect the weather of the place within a short time.	When the atmospheric elements of weather are observed over the decades, those become the affecting conditions of climate. These conditions can include temperature, humidity, wind, etc.
4.	The weather of a particular location can impact the day to day human life like occupation, transportation, communication, agriculture, etc.	The climate of a country significantly impacts industries, agriculture, the livelihood of the inhabitants of that geographical locale.
5.	Weather conditions change very frequently.	Climate conditions change over a long period.
6.	The meteorological department of a place observes the changes in weather conditions. The study of weather forecasting is known as meteorology.	Institutes of climate studies observe and predict the changes in climate. This study is called climatology.

Difference between Climate and Season

Similar to the climate weather difference, the season is different from the climate. The season is determined by the changes in weather during a specific time of the year. Contrastingly, the climate is the behaviour of the atmosphere over a longer timeline. Thus, the prime difference between season and climate is also the measure of duration.

7.10. Atmospheric Temperature

The term "atmospheric temperature" refers to the temperature of the Earth's atmosphere at various layers. Several things make this temperature reach new levels or drop them below levels and factors depends on solar energy, humidity and altitude of that place.

Define atmosphere temperature?

The temperature of the Earth's atmosphere can range from 2,700 degrees Fahrenheit (1,500 degrees Celsius) in the increased level or at high temperatures to 59 degrees Fahrenheit (15 degrees Celsius) near the surface or below sea level.

What role does atmospheric temperature play in our Earth?

Earth's unique temperature enables it to support life on earth. They ensure that earth does not heat up during the day and does not cool down to extreme levels at night.

Can we measure the atmospheric temperature?

Thermometers can be used to measure atmospheric temperatures. In these types of thermometers, there is a big glass rod with a very thin tube installed within it. The tube has a liquid that is transferred from a reservoir, or "bulb," installed at the base of the thermometer.

The sun-Earth space energy relationship

The modification of solar radiation energy by air, clouds, land, sea and other water surfaces tells us about atmospheric temperature. Every layer has a different atmospheric temperature. The temperature in the troposphere consistently decreases at roughly 6.5 °C per 1000 m of altitude. When it reaches 14 km, it abruptly modifies its layer at the tropopause (goes into the stratosphere). After increasing into the stratosphere, it reaches the stratopause at about 50 km, then it undergoes another rapid transition before plummeting back into the mesosphere. Now, it comes at around 80 km altitude where the temperature levels menopause before rapidly rising in the thermosphere thus entering an electrified zone called the ionosphere. This is the final layer after which it reaches space through the exosphere. The temperature of the earth's atmosphere can be determined at every level of the Earth and this varying temperature is called atmospheric temperature. Many factors influence the temperature including clouds, latitude, incoming radiation, land surface, air, altitude, ocean currents, water surface, etc.

The temperature of the atmosphere causes the warmth and coldness on Earth. The sun's rays, or solar energy, are also the primary causes of both cold and warm temperatures in the atmosphere. In a single day, the temperature of a place fluctuates in different areas or it can also change within hours, resulting in seasonal variances.

Range of temperature

The temperature range can be defined as the difference between the maximum and minimum temperature of the atmosphere. There are two types of temperature ranges:

Diurnal range of temperature:

The everyday weather pattern we generally experience can be termed as the diurnal range of temperature. This range can help us define energy fluctuations that happen over a short period. As the earth emits long-wave radiation all night, it gradually becomes colder and cools the air. Cooling happens via conduction on a calm day with no cloud cover. Air temperature on days like this is usually lowest immediately before the sun rises. The temperature of the ground starts to rise as the sun rises. Midday becomes very much hotter, while the peak of air temperature is around 2:00 PM. It has observed that after dawn, the air starts becoming warm. It remains warm because it is heated by long-wave radiation from the ground. But gradually as the night descends it fades away. For example Desert areas. Deserts usually experience the hottest days while the nights are calmer. Desert has the highest temperature while low lying areas experience low temperatures.

The annual average range of temperature:

The annual average range of temperature is defined as the difference between the average temperature of the hottest month and the average temperature of the coldest month of the year. Low latitudes experience a lower yearly temperature range, while high latitudes have a higher annual temperature range. The atmospheric temperature is generally higher across continents and lower over oceans and coastal regions within the same latitudes. The areas with high temperatures can lead to higher precipitation and lower temperatures lead to snowfall.

7.11. Atmospheric pressure

Atmospheric pressure, also known as **barometric pressure** (after the barometer), is the pressure within the atmosphere of Earth. The standard atmosphere (symbol: atm) is a unit of pressure defined as 101,325 Pa (1,013.25 hPa), which is equivalent to 1013.25 millibars, 760 mm Hg, 29.9212 inches Hg, or 14.696 psi. The atm unit is roughly equivalent to the mean sea-level atmospheric pressure on Earth; that is, the Earth's atmospheric pressure at sea level is approximately 1 atm.

Cause:

Atmospheric pressure is caused by the gravitational attraction of the planet on the atmospheric gases above the surface and is a function of the mass of the planet, the radius of the surface, and the amount and composition of the gases and their vertical distribution in the atmosphere.[3][4] It is modified by the planetary rotation and local effects such as wind velocity, density variations due to temperature and variations in composition.

Mean Sea Level Pressure:

The mean sea-level pressure (MSLP) is the atmospheric pressure at mean sea level (PMSL). This is the atmospheric pressure normally given in weather reports on radio, television, and newspapers or on the Internet. When barometers in the home are set to match the local weather reports, they display pressure adjusted to sea level, not the actual local atmospheric pressure. The altimeter setting in aviation is an atmospheric pressure adjustment. Average sea-level pressure is 1013.25h Pa (29.921 in Hg; 760.00 mmHg).

Surface Pressure:

Surface pressure is the atmospheric pressure at a location on Earth's surface (terrain and oceans). It is directly proportional to the mass of air over that location. For numerical reasons, atmospheric models such as general circulation models (GCMs) usually predict the no dimensional logarithm of surface pressure. The average value of surface pressure on Earth is 985 hPa. This is in contrast to mean sea-level pressure, which involves the extrapolation of pressure to sea level for locations above or below sea level. The average pressure at mean sea level (MSL) in the International Standard Atmosphere (ISA) is 1013.25 hPa, or 1 atmosphere (atm), or 29.92 inches of mercury.

Altitude Variation:

Pressure on Earth varies with the altitude of the surface. Air pressure on mountains is usually lower than air pressure at sea level. Pressure varies smoothly from the Earth's surface to the top of the mesosphere. Although the pressure changes with the weather, NASA has averaged the conditions for all parts of the earth year-round. As altitude increases, atmospheric pressure decreases.

Local Variation:

Atmospheric pressure varies widely on Earth, and these changes are important in studying weather and climate. Atmospheric pressure shows a diurnal or semidiurnal (twice-daily) cycle caused by global atmospheric tides. This effect is strongest in tropical zones, with amplitude of a few hectopascals, and almost zero in polar areas. These variations have two superimposed cycles, a circadian (24 h) cycle, and a semi-circadian (12 h) cycle.

7.12. Precipitation

In meteorology, **precipitation** is any product of the condensation of atmospheric water vapor that falls under gravitational pull from clouds.[2] The main forms of precipitation include drizzle, rain, sleet, snow, ice pellets, graupel and hail. Precipitation occurs when a portion of the atmosphere becomes saturated with water vapor (reaching 100% relative humidity), so the water condenses and "precipitates" or falls. Precipitation is a major component of the water cycle, and is responsible for depositing fresh water on the planet.

Examples of Precipitation

Depending on the forms we could witness precipitation in various forms:

In Liquid Form precipitation occurs in:

- *Drizzle*
- *Rain*

When the above comes in contact with the air mass at the subfreezing temperature it becomes

- *Freezing Rain*
- *Freezing Drizzle*

The frozen forms of precipitated water include:

- *Snow*
- *Ice Needles*

- *Hail*
- *Graupel*
- *Sleet*

Forms: The different forms of precipitation are as follows:

1. Rain:

Rain is a form of precipitation that is in the form of water drops of a size that is larger than 0.5mm. The maximum raindrop size is about 6mm. Drops of larger size break up into smaller drops as it falls down on the Earth’s surface.Rainfall is the predominant form of precipitation and therefore, the term precipitation is used synonymously with rainfall. The magnitude of the rainfall shows high temporal and spatial variation. This variation causes the occurrence of hydrologic extremes like floods and droughts.

2. Snow:

Snow consists of ice crystals in a flaky form, having an average density of 0.1g/cc. It is also an important form of precipitation that usually forms in colder climates and higher altitudes.

3. Drizzle

Drizzle is a fine sprinkle of tiny water droplets that have a size less than 0.5mm and an intensity greater than 1mm/h. The tiny drops that form a drizzle appear floating in the air.

4. Glaze or Freezing Rain:

The glaze is formed when rain or drizzle comes in direct contact with the cold ground at around 0 degrees Celsius. This water drops freeze to form an ice coating known as glaze.

5. Sleet:

Sleet is frozen raindrops that are formed when rainfall passes through the air in the atmosphere at subfreezing temperatures.

6. Hail:

Hail is a kind of showery precipitation in the form of pellets or lumps that have a size greater than 8mm. Hail occurs during violent thunderstorms. These are examples of precipitation. There are different types of precipitation.

7. Sun shower:

A sun shower occurs when rain falls while the sun shines. In the absence of clouds, raindrops fall from the sky when rain-bearing winds blow several miles away.As a result, a sun shower occurs when a single rain cloud crosses the earth's surface, allowing the sun's rays to flow through. It is usually accompanied by a rainbow.

8. Grains of Snow:

Snow grains are tiny white ice grains. Snow grains are flat, with a diameter of about 1mm. They are almost as big as a drizzle.

9. Diamond Dust:

Diamond dust is made up of tiny ice crystals that occur at low altitudes and temperatures. The dazzling effect caused by light reflecting off ice crystals in the air gave diamond dust its name.

10. Ice Crystal:

This is a common occurrence in colder regions of the globe. The crystals resemble fog, with water particles freezing into ice. Ice crystals look similar to needles, plates, or columns in shape.

11. Virga:

Virga looks like a strip of rain that comes down from the cloud's base and evaporates before it reaches the ground. Dry or warm air is in the way when rain falls through it.

7.12.1. Types of Precipitation:

Precipitation occurs when the moist air mass undergoes the process of condensation. This process occurs when the air is cooled and saturated with the same moisture amount. This process of cooling the air mass occurs only when the air mass moves up to the higher altitudes. The air mass can be lifted to higher altitudes primarily by three methods based on which there are three different types of precipitation which are as follows:

Cyclonic Precipitation:

Convective Precipitation

Orographic Precipitation

1. Cyclonic Precipitation:

A cyclone is a region in the atmosphere that has a large low pressure having circular wind motion. The cyclonic precipitation is caused due to the movement of moist air mass to this region by the difference in pressure. Cyclonic precipitation is two types: frontal and non-frontal precipitation. Frontal Precipitation is known as the hot moist air mass boundary. This precipitation is caused due to the expansion of air near the frontal surface. Non-Frontal Precipitation is a cold moist air mass boundary that moves and results in precipitation.

2. Convective Precipitation:

The air above the land area gets heated up due to some cause. Most of this warmer air rises up, cools, and precipitates. Convective precipitation is showery by nature. This type of precipitation occurs in varying intensities.

3. Orographic Precipitation:

Moving air masses have a chance to strike barriers such as mountains. Once they strike, they rise up causing condensation and precipitation. The precipitation that occurs is greater on the windward side of the barrier when compared to the leeward side of the barrier.

7.13. Humidity

Humidity is the amount of moisture or water vapour or water molecules present in the atmospheric gas. The more water in the vapour, the higher the humidity. Humidity arises from water evaporating from places like lakes and oceans. Warm water evaporates quickly. So there are the most humid regions near. There are different types warm water bodies in places like the Red Sea, the Persian Gulf, and Miami. Humidity viz: specific, relative, and absolute humidity.

Types of Humidity:

Relative humidity

Specific humidity

Absolute humidity

Relative Humidity:

Relative Humidity

A meteorologist uses the term 'relative humidity'. The relative humidity is a comparison of the amount of moisture present in the air to the amount of moisture air can hold. The amount of moisture the atmosphere can hold totally depends on the temperature. The formula for the relative humidity that the Relative Humidity = Actual amount of water in the air/saturated amount of moisture in the air can hold at that temperature The relative humidity is the function of both water content (moisture) and the temperature. The relative humidity is 100% when the air is saturated with water vapour and 0% when no vapour is present in the atmosphere.

Relative Humidity Explained

The atmosphere is like sponge which is and it is capable of absorbing a fixed amount of water, i.e., a mug of water. Rise in temperature is like as an increase in the sponge size. When the sponge has no water, it means the relative humidity is zero. Now, pour a half bucket of water on the sponge, the relative humidity reaches 50%. We know that a sponge saturated with a half mug of water has 50% humidity, on increasing the size of the sponge (increasing the temperature) without adding water further, the relative humidity decreases because the sponge becomes bigger and is capable to take on water vapour; however, the amount of water remains the same. Soaking a sponge (atmosphere) with water more than the capacity it can hold can lead to dripping; however, it doesn't symbolize rainfall.

Rainfall:

Rainfall occurs when the rising air cannot hold enough water molecules that are gathered in the form of clouds in the sky.

Specific Humidity

Specific humidity is defined as the mass of water vapour present in a given unit mass of moist air. Specific humidity is equal to the ratio of water vapour mass and the air parcel's total (including dry) air mass. Specific humidity is also known as the humidity ratio. It does not change with the expansion or compression of an air parcel. We usually express specific heat as grams of vapour per kg of air, or in air conditioning as grains per pound. The specific humidity has great usage in meteorology.

Absolute Humidity:

The absolute humidity is defined the following sentences: Absolute humidity is equal to the mass of water vapour per unit of volume of air, i.e., grams of water/cm3 of air. The formula for the absolute humidity is given by:

$$\text{Absolute humidity} = \text{Mass of water/volume in cm}^3$$

Absolute humidity does not take temperature into consideration. Absolute humidity of atmosphere is between zero and approximately 30 gm/m3 when the air is saturated at 300 C .Dew point is frequently cited as a more accurate way of evaluating the humidity and comfort of the air than relative humidity because it is an absolute measurement, unlike relative humidity. When the dew point and temperature are the same, the relative humidity is 100 percent. Condensation will occur if the temperature falls lower, and liquid water will form. If the relative humidity is 100 percent, the dew point temperature and absolute air temperature is both the same. The precipitation is unlikely. It simply indicates that the maximum amount of moisture in the air is present at the current temperature. Fog on the surface and clouds in the sky are made up of microscopic water droplets suspended in the air. It can develop from saturation. While dew point provides a quick indication of air moisture content. When relative humidity is not proportional to air temperature. It can be put another way.

One can calculate relative humidity based on the dew point. The actual air temperature must be recorded. The actual saturation vapour pressure ratio is also known as relative humidity, where the real vapour pressure is a measurement of the amount of water vapour in a volume of air that rises with the amount of water vapour. At any given temperature, saturated vapour pressure is the greatest. Vapor Pressure that can exist. Water vapour, whose VP is its SVP at the given temperature, exists in the air with relative humidity (RH) of 100 percent. This is equivalent to air in a state of equilibrium with liquid water. RH is the percentage representation of the VP/SVP ratio. 'dry' air will contain water vapour at the given temperature with a VP smaller than the SVP.

Effects of Humidity:

Humidity can cause various uncomfortable conditions. Bacteria and viruses spread easily in humid conditions. People often fall sick, especially from respiratory issues. When the relative humidity goes above 60%, the viruses spread among people, and they get ill. The rise in the moisture content of air leads to the rise in temperature because of which the evaporation rate of sweat from our bodies slows. This slowdown leads to the following problems:

1. Overheating in our bodies
2. Exhausts easily,
3. Consequences are lethal to health like altered blood circulation, increased respiration rate, and sweating.
4. During humidity, higher levels of dust mites and fungi lead to allergies among people.
5. The spread of airborne chemical contaminants.
6. Detrimental to asthma sufferers.

What Method is used to Determine Humidity?

A hygrometer is mainly used to measure relative humidity. The basic hygrometer is a sling psychomotor consisting of two thermometers connected by a chain and a handle. A single thermometer is standard. The other is a wet-bulb thermometer, a cotton wick over its bulb. The temperature of the air is measured with a dry bulb thermometer. On the other hand, the wet-bulb thermometer has a moist cloth at the tip. As water molecules evaporate from the wet bulb's surface, they carry heat with them, decreasing the thermometer's reading. The vapour pressure, or the amount of water vapour in the air, determines the evaporation rate. No water will evaporate from the wet bulb at 100 percent relative humidity, and the readings on both thermometers will be the same. In a graph, comparing the two temperatures yields relative humidity results.

7.14. Summary

The main cause of climate change is the increase in greenhouse gas emissions, particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These gases trap heat in the atmosphere, leading to the greenhouse effect and subsequent warming of the planet. The Earth's average surface temperature has been steadily rising over the past century. This phenomenon, known as global warming, is a significant consequence of climate change. It leads to various impacts, including melting ice caps, rising sea levels, and more frequent and severe extreme weather events. The warming climate has accelerated the melting of glaciers and ice sheets in Polar Regions, such as Antarctica and Greenland. This contributes to rising sea levels, which pose a threat to coastal communities, low-lying islands, and ecosystems. Climate change is associated with an increase in extreme weather events, including heatwaves, hurricanes, droughts, and floods. These events have devastating consequences for human lives, infrastructure, agriculture, and natural habitats. Increased carbon dioxide in the atmosphere not only warms the planet but also gets absorbed by the oceans, leading to ocean acidification. This process negatively affects marine ecosystems, including coral reefs and shellfish, which depend on specific pH levels for their survival. Climate change has gained significant attention globally, with increasing calls for urgent action. Governments, businesses, and individuals are recognizing the need to transition to a low-carbon and sustainable future to mitigate the worst impacts of climate changes and safeguards the planet for future generations.

7.15. Terminal questions

Q.1: Explain what is the climate change? Explain region of climate change.

Answer:--

Q.2: What is weather? Discuss the role of wind in the formation of weather.

Answer:--

Q.3: What is the Earths Energy Budget? Discuss the atmospheric Energy Budget

Answer:--

Q.4: What are the Winds? Discuss the different types of winds

Answer:--

Q.5: What is the atmosphere? Discuss the composition of the Atmosphere.

Answer:--

Q.6: **Discuss the thermal structure of the atmosphere**

Answer:--

Q.7: What are precipitations? Discuss the types of precipitation.

Answer:--

7.16. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non-conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press.
5. Godfrey, Renewable Energy Power fora Sustainable Future, Boyle, Oxford University Press.

Unit-8: Monsoons

Contents

8.1. Introduction

The term monsoon is derived from Arabic word ‘mausim’ meaning ‘season’. Arabians were known to general pattern of winds in different seasons. As such, Arabians used to sail their ships for the movement of goods and people. It is believed that seamen used to describe alternating winds in Arabian Sea where they appear to blow from north east for six months and from southwest for another six months. A monsoon cyclone, also known as a tropical cyclone, is a large-scale weather system that develops over warm ocean waters and is characterized by strong winds, heavy rainfall, and storm surges. These cyclones typically occur during the monsoon season, which is a seasonal wind pattern that affects many parts of the world, including South Asia, Southeast Asia, and the south-western United States. Monsoon cyclones can be very destructive, causing damage to infrastructure, homes, and crops, and can result in loss of life. La Niña, on the other hand, is a climate pattern that occurs when sea surface temperatures in the central and eastern Pacific Ocean are cooler than normal. This can lead to changes in weather patterns around the world, including increased rainfall in some areas and droughts in others. La Niña is the opposite of El Niño, which is a climate pattern characterized by warmer than normal sea surface temperatures in the Pacific Ocean. La Niña can have significant impacts on global weather patterns, including increased hurricane activity in the Atlantic Ocean, colder than average temperatures in parts of North America, and increased rainfall in parts of South America and Africa. While there is no direct link between monsoon cyclones and La Niña, both weather phenomena can have significant impacts on global weather patterns and can lead to extreme weather events.

Objectives

- To discuss the Mansoon and weather
- To discuss the Cyclone and its types
- To discuss the El-Nino and La-Nino
- To discuss the Indian Ocean Dipole (IOD)

8.2 Monsoon overview

A mansoon is traditionally seasonal reversing wind accompanied by corresponding changes in precipitation but is now used to describe seasonal change in atmospheric circulation and precipitation associated with annual latitudinal oscillation of the Inter Tropical Convergence Zone (ITCZ) between its limits to the north and south of the equator. The term mansoon is used to refer to the rainy phase of a seasonally changing pattern. The term is also sometimes used to describe locally heavy but short-term rains. Term was first used in English in British India which refer to the big seasonal winds blowing from the Bay of Bengal and Arabian Sea in the southwest bringing heavy rainfall to the area

. The monsoon season in India start from June to September. During this time, the prevailing winds shift direction, bringing moisture-laden air from the ocean to the land. The result is often heavy rainfall, which can lead to flooding and landslides. A monsoon is a seasonal change in the direction of the prevailing, or strongest, winds of a region. The summer monsoon and the winter monsoon determine the climate for most of India and Southeast Asia. The monsoon is essential for agriculture in many regions, as it provides much-needed water for crops. However, too much rain can also be detrimental, as it can cause damage to crops and infrastructure. In addition, the monsoon can also affect air quality, as heavy rainfall can wash pollutants out of the atmosphere and onto the ground.

8.3. Summer monsoon

The summer monsoon is associated with heavy rainfall. It usually happens between April and September. As winter ends, warm, moist air from the southwest Indian Ocean blows toward countries like India, Sri Lanka, Bangladesh, and Myanmar. The summer monsoon brings a humid climate and torrential rainfall to these areas. Indian Monsoon is one of the most prominent monsoon systems around the world. It is depicted from the variation and amount of India's annual rainfall. Its effects are felt by India, the Indian subcontinent and the neighbouring water bodies of the Arabian Sea, the Bay of Bengal and the Indian Ocean. During the cold months, the direction of the monsoon is from the north-east, known as the north east monsoon in India. During the time of warmest months of the year the monsoon wind blows from the southwest hence known as the south west monsoon in India. This entire process leads to rainfall in India received during June and July.

Rainfall in India begins with the westerly winds that frequently occur throughout the year almost constantly, around the area near India at the Equator. On the other hand, the surface easterlies reach the latitudes near 20° N in February with a strong northerly component. Moving forward they retire north-side with serious changes in the upper-air circulation. During this time one season of monsoon ends and the next one begins. The high-sun season comes in late March when it reaches the Equator as the wind further moves north. This move takes with it the atmospheric instability, rising and turbulent clouds and rain. Across northern India, the subtropical jet stream towards the west controls the air-flow with the surface winds flowing from the north-east. After March, during April, the high-sun moves northward. This is the time when the summer season is ongoing in the Northern hemisphere. This is also summer time in India and as gradually time progresses the country becomes prone to heating as the cool winds from the north (the central lands in the Asian continent) are obstructed by the Himalayan mountain ranges and other highlands. The three areas around which there is a relative increase in temperature of the troposphere are the southern Bay of Bengal, Plateau of Tibet, and the trunks of various other dry peninsular regions. They are together form a very wide and large heat-source region. In the area over the southern Bay of Bengal, the atmospheric pressure is in-between 500-100 millibar pressure level because of the release of condensation heat from the cumulonimbus clouds along the intercontinental convergence zone. Opposite of this condition is a heat sink, created over the southern Indian Ocean when the cloud-free air cools down any radiation emitted from the surface. Because of the difference between the heat regions, the monsoon winds flow from the heat sink to the heat source. After April, the southwest monsoon gets well-established in May above Sri-Lanka. In May, the drier surface of Tibet absorbs the heat from the radiation of sun-rays and it is transmitted to the air into the troposphere above it. Following this, an anticyclone cell rises at 6000 feet above the surface which in turn causes a strong east wind flowing in the troposphere over north India. There is a sudden change of the subtropical jet stream of its course to the northern side of the anticyclonic ridge plus the highlands with brief intervals of southward wind flow. There is a change in the upper-tropospheric circulation above the northern region of India from the jet stream being westerly to easterly coinciding with the turnaround of the vertical temperature and pressure gradients with the range in-between 600-300 millibars. The inverted triangular peninsular region of India gets heated as the sun progresses towards the north. The accelerating heat in combination with the heat being transported by the winds provides the base for the initial monsoonal activity above the Arabian Sea. When the relative humidity of the coastal districts of India rises above 70%. It leads to some rain. Although the air was within 1500 meters above the heated land it was kept down by the east wind. This is the period of late May when there are also thunderstorms in the area, even though the rainfall hasn't started yet.

The Period of High Rainfall in India The jet stream of the east with 150-100 millibars pressure reaches the highest speed to the southern side of an anticyclonic ridge with a deviation of 15° N from China through India. This position of the jet stream controls the situation of the monsoonal rains. An unstable and strong south-western surface flow provides 80% of the humidity which is the major burst of the monsoon bringing the south-west monsoon. Even though the atmospheric pattern moves equally over the subcontinent, the amount of rainfall in India varies from place to place and year to year. When the early monsoon wind gets accumulated against the Western Ghats, it leads to most of the group of clouds providing major rainfall in the entire region beginning of summer monsoon in India. As the clouds are pushed against the hills some of the inland air absorbs some of the water. The complex pattern of rainfall in India is distributed variable from the region because of various factors such as topography. The oceanic air flowing below 6000 metres is deflected because of the Coriolis Effect. The oncoming air stream gets unstable due to fast convection above the hot land. Because of the thunderstorms and release of the latent heat from the towering clouds, the upper-tropospheric warm air travels northwest from ocean to land. But the main component of air above the 9000 metres altitude is a strong eastward flow. The monsoon gets well-established in the later part of June-July around the 6000 metres altitude. Moist, cloudy and warm weather is spread all over India bringing varying degrees of rainfall in India due to topographical differences. There are huge differences in the average rainfall of India. Examples include 1300 metres of rainfall in Khasi Hills, an average of 2500 metres in Cherapunji, etc. In the months of July-August, low-pressure waves occur in the monsoonal air which is now travelling from east to west. The easterly jet streams provide bursts of speed strengthening the low-level monsoon airflow. This causes an increase in the rainfall and wider distribution than June. When the east wind moves north over the southern Himalayas, heavy downpour occurs in those regions, leaving the central and south region dry. If the wind blows along the south face of the Himalayas, it brings dry weather in the north. On the other hand, the southwest monsoon air flowing over the Indus plain, cannot hold moisture and hence the area beyond remains dry, creating a new heat source.

Retreating Indian Monsoon:

As August proceeds, the intensity and duration of the sunshine decrease causing the temperature to fall and these results in the decrease raining in India due to the south-west monsoon, starting at the end of the monsoon in north India. In September the dry air from the North circulates the west of the highlands and above north-western India. By October there are variable winds all over India covered with northern air. As the surface flow turns to the northeast, it causes the winter monsoon in India or the northeast monsoon in October - December in the south and south-eastern parts. With the retreat of the moist winds, the monsoon time in India comes to an end. With most of India now in the sunny, dry, and dusty season, such weather spreads through Punjab in November, Central India, Bengal and Assam in December, Deccan in January and south Deccan in February. Following this, the cycle starts all over again. The Indian meteorological department is the body responsible for weather forecasting and monitoring and predicts the monsoon periods. It collects data from different weather patterns across the world for more accuracy. For example, for the forecast of early June, a positive correlation of the South American pressure and Indian upper-wind data is accounted for in April. Other such agencies include Skymet India which is a private agency of weather forecasting and rainfall in India prediction. In a nutshell the Indian monsoon patterns are very complex and it can be inferred from many factors making a geographical convergence of moist wind belts to bring rain to the country. Although rainfall in India is continuous from June to December due to different types of monsoon in India. However, June - September/October are considered to be the major rainy months in India. The Indian meteorological department of the Government of India is the major agency that tries its best to follow and understand the dynamics of wind patterns and predicts the forecast through a meticulous examination of various factors.

8.4. Cyclone

The term Cyclone is obtained from the Greek word Cyclones meaning the coils of a snake. This term is coined by Henry Peddington because the tropical storms in the Bay of Bengal and the Arabian Sea appear like coiled serpents.

The temperature variation between the warm, rising and cooler environment directed to the rise of air to convert floating and then moves upward. Then the high-pressure space fills the air in the low-pressure area. This cycle perpetuates as warm air rises and a low-pressure area packed with cool air. They build then, the entire system of clouds and breeze spins and grows, supported by the ocean's heat and water evaporating from the ocean.

Thus, the **reasons for the formation** of the cyclones can be sorted as

- Sufficient warm temperature at the sea surface
- Instability in the atmosphere
- The impact area of Coriolis, where low pressure is developed
- High humidity range in the lower middle levels of the troposphere
- Low-level focus and disturbances
- Low vertical wind range

8.4.1. Types of Cyclones

1. Tropical Cyclone

Tropical Cyclones occur over tropical ocean areas. The two types of Tropical Cyclones are **Hurricanes and Typhoons**. Particularly, Hurricanes are observed in the Atlantic and Northeast Pacific and Typhoons are found in the Northwest Pacific. Based on energy and wind speed. The cyclone is divided into five sections 1, 2, 3, 4 or 5. Section 5 becomes a wind speed of 155 mph or above.

When a tropical storm increases, the air rises in strong thunderstorms and manages to spread out horizontally at the tropopause level. Once air flows out, a positive disturbance pressure at high levels is presented, which accelerates the descending motion of air due to convection. Commonly, the 'Eye' of the storms has three basic shapes

- Circular
- Concentric
- Elliptical

A tropical cyclone starts to decline in times of its central low pressure, internal temperature and extremely high speeds, as soon as its origin of warm moist air begin to ebb, or is abruptly cut off. The weakening of a cyclone does not mean that the threat is over.

2. Polar Cyclone

The Polar Cyclone as the title suggests occurs over Polar Regions of Greenland, Siberia and Antarctica. It is active throughout the winter season. Polar vortices are most vulnerable during summer and strongest in winter.

3. Mesocyclone

The Mesocyclone is a whirlwind of air within a convective storm. It is the air that lifts and circulates a vertical axis, usually in the same direction as low-pressure systems in a given region. These types of cyclones are followed by the rotating air inside the thunderstorm.

List of Cyclones in India

Read here for the names of cyclones in India over certain years. Also know about the list of cyclones in India 2021 and about the biggest cyclone in India.

SL	**Name of the Cyclone**	**Year**	**About the Cyclone**
1	Cyclone Tauktae	2021	Tauktae caused massive rainfall and powerful gusty winds in South India, Gujarat, Goa and Maharashtra. Also, made landfall on the southern coast of the Saurashtra peninsula in Gujarat.
2	Cyclone Amphan	2020	The storm made landfall near the coastal town of Alibag in Maharashtra on June 3. It was the first cyclone to make landfall in Maharashtra after Cyclone Phyan in the year 2009
3	Fani	2019	Fani was a severe cyclonic storm that hit the Indian state of Odisha. Causing massive destruction killing over 40 people, eradicating trees and the communication system. Fani rapidly intensified into an extremely severe cyclonic storm and reached its peak intensity on May 2, as a high-end extremely severe cyclonic storm. It was equivalent to a high-end Category 4 major hurricane.
4	Cyclone Titli	2018	Cyclone Titli caused huge rainfall in western Uttar Pradesh and the Indian capital of New Delhi. Rainfall topped at Meerut in Uttar Pradesh which received 226 mm of rain in 24 hours. The river Yamuna passed the emergency level and moved to 205.5 meters by July

			29, resulting in evacuation.
5	Ockhi	2017	Cyclone Ockhi was the powerful and one of the most active tropical cyclone of the 2017 North Indian Ocean cyclone. Ockhi from the Arabian Sea struck mainland India along with coastal areas of Kerala, Tamil Nadu and Gujarat. A result of 245 people lost their lives as an impact of this cyclone
6	Vardah	2016	Vardah brought heavy rainfall to Andaman and Nicobar Islands and then crossed the eastern coast of India and affected Chennai, Kancheepuram and Visakhapatnam. 38 people had lost their lives in the aftermath of the cyclone. Originating as a low-pressure area near the Malay Peninsula on December 3, the storm designated a depression on December 6. It gradually intensified into a Deep Depression on the following day, skirting off the Andaman and Nicobar Islands, and intensified into a Cyclonic Storm on December 8.
7	Cyclone Komen	2015	Cyclonic Storm Komen after hitting Bangladesh penetrated India and produced the most serious flooding over East India killing 285 people.
8	Cyclone Hudhud	2014	Cyclone Hudhud was a heavy tropical cyclone, that created destruction to Visakhapatnam in Andhra Pradesh. Visakhapatnam or Vizag along with Odisha was mostly stirred by Hudhud. At least 124 people had lost their lives and caused massive destruction.
9	Phailin	2013	Cyclonic storm Phailin was the most powerful tropical cyclone. The system was first noted as a tropical depression on October 4, 2013, within the Gulf of Thailand, to the west of Phnom Penh in Cambodia.
10	Helen	2013	Helen was a comparatively weak tropical cyclone that developed in the Bay of Bengal Region on November 18, 2013, from the remains of Tropical Storm Podul. It was named Deep Depression BOB 06 by the IMD on November 19.
11	Nilam	2012	Nilam was the most dangerous tropical cyclone to immediately affect South India since Cyclone Jal in 2010. It reached landfall near Mahabalipuram on October 31 and seawater reached nearly 100 m (330 ft) inland. This cyclone recorded 75 deaths.
12	Thane	2011	Cyclonic Storm Thane created landfall over Cuddalore in Tamilnadu on 30 December which indicates the most advanced date for a cyclone to make landfall anywhere in the Indian Ocean.
13	Laila	2010	Storm Laila caused massive damage and 65 people were killed. It survived the first cyclone to hit South

			India during the pre-monsoon season in 20 years
14	Phyan	2009	Phyan emerged as a tropical disturbance to the southwest of Colombo in Sri Lanka on November 4, 2009. It made landfall in Southern India on November 7. Cyclone Phyan produced substantial rainfall in Tamil Nadu, Maharashtra and Gujarat.
15	Odisha Cyclone	1999	Odisha cyclone was the most energetic registered tropical cyclone in the North Indian Ocean and among the deadliest in the region. It formed into a tropical depression in the Andaman Sea on 25 October. The destruction leads to 15,000 deaths. Also in the record as the biggest cyclone in India.

8.4.2. Features of Cyclones in India

In the begging the cyclones were moved arbitrarily after boats, catholic saints etc. In the early 1900 feminine names were given to cyclones while male names included in 1979. They are names to help people remember them easily as technical terms are different to memories.

The Indian subcontinent is one of the most seriously affected regions in the world, which is exposed to nearly 10 per cent of the world's tropical cyclones. The majority of them have their origin over the Bay of Bengal and beat the East coast of India. On criterion, five to six tropical hurricanes form every year, of which two or three could be harsh and detrimental. Tropical cyclones happen in the periods of May-June and October-November. Storms of severe intensity and regularity in the North Indian Ocean are bi-modal and report individual cyclones, disseminate warnings increase community preparedness and ward off confusion in areas that witness multiple cyclones with their primary peak in November and secondary peak in May. The hazard potential is especially high during landfall in the North Indian Ocean. The cyclones that are formed in any ocean basin around the world are named by the Regional Specialised Metrological Centres (RSMCs) and Tropical Cyclone Warning Centres (TCWCs). There are a total of six RSMCs in the world including the Indian Metrological Department (IMD). In April 2020, IMD released a list of 169 cyclone names. Names makes it easier for media, scientific community and disaster management community to identity to identify.

Notably, the storm waves cause the greatest destruction as seawater submerges low lying areas of coastal regions and produces heavy floods. Cyclones range in diameter from 50 to 320 km but their results dominate thousands of square kilometers of the ocean surface and the lower atmosphere. Cyclones are identified by their destructive potential to ruin structures like houses, lifeline infrastructure and communication towers, hospitals, food storage facilities, roads etc.

Regional names of cyclone

1. Typhoons – China Sea
2. Tropical Cyclones – Indian Ocean
3. Hurricanes – Caribbean Sea
4. Tornadoes – USA
5. Wily Willies – Northern Australia
6. Baguio – Philippines
7. Taifu – Japan

8.4.3. Cyclone Prone Areas in India

According to the record maintained by the Meteorological Department of (IMD), India stated, that India is prone to storms and cyclones. The areas of Union Terrorises in India are prone to earthquakes, droughts and floods. The states namely, Andhra Pradesh, Odisha, Tamil-Nadu, UT Pondicherry, Gujarat, West Bengal are having the highest rate of possibility to be affected by cyclones and natural disasters.

Indian Meteorological Department

Indian Meteorological Department (IMD), formulated the following classification which sorts the low-pressure systems in the Bay of Bengal and the Arabian Sea based on capacity to damage.

Type of Disturbances	Wind Speed in Km/h	Wind Speed in Knots
Low Pressure	Less than 31	Less than 17
Depression	31-49	17-27
Deep Depression	49-61	27-33
Cyclonic Storm	61-88	33-47
Severe Cyclonic Storm	88-117	47-63
Super Cyclone	More than 221	More than 120

Here the cyclone classification is made as per the capacity of damage or destruction caused

Category	Wind Speed in Km/h	Damage Capacity
1	120-150	Minimal
2	150-180	Moderate
3	180-210	Extensive
4	210-250	Extreme
5	250 and above	Catastrophic

8.5. El-Nino

El Niño is a climate pattern that describes the unusual warming of surface waters in the eastern tropical Pacific Ocean. El Niño is the “warm phase” of a larger phenomenon called the El Niño-Southern Oscillation (ENSO). La Niña, the “cool phase” of ENSO, is a pattern that describes the unusual cooling of the region’s surface waters. El Niño and La Niña are considered the ocean part of ENSO, while the Southern Oscillation is its atmospheric changes.

El Niño has an impact on ocean temperatures, on the speed and strength of ocean currents, the health of coastal fisheries, and on the local weather from Australia to South America and beyond. El Niño events occur irregularly at two- to seven-year intervals. However, El Niño is not a regular cycle, or predictable in the sense that of ocean tides.

El Niño was recognized by fishers off the coast of Peru as the appearance of unusually warm water. We have no real record of what indigenous Peruvians called the phenomenon, but Spanish immigrants called it El Niño, meaning “the little boy” in Spanish. When capitalized, El Niño means the Christ Child, and was used because the phenomenon often arrived around Christmas. El Niño soon came to describe irregular and intense climate changes rather than just the warming of coastal surface waters.

Led by the work of Sir Gilbert Walker in the 1930s, climatologists determined that El Niño occurs simultaneously with the Southern Oscillation. The Southern Oscillation is a change in air pressure over the tropical Pacific Ocean. When coastal waters become warmer in the eastern tropical Pacific (El Niño), the atmospheric pressure above the ocean decreases. Climatologists define these linked phenomena as El Niño-Southern Oscillation (ENSO). Today, most scientists use the terms El Niño and ENSO interchangeably.

Scientists use the Oceanic Nino Index (ONI) to measure deviations from normal sea-surface temperatures. El Niño events are indicated by sea surface temperature that increases of more than 0.9° Fahrenheit for at least five successive three-month seasons. The intensity of El Niño events varies from weak temperature increases (about 4–5° F) with only moderate local effects on weather and climate to very strong increases (14–18° F) associated with worldwide climatic changes.

Upwelling

In order to understand the development of El Niño, it's important to be familiar with non-El Niño conditions in the Pacific Ocean. Normally, strong trade winds blow westward across the tropical Pacific, the region of the Pacific Ocean located between the Tropic of Cancer and the Tropic of Capricorn. These winds push warm surface water toward the western Pacific, where it borders Asia and Australia.

Due to the warm trade winds, the sea surface is normally about 0.5 meter (1.5 feet) higher and 7.2° C (45° F) warmer in Indonesia than Ecuador. The westward movement of warmer waters causes cooler waters to rise up toward the surface on the coasts of Ecuador, Peru, and Chile. This process is known as upwelling.

Upwelling elevates cold, nutrient-rich water to the euphotic zone, the upper layer of the ocean. Nutrients in the cold water include nitrates and phosphates. Tiny organisms called phytoplankton use them for photosynthesis, the process that creates chemical energy from sunlight. Other organisms, such as clams, eat the plankton, while predators like fish or marine mammals prey on clams.

Upwelling provides food for a wide variety of marine life, including most major fisheries. Fishing is one of the primary industries of Peru, Ecuador, and Chile. Some of the fisheries include anchovy, sardine, mackerel, shrimp, tuna, and hake.

The upwelling process also influences global climate. The warm ocean temperature in the western Pacific contributes to increased rainfall around the islands of Indonesia and New Guinea. The air influenced by the cool eastern Pacific, along the coast of South America, remains relatively dry.

8.5.1. El Niño Events

The EL Nino is the name given to the strong, recurring climate pattern over the tropical pacific ocean. It has widespread impact on the global climate and hurricane society. El-Nino can cause dry, inadequate monsoon in the summer and wind weather over the Indian, sub-continental in the winter. As a result, it affects agriculture and results draughtiness. Crops including peanuts, maize, guar, castor, moog are many more suffer greatly under El-Nino conditions.

El Niño events are defined by their wide-ranging teleconnections. Teleconnections are large-scale, long-lasting climate anomalies or patterns that are related to each other and can affect much of the globe. During an El Niño event, westward-blowing trade winds weaken along the Equator. These changes in air pressure and wind speed cause warm surface water to move eastward along the Equator, from the western Pacific to the coast of northern South America.

These warm surface waters deepen the thermo cline, the level of ocean depth that separates warm surface water from the colder water below. During an El Niño event, the thermocline can dip as far as 152 meters (500 feet). This thick layer of warm water does not allow normal upwelling to occur. Without an upwelling of nutrient-rich cold water, the euphotic zone of the eastern Pacific can no longer support its normally productive coastal ecosystem. Fish populations die or migrate. El Niño has a devastating impact on Ecuadorian and Peruvian economies.

El Niño also produces widespread and sometimes severe changes in the climate. Convection above warmer surface waters bring increased precipitation. Rainfall increases drastically in Ecuador and northern Peru, contributing to coastal flooding and erosion. Rains and floods may destroy homes, schools, hospitals, and businesses. They also limit transportation and destroy crops. As El Niño brings rain to South America, it brings droughts to Indonesia and Australia. These droughts threaten the region's water supplies, as reservoirs dry and rivers carry less water. Agriculture, which depends on water for irrigation, is threatened.

Stronger El Niño events also disrupt global atmospheric circulation. Global atmospheric circulation is the large-scale movement of air that helps distribute thermal energy (heat) across the surface of Earth. The eastward movement of oceanic and atmospheric heat sources cause unusually severe winter weather at the higher latitudes of North and South

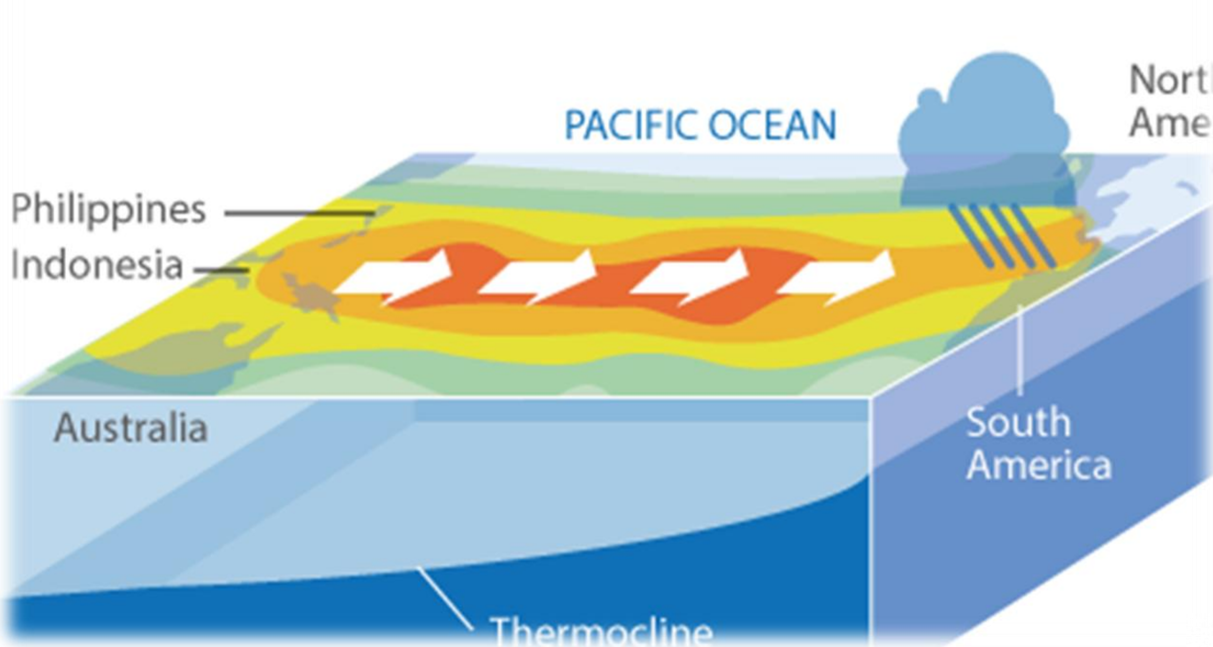
America. Regions as far north as the U.S. states of California and Washington may experience longer, colder winters because of El Niño.

El Niño events of 1982-83 and 1997-98 were the most intense of the 20th century. During the 1982-83 events, sea-surface temperatures in the eastern tropical Pacific rise to 7.8-12.8° C (9-18° F) above normal. These strong temperature increases caused severe climatic changes: Australia experienced harsh drought conditions; typhoons occurred in Tahiti; and record rainfall and flooding hit central Chile. The west coast of North America was unusually stormy during the winter season, and fish catches were dramatically reduced from Chile to the U.S. state of Alaska.

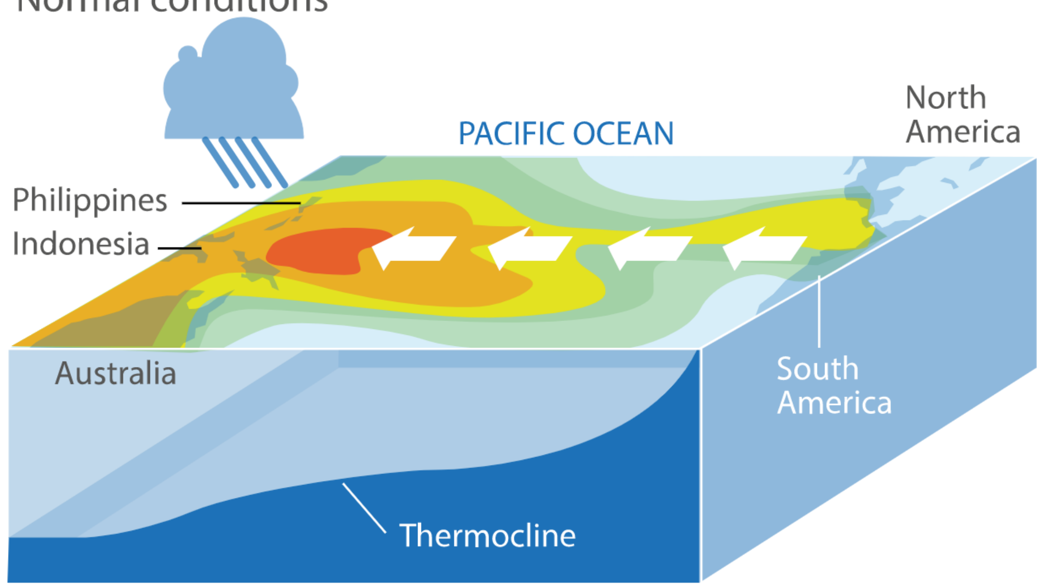
The El Niño event of 1997-98 was the first El Niño event to be scientifically monitored from beginning to end. The 1997-98 event produced drought conditions in Indonesia, Malaysia, and the Philippines. Peru experienced very heavy rains and severe flooding. In the United States, increased winter rainfall hit California, while the Midwest experienced record-breaking warm temperatures during a period known as "the year without a winter."

El Niño-related disruption of global atmospheric circulation extends beyond Pacific Rim nations. Strong El Niño events contribute to weaker monsoons in India and Southeast Asia. ENSO has even contributed to increased rainfall during the rainy season in sub-Saharan Africa. Diseases thrive in communities devastated by natural hazards such as flood or drought. El Niño-related flooding is associated with increases in cholera, dengue, and malaria in some parts of the world, while drought can lead to wildfires that produce respiratory problems.

El Niño conditions



Normal conditions



8.6. La-Nina:

La Niña is a climate pattern that describes the cooling of surface-ocean waters along the tropical west coast of South America. La Niña is considered to be the counterpart to El Niño, which is characterized by unusually warm ocean temperatures in the equatorial region of the Pacific Ocean.

Together, La Niña and El Niño are the "cold" (La Niña) and "warm" (El Niño) phases of the El Nino-Southern Oscillation (ENSO). ENSO is series of linked weather- and ocean-related phenomena. Besides unusually warm or cool sea-surface temperatures, ENSO is also characterized by changes in atmospheric pressure.

La Niña events sometimes follow El Niño events, which occur at irregular intervals of about two to seven years. The local effects on weather caused by La Niña ("little girl" in Spanish) are generally the opposite of those associated with El Niño ("little boy" in Spanish). For this reason, La Niña is also called anti-El Niño and El Viejo (the old man in Spanish).

Scientists use the Oceanic Nino Index to measure the deviations from normal sea-surface temperatures that El Niño and La Niña produce in the east-central Pacific Ocean. La Niña events are indicated by sea-surface temperature decrease of more than 0.5 degrees Celsius (0.9 degrees Fahrenheit) for at least five successive three-month seasons.

La Niña is caused by a build-up of cooler-than-normal waters in the tropical Pacific, area of the Pacific Ocean between the Tropic of Cancer and the Tropic of Capricorn. Unusually strong, eastward-moving trade winds and ocean currents bring this cold water to the surface, a process known as upwelling. Upwelling can cause a drastic drop in sea-surface temperature.

Coastal sea-surface temperatures near Ecuador and Peru dropped nearly 4 degrees Celsius (7 degrees Fahrenheit) during the 1988-89 La Niña events.

8.6.1. Effects of La Niña

Both El Niño and La Niña affect patterns of rainfall, atmospheric pressure, and global atmospheric circulation. Atmospheric circulation is the large-scale movement of air that, together with ocean currents, distributes thermal energy on the surface of Earth. These changes are the main sources of variability in climate for many areas worldwide.

La Niña is characterized by lower-than-normal air pressure over the western Pacific. These low-pressure zones contribute to increased rainfall. Rainfall associated with the summer monsoon in Southeast Asia tends to be greater than normal, especially in northwest India and Bangladesh. This generally benefits the Indian economy, which depends on the monsoon for agriculture and industry. However, strong La Niña events are associated with catastrophic floods in northern Australia. The 2010 La Niña event correlates with one of the worst floods in the history of Queensland, Australia. More than 10,000 people were forced to evacuate, and damage from the disaster was estimated at more than two billion dollars.

La Niña events are also associated with rainier-than-normal conditions are over south-eastern Africa and northern Brazil. La Niña is also characterized by higher-than-normal pressure over the central and eastern Pacific. This results in decreased cloud production and rainfall in that region. Drier-than-normal conditions are observed along the west coast of tropical South America, the Gulf Coast of the United States, and the pampas region of southern South America.

La Niña usually has a positive impact on the fishing industry of western South America. Upwelling brings cold, nutrient-rich waters to the surface. Nutrients include plankton eaten by fish and crustaceans. Higher-level predators, including high-value fish species such as sea bass, prey on the crustaceans.

La Niña events may last between one and three years, unlike El Niño, which usually lasts no more than a year. Both phenomena tend to peak during the Northern Hemisphere winter.

8.7. The Indian Ocean Dipole (IOD)

The Indian Ocean Dipole (IOD) is defined by the difference in sea surface temperature between two areas (or poles, hence a dipole) – a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the eastern Indian Ocean south of Indonesia. The IOD affects the climate of Australia and other countries that surround the Indian Ocean Basin, and is a significant contributor to rainfall variability in this region.

Like ENSO, the change in temperature gradients across the Indian Ocean results in changes in the preferred regions of rising and descending moisture and air.

In scientific terms, the IOD is a coupled ocean and atmosphere phenomenon, similar to ENSO but in the equatorial Indian Ocean. It is thought that the IOD has a link with ENSO events through an extension of the Walker Circulation to the west and associated Indonesian throughflow (the flow of warm tropical ocean water from the Pacific into the Indian Ocean). Hence, positive IOD events are often associated with El Niño and negative events with La Niña. When the IOD and ENSO are in phase the impacts of El Niño and La Niña events are often most extreme over Australia, while when they are out of phase the impacts of El Niño and La Niña events can be diminished.

Positive event:

- warmer sea surface temperatures in the western Indian Ocean relative to the east
- easterly wind anomalies across the Indian Ocean and less cloudiness to Australia's northwest
- Less rainfall over southern Australia and the Top End.

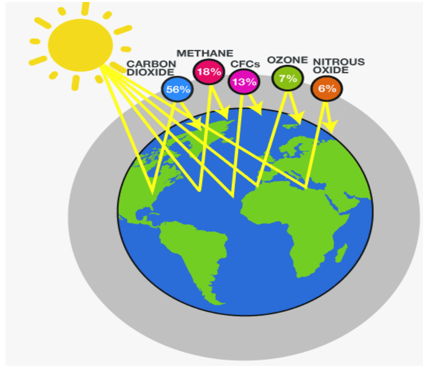
Negative event:

- cooler sea surface temperatures in the western Indian Ocean relative to the east
- winds become more westerly, bringing increased cloudiness to Australia's northwest
- more rainfall in the Top End and southern Australia.

8.8. Green House Effect:

Definition

“Greenhouse effect is the process by which radiations from the sun are absorbed by the greenhouse gases and not reflected back into space. This insulates the surface of the earth and prevents it from freezing.”



What is the Greenhouse Effect?

A greenhouse is a house made of glass that can be used to grow plants. The sun's radiations warm the plants and the air inside the greenhouse. The heat trapped inside can't escape out and warms the greenhouse which is essential for the growth of the plants. Same is the case in the earth's atmosphere.

During the day the sun heats up the earth's atmosphere. At night, when the earth cools down the heat is radiated back into the atmosphere. During this process, the heat is absorbed by the greenhouse gases in the earth's atmosphere. This is what makes the surface of the earth warmer that makes the survival of living beings on earth possible.

However, due to the increased levels of greenhouse gases, the temperature of the earth has increased considerably. This has led to several drastic effects.

The major contributors to the greenhouse gases are factories, automobiles, deforestation, etc. The increased number of factories and automobiles increases the amount of these gases in the atmosphere. The greenhouse gases never let the radiations escape from the earth and increase the surface temperature of the earth. This then leads to global warming.

Causes of Greenhouse Effect

The major causes of the greenhouse effect are:

- **Burning of Fossil Fuels**

Fossil fuels are an important part of our lives. They are widely used in transportation and to produce electricity. Burning of fossil fuels releases carbon dioxide. With the increase in population, the utilization of fossil fuels has increased. This has led to an increase in the release of greenhouse gases in the atmosphere.

- **Deforestation**

Plants and trees take in carbon dioxide and release oxygen. Due to the cutting of trees, there is a considerable increase in the greenhouse gases which increases the earth's temperature.

- **Farming**

Nitrous oxide used in fertilizers is one of the contributors to the greenhouse effect in the atmosphere.

- **Industrial Waste and Landfills**

The industries and factories produce harmful gases which are released in the atmosphere. Landfills also release carbon dioxide and methane that adds to the greenhouse gases.

Effects of Greenhouse Effect

The main effects of increased greenhouse gases are:

- **Global Warming**

It is the phenomenon of a gradual increase in the average temperature of the Earth's atmosphere. The main cause for this environmental issue is the increased volumes of greenhouse gases such as carbon dioxide and methane released by the burning of fossil fuels, emissions from the vehicles, industries and other human activities.

- **Depletion of Ozone Layer**

Ozone Layer protects the earth from harmful ultraviolet rays from the sun. It is found in the upper regions of the stratosphere. The depletion of the ozone layer results in the entry of the harmful UV rays to the earth's surface that might lead to skin cancer and can also change the climate drastically.

The major cause of this phenomenon is the accumulation of natural greenhouse gases including chlorofluorocarbons, carbon dioxide, methane, etc.

- **Smog and Air Pollution**

Smog is formed by the combination of smoke and fog. It can be caused both by natural means and man-made activities.

In general, smog is generally formed by the accumulation of more greenhouse gases including nitrogen and sulfur oxides. The major contributors to the formation of smog are automobile and industrial emissions, agricultural fires, natural forest fires and the reaction of these chemicals among themselves.

- **Acidification of Water Bodies**

Increase in the total amount of greenhouse gases in the air has turned most of the world's water bodies acidic. The greenhouse gases mix with the rainwater and fall as acid rain. This leads to the acidification of water bodies. Also, the rainwater carries the contaminants along with it and falls into the river, streams and lakes thereby causing their acidification.

- **Runaway Greenhouse Effect**

This phenomenon occurs when the planet absorbs more radiation than it can radiate back. Thus, the heat lost from the earth's surface is less and the temperature of the planet keeps rising. Scientists believe that this phenomenon took place on the surface of Venus billions of years ago. This phenomenon is believed to have occurred in the following manner:

- A runaway greenhouse effect arises when the temperature of a planet rises to a level of the boiling point of water. As a result, all the water from the oceans converts into water vapour, which traps more heat coming from the sun and further increases the planet's temperature. This eventually accelerates the greenhouse effect. This is also called the "positive feedback loop".
- There is another scenario giving way to the runaway greenhouse effect. Suppose the temperature rise due to the above causes reaches such a high level that the chemical reactions begin to occur. These chemical reactions drive carbon dioxide from the rocks into the atmosphere. This would heat the surface of the planet which would further accelerate the transfer of carbon dioxide from the rocks to the atmosphere, giving rise to the runaway greenhouse effect. In simple words, increasing the greenhouse effect gives rise to a runaway greenhouse effect which would increase the temperature of the earth to such an extent that no life will exist in the near future.

8.9. Summary

Global warming is the phenomenon of a gradual increase in the average temperature of the Earth’s atmosphere. A greenhouse is a house made of glass that can be used to grow plants. The sun’s radiations warm the plants and the air inside the greenhouse. The heat trapped inside can’t escape out and warms the greenhouse which is essential for the growth of the plants. Same is the case in the earth’s atmosphere. El Niño was recognized by fishers off the coast of Peru as the appearance of unusually warm water. We have no real record of what indigenous Peruvians called the phenomenon, but Spanish immigrants called it El Niño, meaning “the little boy” in Spanish. La Niña usually has a positive impact on the fishing industry of western South America. Upwelling brings cold, nutrient-rich waters to the surface. Nutrients include plankton eaten by fish and crustaceans.

8.10. Terminal questions

Monsoon cyclones are large-scale weather systems that develop over warm ocean waters and are characterized by strong winds, heavy rainfall, and storm surges. They typically occur during the monsoon season in many parts of the world, including South Asia, Southeast Asia, and the south-western United States. Monsoon cyclones can cause significant damage to infrastructure, homes, and crops, and can result in loss of life. The greenhouse effect is a process in which certain gases in Earth's atmosphere, such as carbon dioxide, water vapor, and methane, trap heat from the sun and cause the Earth's temperature to rise. This can lead to climate change and can have significant impacts on global weather patterns and ecosystems. There is no direct link between monsoon cyclones and the greenhouse effect, but the greenhouse effect can contribute to climate change, which in turn can affect the frequency and intensity of extreme weather events like monsoon cyclones. Climate change can also lead to rising sea levels, which can exacerbate the impacts of storm surges during cyclones.

8.11. Terminal questions

Q.1. **What are monsoon? Discuss the summer monsoon of India.**

Answer:--

-

Q.2. **What are Cyclones: Discuss the types of Cyclones** in India.

Answer:--

-

Q.3. Discuss about the Cyclone Prone Areas in India.

Answer:--

-

Q.4. What is the El-Niño? Discuss about **El Niño Events.**

Answer:--

-

Q.5. What is the La-Niña? Discuss about **La Niña Events.**

Answer:--

-

Q.6. **Discuss about the** The Indian Ocean Dipole (IOD).

Answer:--

-

Q.7. What are Green House Effects? Write the major cause of green house effects.

Answer:--

-

8.12. Suggested further readings

12. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011

13. Non conventional Energy Resources, D.S. Chauhan, New Age International.

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

15. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey," Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.

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

Unit-9: Green House Effects and Global Warming

Contents

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9.1. Introduction

The greenhouse effect is a term that describes how natural gases in the earth's atmosphere reduce the amount of heat escaping from the earth into the atmosphere. Greenhouses work by trapping heat from the sun. The glass panels of the greenhouse let in light but keep heat from escaping. Greenhouse gasses are those which cause the Greenhouse effect. The Methane, Nitrous Oxide, Carbon dioxide and Water Vapour are green house gases responsible of global warming. The global warming trend is expected to bring droughts and flooding of low lying coastal areas as the polar ice caps melt and raise sea level. The expected negative impact of the greenhouse effect on human life. It has been assessed by some scientists to be second only to global nuclear war. The average global temperature has increased by almost 1º F over the past century. Scientists predicted that the average global temperature will increase to additional 2º to 6º F over the next hundred years. Even a small increase in temperature over a long time can change the climate.

Objectives

- To discuss the green house gases, its sources and sinks
- To discuss the human impacts of green house gases
- To discuss the urban heat island
- To discuss the ozone depletion

9.2. Green House Gases

Gases that trap heat in **Green House Gases:** This section provides information on regarding emissions and removals of the main greenhouse gases from the atmosphere. Here are a few of the gases that can play a part in climate changes. Water vapour is the most abundant fast that plays a part in the greenhouse effects. It increases because the earth is getting warmer and it also makes more clouds and precipitation.

- **Carbon dioxide (CO_2)**: Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). Through are verities of different processes including respiration, volcanic activity and deforestation. Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.

- **Methane (CH_4)**: Methane which is a hydrogen gas is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from domestic livestock and other agricultural practices, land use and by the decay of organic waste in municipal solid waste landfills. These gases are active in the greenhouse effect, leading to more climate change.
- **Nitrous oxide (N_2O)**: Nitrous oxide is emitted during agricultural, land use, and industrial activities; combustion of fossil fuels and solid waste; as well as during treatment of wastewater.
- **Fluorinated gases**: Hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of household, commercial, and industrial applications and processes. Fluorinated gases (especially hydrofluorocarbons) are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). Fluorinated gases are typically emitted in smaller quantities other than greenhouse gases, but they are potent greenhouse gases. With global warming potentials (GWPs) that typically range from thousands to tens of thousands, they are sometimes referred to as high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO_2.

9.2.1. Emission of Carbon Dioxide

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. In 2020, CO_2 accounted for about 79% of all U.S. greenhouse gas emissions from human activities. Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle–both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests and soils, to remove and store CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution.

The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. Certain industrial processes and land-use changes also emit CO_2. The main sources of CO_2 underlined below.

- **Transportation**: The combustion of fossil fuels such as gasoline and diesel to transport people and goods was the largest source of CO_2 emissions in 2020, accounting for about 33% of total U.S. CO_2 emissions and 26% of total greenhouse gas emissions. This category includes domestic transportation sources such as highway and passenger vehicles, air travel, marine transportation, and rail.
- **Electricity**. Electricity is a significant source of energy and is used to power homes, business, and industry. In 2020, the combustion of fossil fuels to generate electricity was the second largest source of CO_2 emissions accounting 31% of total CO_2 emissions and 24% of total greenhouse gas emissions. The types of fossil fuel used to generate electricity emit different amounts of CO_2. To produce a given amount of electricity, burning coal will produce more CO_2 than natural gas or oil.
- **Industry**. Many industrial processes emit CO_2 through fossil fuel consumption. Several processes also produce CO_2 emissions that do not involve combustion for examples the production of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. The fossil fuel combustion component of various industrial processes accounted for about 16% of total. CO_2 emissions and 13% of total greenhouse gas emissions in 2020. Many industrial processes also use electricity and therefore indirectly result in CO_2 emissions from electricity generation.

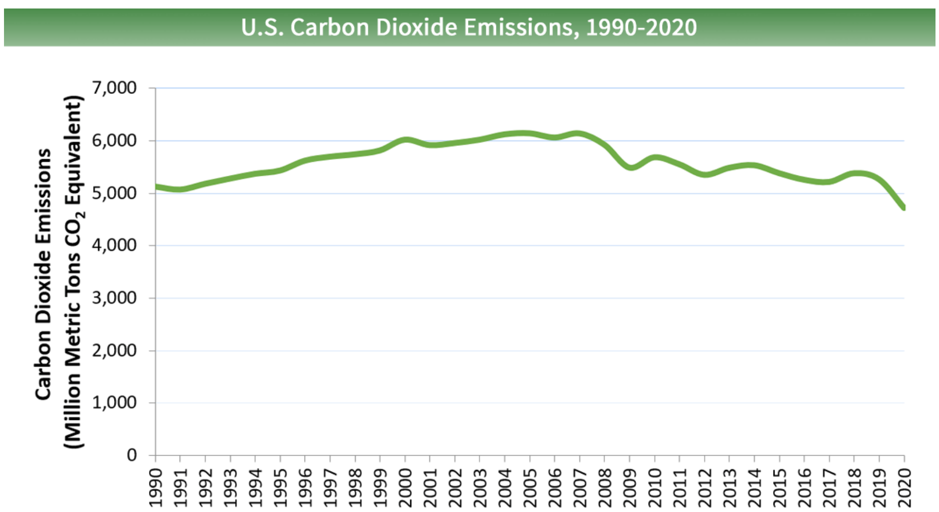
Carbon dioxide is constantly being exchanged among the atmosphere, ocean, and land surface as it is both produced and absorbed by many microorganisms, plants, and animals. Emissions and removal of CO_2 by these natural processes, however, tend to balance, absent anthropogenic impacts. Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere.

In the United States, the management of forests and other land (e.g., cropland, grasslands, etc.) has acted as a net sink of CO_2, which means that more CO_2 is removed from the atmosphere, and stored in plants and trees, than is emitted. This carbon sink offset is about

14% of total emissions in 2020 and is discussed in more detail in the Land Use, Land-Use Change, and Forestry section.

- **Emissions and Trends**

Carbon dioxide emissions in the United States decreased by about 8% between 1990 and 2020 Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population growth, economic growth, changing energy prices, new technologies, changing behaviour, and seasonal temperatures. In 2020, the decrease in CO_2 emissions from fossil fuel combustion corresponded with a decrease in energy use as a result of decreases in economic, manufacturing, and travel activity in response to the corona virus pandemic, in addition to a continued shift from coal to less carbon-intensive natural gas and renewable in the electric power sector.



Reducing Carbon Dioxide Emissions

The most effective way to reduce CO_2 emissions is to reduce fossil fuel consumption. It should be replaced with renewable and efficient energy sources. Transiting from fossil fuels to the key to winning the fight against climate change. EPA is taking common sense regulatory actions to reduce greenhouse gas emissions.

- Learn about EPA's motor vehicle standards.

Examples of Reduction Opportunities for Carbon Dioxide	
Strategy	**Examples of How Emissions Can be Reduced**
Energy Efficiency	Improving the insulation of buildings, travelling in more fuel-efficient vehicles, and using more efficient electrical appliances are all ways to

	reduce energy use, and thus CO_2 emissions.
Energy Conservation	Reducing personal energy use by turning off lights and electronics when not in use reduces electricity demand. Reducing distance travelled in vehicles reduces petroleum consumption. Both are ways to reduce energy CO_2 emissions through conservation.
Fuel Switching	Producing more energy from renewable sources and using fuels with lower carbon contents are ways to reduce carbon emissions.
Carbon Capture and Sequestration (CCS)	Carbon dioxide capture and sequestration is a set of technologies that can potentially reduce CO_2 emissions from new and existing coal- and gas-fired power plants, industrial processes, and other stationary sources of CO_2. For example, a CCS project might capture CO_2 from the stacks of a coal-fired power plant before it enters the atmosphere, transport the CO_2 via pipeline, and inject the CO_2 deep underground at a carefully selected and suitable subsurface geologic formation, such as a nearby abandoned oil field, where it is securely stored.

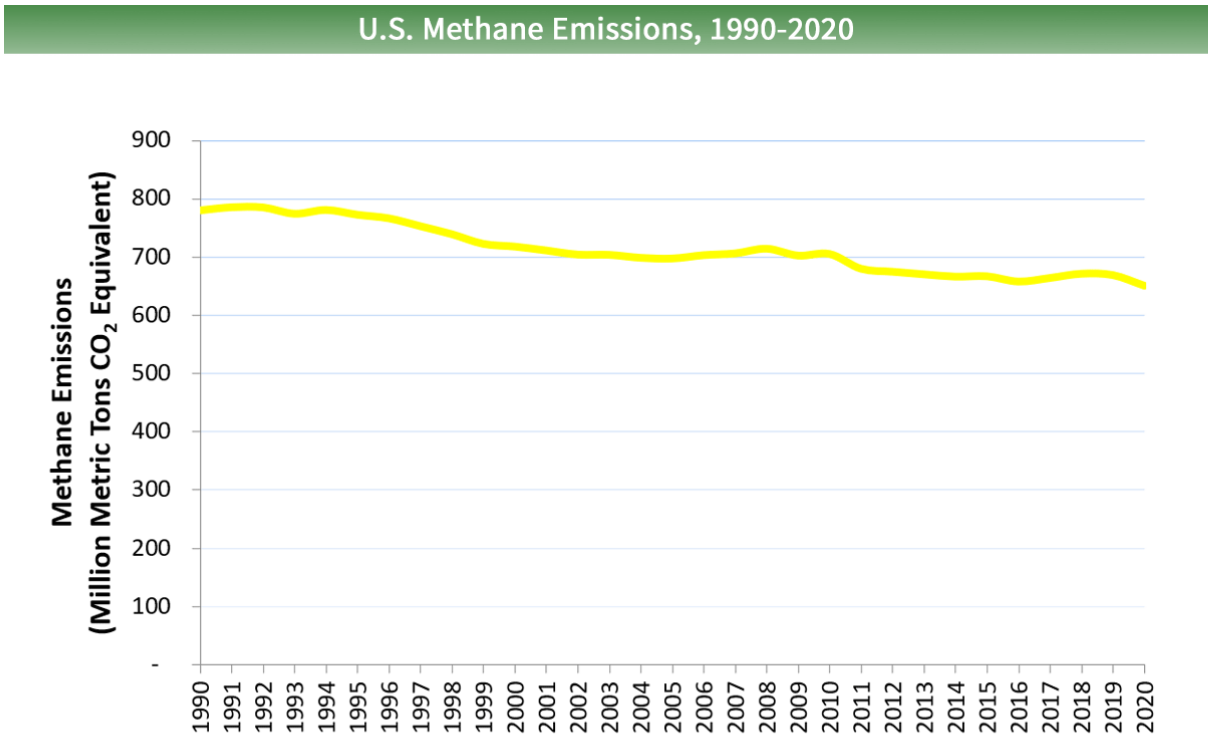
9.2.2. Methane Emissions

In 2020, methane (CH_4) accounted for about 11% of all U.S. greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and the raising of livestock. Methane is also emitted by natural sources such as natural wetlands. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH_4 from the atmosphere. Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 is more efficient at trapping radiation than CO_2. Pound for pound, the comparative impact of CH_4 is 25 times greater than CO_2 over a 100-year period.[1]

Globally, 50-65% of total CH_4 emissions come from human activities.[2, 3] Methane is emitted from energy, industry, agriculture, land use, and waste management activities, described below.

- Agriculture. Domestic livestock such as cattle, swine, sheep, and goats produce CH_4 as part of their normal digestive process. Also, when animal manure is stored or managed in lagoons or holding tanks, CH_4 is produced. Because humans raise these animals for food and other products, the emissions are considered human-related. The Agriculture sector is the largest source of CH_4 emissions in the United States. While not shown in the figure and less significant, emissions of CH_4 also occur as a result of land use and land management activities in the Land Use, Land-Use Change, and Forestry sector (e.g. forest and grassland fires, decomposition of organic matter in coastal wetlands).
- Energy and Industry. Natural gas and petroleum systems are the second largest source of CH_4 emissions in the United States. Methane is the primary component of natural gas. Methane is emitted to the atmosphere during the production, processing, storage, transmission, and distribution of natural gas and the production, refinement, transportation, and storage of crude oil. Coal mining is also a source of CH_4 emissions.
- **Waste from Homes and Businesses.** Methane is generated in landfills as waste decomposes and in the treatment of wastewater. Landfills are the third-largest source of CH_4 emissions in the United States. Methane is also generated from domestic and industrial wastewater treatment and from composting and anaerobic digestion. Methane is also emitted from a number of natural sources. Natural wetlands are the largest source, emitting CH_4 from bacteria that decompose organic materials in the absence of oxygen. Smaller sources include termites, oceans, sediments, volcanoes, and wildfires.
- **Emissions and Trends**

Methane emissions in the United States decreased by 17% between 1990 and 2020. During this time period, emissions increased from sources associated with agricultural activities, while emissions decreased from other sources including landfills and coal mining and from natural gas and petroleum systems.



Reducing Methane Emissions

There are a number of ways to reduce CH_4 emissions. EPA has a series of voluntary programs for reducing CH_4 emissions, in addition to regulatory initiatives. EPA also supports the Global Methane Initiative, an international partnership encouraging global methane reduction strategies.

Examples of Reduction Opportunities for Methane	
Emissions Source	**How Emissions Can be Reduced**
Industry	Upgrading the equipment used to produce, store, and transport oil and natural gas can reduce many of the leaks that contribute to CH_4 emissions. Methane from coal mines can also be captured and used for energy.
Agriculture	Methane from manure management practices can be reduced and captured by altering manure management strategies. Additionally, modifications to animal feeding practices may reduce emissions from enteric fermentation.
Waste from Homes and Businesses	Because CH_4 emissions from landfill gas are a major source of CH_4 emissions in the United States, emission controls that capture landfill CH_4 are an effective reduction strategy. .

9.2.3. Emission of Nitrous Oxide:

In 2020, nitrous oxide (N_2O) accounted for about 7% of all U.S. greenhouse gas emissions from human activities. Human activities such as agriculture, fuel combustion, wastewater management, and industrial processes are increasing the amount of N_2O in the atmosphere. Nitrous oxide is also naturally present in the atmosphere as part of the Earth's nitrogen cycle and has a variety of natural sources. Nitrous oxide molecules stay in the atmosphere for an average of 114 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 pound of N_2O on warming the atmosphere is almost 300 times that of 1 pound of carbon dioxide.[1]

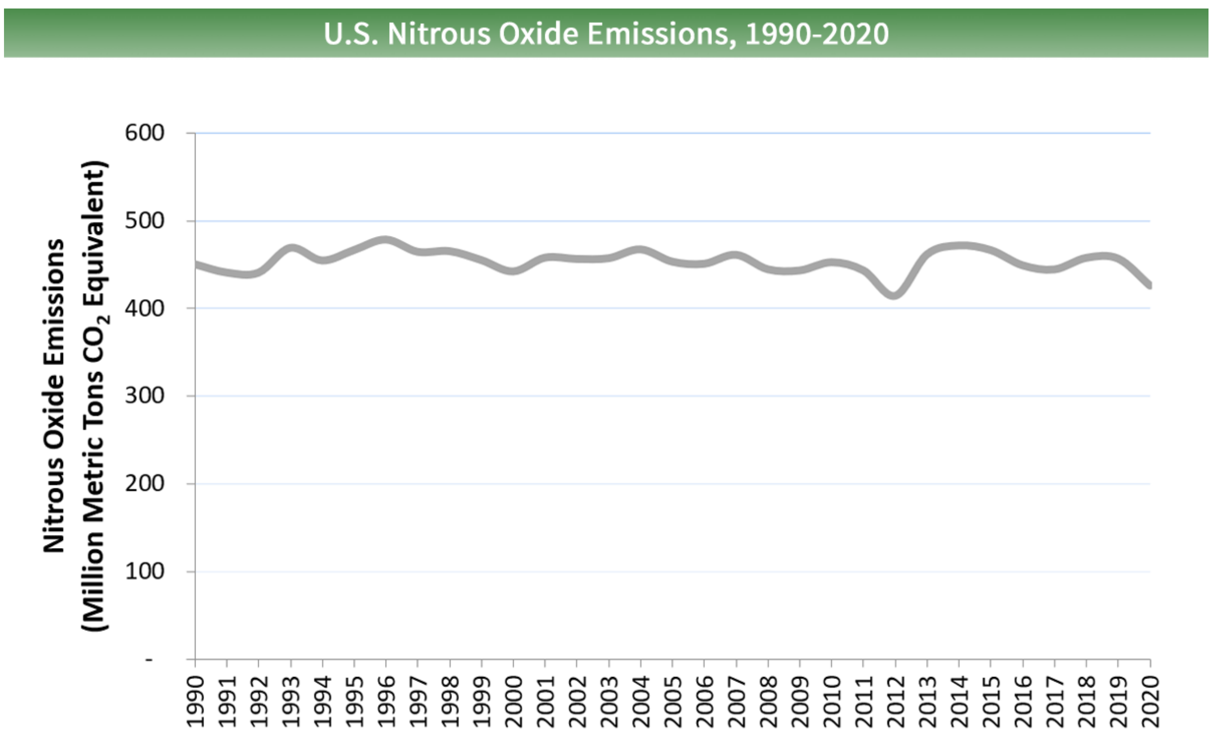
Globally, about 40% of total N_2O emissions come from human activities. Nitrous oxide is emitted from agriculture, land use, transportation, industry, and other activities, described below.

- **Agriculture.** Nitrous oxide can result from various agricultural soil management activities, such as application of synthetic and organic fertilizers and other cropping practices, the management of manure, or burning of agricultural residues. Agricultural soil management is the largest source of N_2O emissions in the United States, accounting for about 74% of total U.S. N_2O emissions in 2020. Emissions of N_2O also occur as a result of land use and land management activities in the Land Use, Land-Use Change, and Forestry sector (e.g. forest and grassland fires, application of synthetic nitrogen fertilizers to urban soils (e.g., lawns, golf courses) and forest lands, etc.).
- Fuel Combustion**.** Nitrous oxide is emitted when fuels are burned. The amount of N_2O emitted from burning fuels depends on the type of fuel and combustion technology, maintenance, and operating practices.
- Industry**.** Nitrous oxide is generated as a byproduct during the production of chemicals such as nitric acid, which is used to make synthetic commercial fertilizer, and in the production of adipic acid, which is used to make fibers, like nylon, and other synthetic products.
- Waste**.** Nitrous oxide is also generated from treatment of domestic wastewater during nitrification and denitrification of the nitrogen present, usually in the form of urea, ammonia, and proteins. Nitrous oxide emissions occur naturally through many sources

associated with the nitrogen cycle, which is the natural circulation of nitrogen among the atmosphere, plants, animals, and microorganisms that live in soil and water. Nitrogen takes on a variety of chemical forms throughout the nitrogen cycle, including N_2O. Natural emissions of N_2O are mainly from bacteria breaking down nitrogen in soils and the oceans. Nitrous oxide is removed from the atmosphere when it is absorbed by certain types of bacteria or destroyed by ultraviolet radiation or chemical reactions.

Emissions and Trends

Nitrous oxide emissions in the United States decreased by 5% between 1990 and 2020. During this time, nitrous oxide emissions from mobile combustion decreased by 61% as a result of emission control standards for on-road vehicles. Nitrous oxide emissions from agricultural soils have varied during this period and were about the same in 2020 as in 1990.



Examples of Reduction Opportunities for Nitrous Oxide Emissions	
Emissions Source	**Examples of How Emissions Can be Reduced**
Agriculture	The application of nitrogen fertilizers accounts for the majority of N_2O emissions in the United States. Emissions can be reduced by reducing nitrogen-

	based fertilizer applications and applying these fertilizers more efficiently,[3] as well as modifying a farm's manure management practices.
Fuel Combustion	Nitrous oxide is a by-product of fuel combustion, so reducing fuel consumption in motor vehicles and secondary sources can reduce emissions. Additionally, the introduction of pollution control technologies (e.g., catalytic converters to reduce exhaust pollutants from passenger cars) can also reduce emissions of N_2O.
Industry	Nitrous oxide is generally emitted from industry through fossil fuel combustion, so technological upgrades and fuel switching are effective ways to reduce industry emissions of N_2O. Production of nitric acid and adipic acid result in N_2O emissions that can be reduced through technological upgrades and use of abatement equipment.

9.2.4. Emissions of Fluorinated Gases:

Unlike many other greenhouse gases, fluorinated gases have no significant natural sources and come almost entirely from human-related activities. They are emitted through their use as substitutes for ozone-depleting substances (e.g., as refrigerants) and through a variety of industrial processes such as aluminium and semiconductor manufacturing. Many fluorinated gases have very high global warming potentials (GWPs) relative to other greenhouse gases, so small atmospheric concentrations can have disproportionately large effects on global temperatures. They can also have long atmospheric lifetimes—in some cases, lasting thousands of years. Like other long-lived greenhouse gases, most fluorinated gases are well-mixed in the atmosphere, spreading around the world after they are emitted. Many fluorinated gases are removed from the atmosphere only when they are destroyed by sunlight in the far upper atmosphere. In general, fluorinated gases are the most potent and longest lasting type of greenhouse gases emitted by human activities.

There are four main categories of fluorinated gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). The largest sources of fluorinated gas emissions are described below.

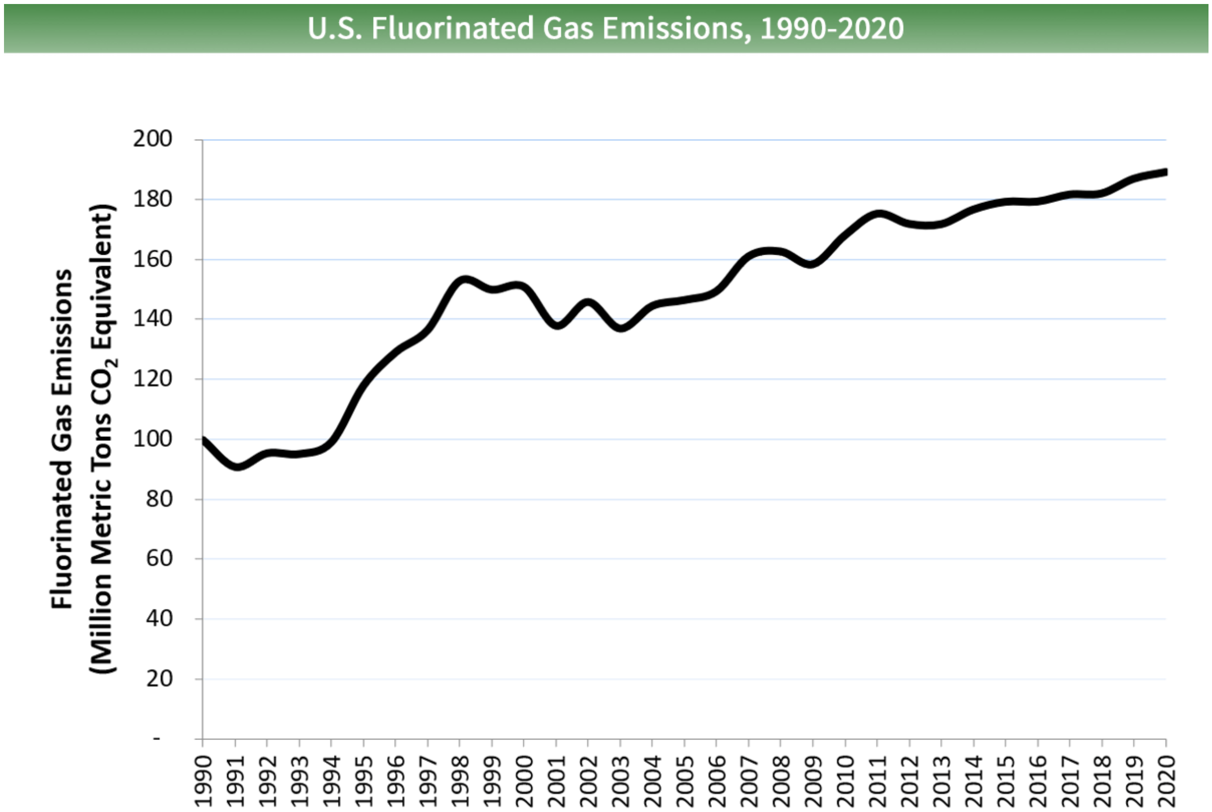
Substitution for Ozone-Depleting Substances**.**

Hydro fluorocarbons are used as refrigerants, aerosol propellants, and foam blowing agents, solvents, and fire retardants. The major emissions source of these compounds is their use as refrigerants for example, in air conditioning systems in both vehicles and buildings. These chemicals were developed as a replacement for chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) because they do not deplete the stratospheric ozone layer. Chlorofluorocarbons and HCFCs are also greenhouse gases; but they are being phased out under an international agreement, called the Montreal Protocol. HFCs are potent greenhouse gases with high GWPs, and they are released into the atmosphere during manufacturing processes and through leaks, servicing, and disposal of equipment in which they are used. Newly developed hydrofluoroolefins (HFOs) are a subset of HFCs and are characterized by short atmospheric lifetimes and lower GWPs. HFOs are currently being introduced as refrigerants, aerosol propellants and foam blowing agents. The American Innovation and Manufacturing (AIM) Act of 2020 directs EPA to address HFCs by providing new authorities in three main areas: to phase down the production and consumption of listed HFCs in the United States by 85% over the next 15 years, manage these HFCs and their substitutes, and facilitate the transition to next-generation technologies that do not rely on HFCs.

- Industry**.** Perfluorocarbons are produced as a by product of aluminum production and are used in the manufacturing of semiconductors. PFCs generally have long atmospheric lifetimes and GWPs near 10,000. Sulphur hexafluoride is used in magnesium processing and semiconductor manufacturing, as well as a tracer gas for leak detection. Nitrogen trifluoride is used in semiconductor manufacturing. HFC-23 is produced as a by-product of HCFC-22 production and is used in semiconductor manufacturing.
- Transmission and Distribution of Electricity**.** Sulphur hexafluoride is used as an insulating gas in electrical transmission equipment, including circuit breakers. The GWP of SF_6 is 22,800, making it the most potent greenhouse gas that the Intergovernmental Panel on Climate Change has evaluated.
    - **Emissions and Trends**

Overall, fluorinated gas emissions in the United States have increased by about 90% between 1990 and 2020. This increase has been driven by a 284% increase in emissions of hydrofluorocarbons (HFCs) since 1990, as they have been widely used as a substitute for ozone-depleting substances. Emissions of per fluorocarbons (PFCs) and sulphur hexafluoride

(SF_6) have actually declined during this time due to emission-reduction efforts in the aluminum production industry (PFCs) and the electrical transmission and distribution industry (SF_6).



Note: All emission estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020.

Reducing Fluorinated Gas Emissions

Because most fluorinated gases have a very long atmospheric lifetime, it will take many years to see a noticeable decline in current concentrations. There are, however, a number of ways to reduce emissions of fluorinated gases, described below.

Examples of Reduction Opportunities for Fluorinated Gases	
Emissions Source	**Examples of How Emissions Can be Reduced**
Substitution of Ozone-Depleting Substances in Homes and Businesses	Refrigerants used by businesses and residences emit fluorinated gases. Emissions can be reduced by better handling of these gases and use of substitutes with lower global warming potentials and other technological improvements. Visit EPA's Ozone Layer Protection

	site and HFC Phasedown site to learn more about reduction opportunities in this sector.
Industry	Industrial users of fluorinated gases can reduce emissions by adopting fluorinated gas recycling and destruction processes, optimizing production to minimize emissions, and replacing these gases with alternatives. EPA has experience with these gases in the following sectors: Aluminum Magnesium Semiconductor
Electricity Transmission and Distribution	Sulphur hexafluoride is an extremely potent greenhouse gas that is used for several purposes when transmitting electricity through the power grid. EPA is working with industry to reduce emissions through the SF_6 Emission Reduction Partnership for Electric Power Systems, which promotes leak detection and repair, use of recycling equipment, and consideration of alternative technologies that do not use SF_6.
Transportation	Hydrofluorocarbons (HFCs) are released through the leakage of refrigerants used in vehicle air-conditioning systems. Leakage can be reduced through better system components and through the use of alternative refrigerants with lower global warming potentials than those presently used. EPA's light-duty and heavy-duty vehicle standards provided incentives for manufacturers to produce vehicles with lower HFC emissions.

9.3. Sink of Carbon Dioxide:

- **Soil**

Soils contain mineral particles, broken-down plant matter, air, water, and even living organisms. This means they retain a large amount of carbon that those materials, predominantly plants, have taken from the atmosphere previously. Soils can store this carbon, which would have otherwise returned to the atmosphere as carbon dioxide, for a very long time.

Peat lands are wetlands where waterlogged conditions slow down plant decomposition to create carbon-rich soil, or "peat," in abundance. The plants that already absorbed carbon from the atmosphere is then naturally stored within these peat soils, helping to mitigate global warming. And though peat soils cover only about 3% of the global land surface, they contain over 600 gigatonnes of carbon and represent 44% of all soil carbon, making peat lands the world's largest terrestrial carbon sink.

- **Plants and Forests**

Plants and forests absorb carbon from the atmosphere through photosynthesis, which then becomes deposited and stored in forest biomass like tree trunks, branches, roots, and leaves. Large areas of trees and forests act as more significant carbon sinks simply because of their size and longer lifespans.

Grasslands also sequester a large amount of carbon. In places like California, where forests are more greatly threatened by wildfires and droughts, they could be considered more reliable carbon sinks than trees.

- **Ocean**

The world's oceans play a huge role in carbon sequestration, both by dissolving and absorbing CO2 from the surface water and also through photosynthesis by phytoplankton, seaweeds, and sea grasses. Microscopic plants called diatoms have been found to absorb 10 to 20 billion metric tons of carbon dioxide each year simply by floating on the surface of the ocean. Coastal vegetation like mangrove forests are also massive contributors to global carbon sequestration (typically referred to as "blue carbon") since the soils of marine plant habitats have a significantly higher rate of carbon absorption than terrestrial ecosystems. Carbon sinks are critical to managing the carbon levels in our atmosphere and ensuring that global warming is kept under control. The only problem is, carbon sinks have a maximum limit.

When carbon sinks are damaged or destroyed (for instance, as fires rage in the Amazon rainforest or when excess carbon in the ocean causes the water to become acidic), these ecosystems may stop absorbing carbon altogether and even emit stored carbon back into the atmosphere. Ocean warming, for instance, affects the ability of marine ecosystems to absorb CO_2 because warmer water naturally absorbs less CO_2 and because it stresses marine habitats that are designed to survive in cooler temperatures.[5]

Burning fossil fuels like coal, oil, and natural gas is the greatest contributor to climate change by far. According to the United Nations, it accounts for almost 90% of all carbon dioxide emissions and over 75% of global greenhouse gas emissions.[6]

Protecting Our Carbon Sinks

Natural carbon sinks that absorb CO_2 perform biological carbon sequestration, but climate engineers are also developing new technologies that capture carbon from industrial sources and inject it into underground storage. However, these solutions come nowhere close to providing enough carbon storage to reduce current atmospheric CO_2 concentrations and can't replace the power of natural carbon sinks.

Unfortunately, human activity and subsequent increased CO_2 release is upsetting the delicate balance between carbon and the earth's atmosphere. Protecting and restoring our most indispensable carbon sinks and other important natural resources is essential to maintaining a stable future environment.

9.4. Methane Sinks - The Atmosphere

The methane emissions are removed within 12 years from atmosphere by one of several methane sinks. The three sinks for methane are tropospheric hydroxyl radicals (OH), stratospheric losses, and soils.

The atmosphere, more precisely the troposphere, is the largest sink for methane. Methane in the troposphere reacts with hydroxyl (OH) radicals, forming mainly water and carbon dioxide.

In total this reaction accounts for about 500 million tonnes of methane each year. An indirect effect of atmospheric methane oxidation is that it can magnify the effects of other pollutants. Increased methane in the atmosphere means fewer OH radicals and so less oxidizing power in the atmosphere as a whole. About 40 million tonnes of methane per year is oxidized in our stratosphere, similarly.

9.5. Sinks of N_2O

Many terrestrial and aquatic systems exchange N_2O with the atmosphere Fig. 9.1. Most N_2O is formed during bacterial denitrification, during which nitrate (NO3-) is reduced to the gaseous nitrogen compounds, nitric oxide (NO) and N_2O. In some cases, the denitrification process stops here, so that theN_2O can escape to the atmosphere (fluxes F1and F3 in Fig. 9.1).One of the characteristics of N_2O is that it easily dissolves in water. As a result, atmo-spheric N2O may enter soil pores, and if the soil is wet, N_2O may be dissolved in soil water (fluxes F2 and F4 in Fig.9.1).

Consecutively, it may be denitrified by bacteria to N_2. This way, soils and aquatic systems can remove N_2O from the atmosphere. Since N_2O and NO_3- may be lost from the soils through leaching and runoff (fluxes F5and F7 in Fig. 9.1). The groundwater and riparian zones can also act as potential important sinks for atmospheric N_2O. There may also be some reverse flows of N_2O and NO_3^- from sub-soils to the top soils in case of lateral water flows (fluxes F6 and F8 in Fig. 15.1).However, these fluxes are usually much smaller than the leaching fluxes (F6 << F5and F8 << F7).

Through leaching (and run-off), N_2O and NO_3^- may be transported not only to sub-soils but also to deeper ground-water, riparian zones and, eventually, to aquatic systems such as rivers and coastal waters (fluxes F9 and F10 in Fig. 15.1). In the course of this transport, denitrification may take place, during which N_2O is formed from NO_3^- and/or reduced to N_2. However, we suspect that sub-soils and ground water systems do not play an important role as a sink for atmospheric N_2O.Whether a system is considered a source or a sink depends on the strengths of the fluxes F1, F2, F3 and F4. Net N_2O uptake may occur when N_2O uptake exceeds emission. A complicating factor is the temporal and spatial variability of all these fluxes. Both the emissions (F1 and F3) and uptake (F2 and F4) of N_2O are extremely variable in time and space. However, in most soils and aquatic systems overall emissions largely exceed overall uptake. In this chapter, we concentrate on sys-tems in which net N_2O uptake occurs (F2> F1 or F4 > F3) over a relatively large area (e.g. 1 ha) and prolonged period of time (e.g.1 year) because it is very difficult to assess the importance of temporal sink activity in systems with overall net emissions. The aim is to deduce some general characteristics of systems that act as an N_2O sink and to identify their likely importance on a global scale.

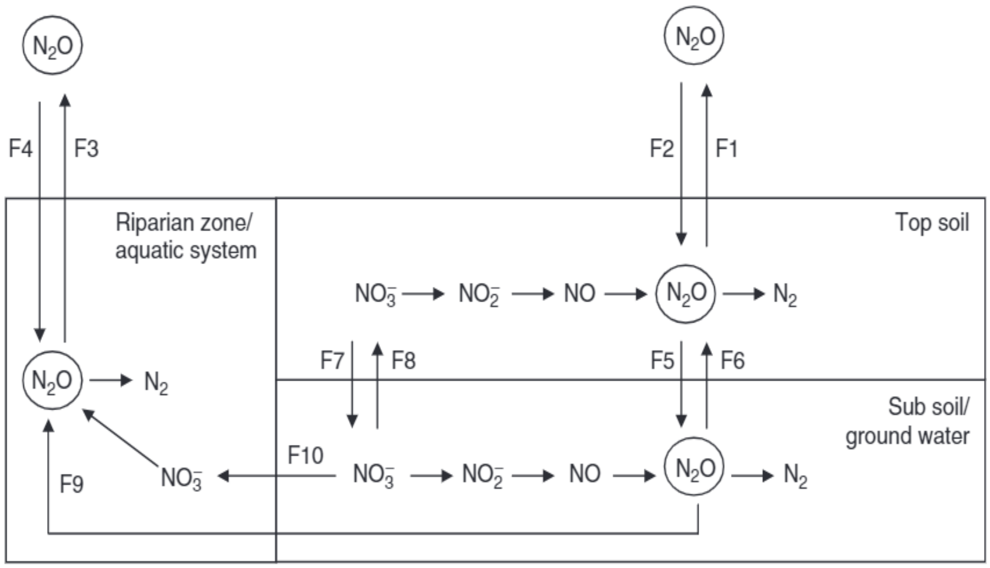


Fig. 9.1: Source and sinks for nitrous (N2O) at the Earth's surface

9.6. Human Impact of Green house Gases

Overall the direct human impact on the atmospheric destruction of methane is relatively minor. However, our emissions of other atmopsheric pollutants, such as nitrogen oxide (NOx) gases may reduce the levels of OH radicals in our atmopshere, so prolonging the existance of methane in our atmosphere. Additionally, our past use of ozone depleting aerosols, and the destruction of ozone in the stratosphere, may lead to increases in tropospheric ozone and so to an overall lowering of methane concentrations.

Potential for control

Our potential for control of the atmospheric methane sink is minimal and essentially lies in reduction of the amounts of methane emitted to the atmosphere in the first place. Recent trends indicate that the rate of methane increase in our atmosphere has accelerated and it has been suggested that this is due to increased methane emissions from fracking, more methane from wetlands, more from ruminants, or a decrease in the atmospheric methane sink. It may well be that a combination of these factors is actually causing the increase

9.7. Urban Heat Island

An **urban heat island** (**UHI**) is an urban or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The temperature difference is usually larger at night than during the day, and is most apparent when winds are weak. UHI is most noticeable during the summer and winter. The main cause of the UHI effect is from the modification of land surfaces. A study has shown that heat islands can be affected by proximity to different types of land cover, so that proximity to barren land causes urban land to become hotter and proximity to vegetation makes it cooler. Waste heat generated by energy usage is a secondary contributor. When the population centre grows, it tends to expand its area and increase its average temperature. The term **heat island** is also used; the term can be used to refer to any area that is relatively hotter than the surrounding, but generally refers to human-disturbed areas.

Monthly rainfall is greater downwind of cities, partially due to the UHI. Increase in heat within urban centres increases the length of growing seasons and decreases the occurrence of weak tornadoes. The UHI decreases air quality by increasing the production of pollutants such as ozone, and decreases water quality as warmer waters flow into area streams and put stress on their ecosystems.

Not all cities have a distinct urban heat island, and the heat island characteristics depend strongly on the background climate of the area in which the city is located. Effects within a city can vary significantly depending on local environmental conditions. Heat can be mitigated by tree cover and green space, which act as sources of shade and promote evaporative cooling. Mitigation of the urban heat island effect also can be accomplished through the use of green roofs, passive daytime radioactive cooling applications, and the use of lighter-colored surfaces and less absorptive building materials in urban areas, to reflect more sunlight and absorb less heat. Urbanization has made the effects of climate change worse in cities.

Causes:

There are several causes of an urban heat island (UHI); for example, dark surfaces absorb significantly more solar radiation, which causes urban concentrations of roads and buildings to heat more than suburban and rural areas during the day; materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas. This causes a change in the energy budget of the urban area, often leading to higher temperatures than surrounding rural areas. Another major reason is the lack of evapotranspiration (for example, through lack of vegetation) in urban areas. The U.S. Forest Service found in 2018 that cities in the United States are losing 36 million trees each year. With a decreased amount of vegetation, cities also lose the shade and evaporative cooling effect of trees.

Other causes of a UHI are due to geometric effects. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. This is called the "urban canyon effect". Another effect of buildings is the blocking of wind, which also inhibits cooling by convection and prevents pollutants from dissipating. Waste heat from automobiles, air conditioning, industry, and other sources also contributes to the UHI. High levels of pollution in urban areas can also increase the UHI, as many forms of pollution change the radiative properties of the atmosphere. UHI not only raises urban temperatures but also increases ozone concentrations because ozone is a greenhouse gas whose formation will accelerate with the increase of temperature.

For most cities, the difference in temperature between the urban and surrounding rural area is largest at night. While temperature difference is significant all year round. The difference is generally bigger in winter. The typical temperature difference is several degrees between the centre of the city and surrounding fields. The difference in temperature between an inner city and its surrounding suburbs is frequently mentioned in weather reports, as in "68 °F (20 °C) downtown, 64 °F (18 °C) in the suburbs". "The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4 °F (1.0–3.0 °C) warmer than its surroundings. In the evening, the difference can be as high as 22 °F (12 °C).

The UHI can be defined as either the air temperature difference (the canopy UHI) or the surface temperature difference (surface UHI) between the urban and the rural area. These two show slightly different diurnal and seasonal variability and have different causes.

Impact on animals

Ant colonies in urban heat islands have an increased heat tolerance at no cost to cold tolerance.

Species that are good at colonizing can utilize conditions provided by urban heat islands to thrive in regions outside of their normal range. Examples of this include the grey-headed flying fox (*Pteropus poliocephalus*) and the common house gecko (*Hemidactylus frenatus*).[44] Grey-headed flying foxes, found in Melbourne, Australia, colonized urban habitats following the increase in temperatures there. Increased temperatures, causing warmer winter conditions, made the city more similar in climate to the more northerly wildland habitat of the species.

With attempts to mitigate and manage urban heat islands, temperature changes and the availability of food and water are reduced. With temperate climates, urban heat islands will extend the growing season, therefore altering breeding strategies of inhabiting species. This can be best observed in the effects that urban heat islands have on water temperature. With the temperature of the nearby buildings reaching an over 50 °F (28 °C) difference from the near-surface air temperature. The precipitation will warm rapidly, causing run-off into nearby streams, lakes and rivers (or other bodies of water) to provide excessive thermal pollution. The increase in thermal pollution has the potential to increase water temperature by 20 to 30 °F (11 to 17 °C). This increase will cause the fish species inhabiting the body of water to undergo thermal stress and shock due to the rapid change in temperature of their habitat.

Urban heat islands caused by cities have altered the natural selection process. Selective pressures like temporal variation in food, predation and water are relaxed causing a new set of selective forces to roll out. For example, within urban habitats, insects are more abundant than in rural areas. Insects are ectotherms. This means that they depend on the temperature of the environment to control their body temperature, making the warmer climates of the city perfect for their ability to thrive. A study done in Raleigh, North Carolina conducted on Parthenolecanium quercifex (oak scales), showed that this particular species preferred warmer climates and were therefore found in higher abundance in urban habitats than on oak trees in rural habitats. Over time spent living in urban habitats, they have adapted to thrive in warmer climates than in cooler ones.

The presence of non-native species is heavily dependent on the amount of human activity. An example of this can be found in the populations of cliff swallows seen nesting under the eaves of buildings in urban habitats. They make their homes using the shelter provided by humans in the upper regions of homes, allowing for an influx in their populations due to added protection and reduced predator numbers.

Other impacts on weather and climate

Aside from the effect on temperature, UHIs can produce secondary effects on local meteorology, including the altering of local wind patterns, the development of clouds and fog, the humidity, and the rates of precipitation. The extra heat provided by the UHI leads to greater upward motion, which can induce additional shower and thunderstorm activity. In addition, the UHI creates during the day a local low pressure area where relatively moist air from its rural surroundings converges, possibly leading to more favourable conditions for cloud formation. Rainfall rates downwind of cities are increased between 48% and 116%. Partly as a result of this warming, monthly rainfall is about 28% greater between 20 miles (32 km) to 40 miles (64 km) downwind of cities, compared with upwind. Some cities show a total precipitation increase of 51%.

Research has been done in a few areas suggesting that metropolitan areas are less susceptible to weak tornadoes due to the turbulent mixing caused by the warmth of the urban heat island. Using satellite images, researchers discovered that city climates have a noticeable influence on plant growing seasons up to 10 kilometers (6.2 miles) away from a city's edges. Growing seasons in 70 cities in eastern North America were about 15 days longer in urban areas compared to rural areas outside of a city's influence.

Research in China indicates that urban heat island effect contributes to climate warming by about 30%. On the other hand in 1999 comparison between urban and rural areas proposed that urban heat island effects little influence on global mean temperature trends. However, the study concluded, that cities change the climate in area 2–4 times larger than their own area. Other suggested that urban heat islands affect global climate by impacting the jet stream. Several studies have revealed increases in the severity of the effect of heat islands with the progress of climate change.

Health Impacts:

UHIs have the potential to directly influence the health and welfare of urban residents. Within the United States alone, an average of 1,000 people dies each year due to extreme heat. As UHIs are characterized by increased temperature, they can potentially increase the magnitude and duration of heat waves within cities. Researchers found that the mortality rate during a heat wave increase exponentially, with the maximum temperature, the effect is exacerbated by the UHI. The number of individuals exposed to extreme temperatures is increased by the UHI-induced warming. The night time effect of UHIs can be particularly harmful during a heat wave, as it deprives urban residents of the cool.

Impact on nearby water bodies

UHIs also impair water quality. Hot pavement and rooftop surfaces, transfer their excess heat to storm water, which then drains into storm sewers and raises water temperatures as it is released into streams, rivers, ponds, and lakes. Additionally, increased urban water body temperatures lead to a decrease in diversity in the water. In August 2001, rains over Cedar Rapids, Iowa, led to a 10.5C (18.9F) rise in the nearby stream within one hour, which led to a fish kill. Since the temperature of the rain was comparatively cool, it could be attributed to the hot pavement of the city. Similar events have been documented across the American Midwest, as well as Oregon and California. Rapid temperature changes can be stressful to aquatic ecosystems. Permeable pavements may mitigate these effects by percolating water through the pavement into subsurface storage areas where it can be dissipated through absorption and evaporation.

Impacts on Energy Uses:

Another consequence of urban heat islands is the increased energy required for air conditioning and refrigeration in cities that are in comparatively hot climates. The Heat Island Group estimates that the heat island effect costs about US$100 million per year in energy. Conversely, those that are in cold climates such as Moscow, Russia would have less expense for heating. However, through the implementation of heat island reduction strategies, significant annual net energy savings have been calculated for northern locations such as Chicago, Salt Lake City, and Toronto.

Mitigation strategies include:

- **White roofs**: Painting rooftops white has become a common strategy to reduce the heat island effect. In cities, there are many dark colored surfaces that absorb the heat of the sun in turn lowering the albedo of the city. White rooftops allow high solar reflectance and high solar emittance, increasing the albedo effect of the city area is occurring.
- **Passive daytime radiative cooling**: A passive daytime radiative cooling roof application can double the energy savings of a white roof, attributed to high solar reflectance and thermal emittance in the infrared window, with the highest cooling potential in hot and dry cities such as Phoenix and Las Vegas. When installed on roofs in dense urban areas, passive daytime radiative cooling panels can significantly lower outdoor surface temperatures at the pedestrian level.

- **Green roofs**: Green roofs are another method of decreasing the urban heat island effect. Green roofery is the practice of having vegetation on a roof; such as having trees or a garden. The plants that are on the roof increase the albedo and decrease the urban heat island effect. This method has been studied and criticized for the fact that green roofs are affected by climatic conditions, green roof variables are hard to measure, and are very complex systems.
- **Planting trees in cities**: Planting trees around the city can be another way of increasing albedo and decreasing the urban heat island effect. It is recommended to plant deciduous trees because they can provide many benefits such as more shade in the summer and not blocking warmth in winter.
- Green parking lots**:** Green parking lots use vegetation and surfaces other than asphalt to limit the urban heat island effect.

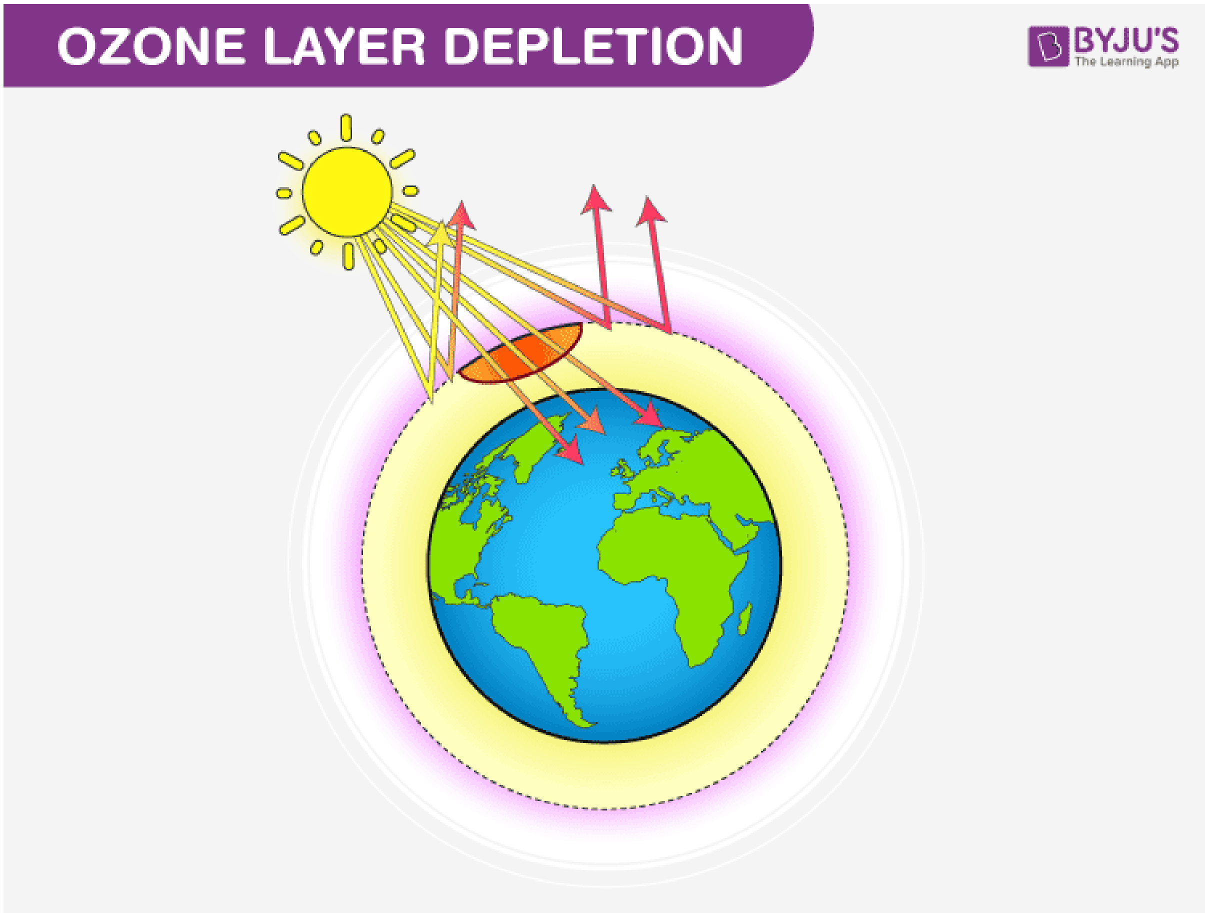
9.8. Ozone Layer Depletion:

The ozone layer is mainly found in the lower portion of the earth's atmosphere. It has the potential to absorb around 97-99% of the harmful ultraviolet radiations coming from the sun that can damage life on earth. If the ozone layer was absent, millions of people would develop skin diseases and may have weakened immune systems.

However, scientists have discovered a hole in the ozone layer over Antarctica. This has focussed their concern on various environmental issues and steps to control them. The main reasons for the ozone hole are chlorofluorocarbons, carbon tetrachloride, methyl bromide and hydro chlorofluorocarbons.

Ozone Layer Depletion

"Ozone layer depletion is the gradual thinning of the earth's ozone layer in the upper atmosphere caused due to the release of chemical compounds containing gaseous bromine or chlorine from industries or other human activities."



What is Ozone Layer Depletion?

Ozone layer depletion is the thinning of the ozone layer present in the upper atmosphere. This happens when the chlorine and bromine atoms in the atmosphere come in contact with ozone and destroy the ozone molecules. One chlorine can destroy 100,000 molecules of ozone. It is destroyed more quickly than it is created.

Some compounds release chlorine and bromine on exposure to high ultraviolet light, which then contributes to ozone layer depletion. Such compounds are known as Ozone Depleting Substances (ODS).

The ozone-depleting substances that contain chlorine include chlorofluorocarbon, carbon tetrachloride, hydrochlorofluorocarbons, and methyl chloroform. Whereas, the ozone-depleting substances that contain bromine are halons, methyl bromide, and hydro bromofluorocarbons.

Chlorofluorocarbons are the most abundant ozone-depleting substance. It is only chlorine atom that reacts with some other molecule. It does not react with ozone.

Montreal Protocol was proposed in 1987 to stop the use, production and import of ozone-depleting substances and minimise their concentration in the atmosphere to protect the ozone layer of the earth.

Causes of Ozone Layer Depletion

Ozone layer depletion is a major concern and is associated with a number of factors. The main causes responsible for the depletion of the ozone layer are listed below:

- ***Chlorofluorocarbons***

Chlorofluorocarbons or CFCs are the main cause of ozone layer depletion. These are released by solvents, spray aerosols, refrigerators, air-conditioners, etc. The molecules of chlorofluorocarbons in the stratosphere are broken down by ultraviolet radiations and release chlorine atoms. These atoms react with ozone and destroy it.

- ***Unregulated Rocket Launches***

Researchers say that the unregulated launching of rockets results in much more depletion of the ozone layer than the CFCs do. If not controlled, this might result in a huge loss of the ozone layer by the year 2050.

- ***Nitrogenous Compounds***

The nitrogenous compounds such as NO_2, NO, N_2O are highly responsible for the depletion of the ozone layer.

- ***Natural Causes***

The ozone layer has been found to be depleted by certain natural processes such as Sun-spots and stratospheric winds. But it does not cause more than 1-2% of the ozone layer depletion.

The volcanic eruptions are also responsible for the depletion of the ozone layer.

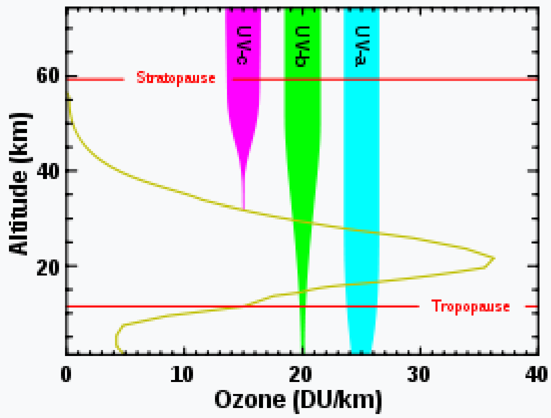
Ozone Depleting Substances (ODS)

"Ozone-depleting substances are the substances such as chlorofluorocarbons, halons, carbon tetrachloride, hydrofluorocarbons, etc. that are responsible for the depletion of the ozone layer."

Following is the list of some main ozone-depleting substances and the sources from where they are released:

Ozone-Depleting Substances	Sources

Chlorofluorocarbons (CFCs)	Refrigerators, air-conditioners, solvents, dry-cleaning agents, etc.
Halons	Fire-extinguishers
Carbon tetrachloride	Fire extinguishers, solvents
Methyl chloroform	Adhesives, aerosols
Hydrofluorocarbons	fire extinguishers, air-conditioners, solvents

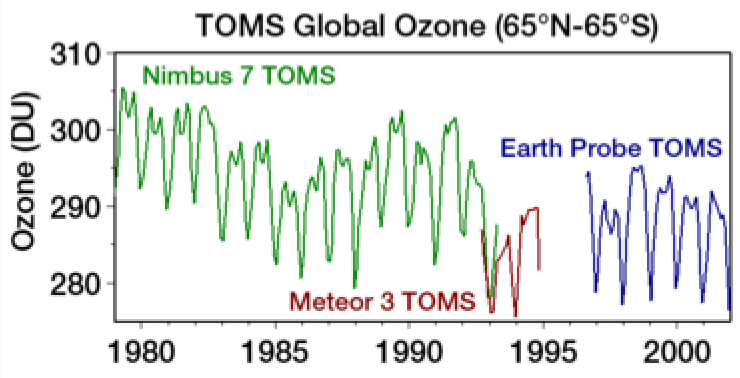


Levels of ozone at various altitudes (DU/km) and blocking of different bands of ultraviolet radiation: In essence, all UVC is blocked by diatomic oxygen (100–200 nm) or by ozone (triatomic oxygen) (200–280 nm) in the atmosphere. The ozone layer then blocks most UVB. Meanwhile, UVA is hardly affected by ozone, and most of it reaches the ground. UVA makes up almost all UV light that penetrates the Earth's atmosphere.

The total amount of ozone in the stratosphere is determined by a balance between photochemical production and recombination.

Ozone can be destroyed by a number of free radical catalysts; the most important are the hydroxyl radical (OH·), nitric oxide radical (NO·), chlorine radical (Cl·) and bromine radical (Br·). The dot is a notation to indicate that each species has an unpaired electron and is thus extremely reactive. All of these have both natural and man-made sources; at present, most of the OH· and NO· in the stratosphere is naturally occurring, but human activity has drastically increased the levels of chlorine and bromine.[16] These elements are found in stable organic compounds, especially chlorofluorocarbons, which can travel to the stratosphere without being destroyed in the troposphere due to their low reactivity. Once in the stratosphere, the Cl and Br atoms are released from the parent compounds by the action of ultraviolet light, e.g.

$$CFCl_3 + \text{electromagnetic radiation} \rightarrow Cl\cdot + \cdot CFCl_2$$



Global monthly average total ozone amount

Ozone is a highly reactive molecule that easily reduces to the more stable oxygen form with the assistance of a catalyst. The Cl and Br atoms destroy ozone molecules through a variety of catalytic cycles.

In the simplest example of such a cycle, a chlorine atom reacts with an ozone molecule (O_3), taking an oxygen atom to form chlorine monoxide (ClO) and leaving an oxygen molecule(O_2). The ClO can react with a second molecule of ozone, releasing the chlorine atom and yielding two molecules of oxygen. The chemical shorthand for these gas-phase reactions is:

$$Cl\cdot + O_3 \rightarrow ClO + O_2$$

A chlorine atom removes an oxygen atom from an ozone molecule to make a ClO molecule

- $ClO + O_3 \rightarrow Cl\cdot + 2\ O_2$

This ClO can also remove an oxygen atom from another ozone molecule; the chlorine is free to repeat this two-step cycle

The overall effect is a decrease in the amount of ozone, though the rate of these processes can be decreased by the effects of null cycles. More complicated mechanisms have also been discovered that lead to ozone destruction in the lower stratosphere.

A single chlorine atom would continuously destroy ozone (thus a catalyst) for up to two years (the time scale for transport back down to the troposphere) except for reactions that remove it from this cycle by forming reservoir species such as hydrogen chloride (HCl) and chlorine nitrate ($ClONO_2$). Bromine is even more efficient than chlorine at destroying ozone on a per-atom basis, but there is much less bromine in the atmosphere at present. Both chlorine and bromine contribute significantly to overall ozone depletion. Laboratory studies have also shown that fluorine and iodine atoms participate in analogous catalytic cycles. However, fluorine atoms react rapidly with water vapour, methane and hydrogen to form strongly bound hydrogen fluoride (HF) in the Earth's stratosphere, while organic molecules containing iodine react so rapidly in the lower atmosphere that they do not reach the stratosphere in significant quantities.

A single chlorine atom is able to react with an average of 100,000 ozone molecules before it is removed from the catalytic cycle. This fact plus the amount of chlorine released into the atmosphere yearly by chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) demonstrates the danger of CFCs and HCFCs to the environment.

Effects of Ozone Layer Depletion Effects

Since the ozone layer absorbs UVB ultraviolet light from the sun, ozone layer depletion increases surface UVB levels (all else equal), which could lead to damage, including an increase in skin cancer. This was the reason for the Montreal Protocol. Although, decreases in stratospheric ozone are well-tied to CFCs and increases in surface UVB. There is no direct observational evidence linking ozone depletion to higher incidence of skin cancer and eye damage in human beings. This is partly because UVA, which has also been implicated in some forms of skin cancer, is not absorbed by ozone, and so it is nearly impossible to control statistics for lifestyle changes over time. Ozone depletion may also influence wind patterns.

Increased UV

Ozone, while a minority constituent in Earth's atmosphere, is responsible for most of the absorption of UVB radiation. The amount of UVB radiation that penetrates through the ozone layer decreases exponentially with the slant-path thickness and density of the layer. When stratospheric ozone levels decreases, higher levels of UVB reach the Earth's surface. UV-driven phenolic formation in tree rings has dated the start of ozone depletion in northern latitudes to the late 1700s.

In October 2008, the Ecuadorian Space Agency published a report called HIPERION. The study used ground instruments in Ecuador and the last 28 years' data from 12 satellites of several countries, and found that the UV radiation reaching equatorial latitudes was far greater than expected, with the UV Index climbing as high as 24 in Quito. The WHO considers 11 as an extreme index and a great risk to health. The report concluded that depleted ozone levels around the mid-latitudes of the planet are already endangering large populations in these areas. Later, the CONIDA, the Peruvian Space Agency, published its own study, which yielded almost the same findings as the Ecuadorian study.

Biological effects.

The main public concern regarding the ozone hole has been the effects of increased surface UV radiation on human health. So far, ozone depletion in most locations has been typically a few percent. No direct evidence of health damage is available in most latitudes. If the high levels of depletion seen in the ozone hole were to be common across the globe, the effects could be substantially more dramatic. As the ozone hole over Antarctica has in some instances grown so large as to affect parts of Australia, New Zealand, Chile, Argentina, and South Africa. Environmentalists have been concerned that the increase in surface UV could be significant.

Ozone depletion would magnify all of the effects of UV on human health, both positive (including production of vitamin D) and negative (including sunburn, skin cancer, and cataracts). In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans.

Basal and squamous cell carcinomas

The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UV-B exposure. The mechanism by which UVB induces these cancers is well understood. Absorption of UV-B radiation causes the pyramiding bases in the DNA molecule to form dimmers, resulting in transcription errors when the DNA replicates. These cancers are relatively mild and rarely fatal, although the treatment of squamous cell carcinoma sometimes requires extensive reconstructive surgery. By combining epidemiological data with results of animal studies, scientists have estimated that every one percent decrease in long-term stratospheric ozone would increase the incidence of these cancers by 2%.

Malignant melanoma

Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15–20 percent of the cases diagnosed. The relationship between malignant melanoma and ultraviolet exposure is not yet fully understood, but it appears that both UV-B and UV-A are involved. Because of this uncertainty, it is difficult to estimate the effect of ozone depletion on melanoma incidence. One study showed that a 10 percent increase in UV-B radiation was associated with a 19 percent increase in melanomas for men and 16 percent for women. A study of people in Punta Arenas, at the southern tip of Chile, showed a 56 percent increase in melanoma and a 46 percent increase in no melanoma skin cancer over a period of seven years, along with decreased ozone and increased UVB levels.

Cortical cataracts

Epidemiological studies suggest an association between ocular cortical cataracts and UV-B exposure, using crude approximations of exposure and various cataract assessment techniques. A detailed assessment of ocular exposure to UV-B was carried out in a study on Chesapeake Bay Watermen, where increases in average annual ocular exposure were associated with increasing risk of cortical opacity. In this highly exposed group of predominantly white males, the evidence linking cortical opacities to sunlight exposure was the strongest to date. Based on these results, ozone depletion is predicted to cause hundreds of thousands of additional cataracts by 2050.

Increased tropospheric ozone

Increased surface UV leads to increased tropospheric ozone. Ground-level ozone is generally recognized to be a health risk, as ozone is toxic due to its strong oxidant properties. The risks are particularly high for young children, the elderly, and those with asthma or other respiratory difficulties. At this time, ozone at ground level is produced mainly by the action of UV radiation on combustion gases from vehicle exhausts.

Increased production of vitamin D

Vitamin D is produced in the skin by ultraviolet light. Thus, higher UVB exposure raises human vitamin D in those deficient in it. Recent research (primarily since the Montreal Protocol) shows that many humans have less than optimal vitamin D levels. In particular, in the U.S. population, the lowest quarter of vitamin D (<17.8 ng/ml) were found using information from the National Health and Nutrition Examination Survey to be associated with an increase in all-cause mortality in the general population. While blood level of vitamin D in excess of 100 ng/ml appears to raise blood calcium excessively and to be associated with higher mortality. The body has mechanisms that prevent sunlight from producing vitamin D in excess of the body's requirements.

Effects on animals

A November 2011 report by scientists at the Institute of Zoology in London found that whales off the coast of California have shown a sharp rise in sun damage, and these scientists "fear that the thinning ozone layer is to blame". The study photographed and took skin biopsies from over 150 whales in the Gulf of California and found "widespread evidence of epidermal damage commonly associated with acute and severe sunburn", having cells that form when the DNA is damaged by UV radiation. The findings suggest "rising UV levels as a result of ozone depletion are to blame for the observed skin damage, in the same way that human skin cancer rates have been on the increase in recent decades." Apart from whales many other animals such as dogs, cats, sheep and terrestrial ecosystems also suffer the negative effects of increased UV-B radiations.

Effects on crops

An increase of UV radiation would be expected to affect crops. A number of economically important species of plants, such as rice, depend on cyanobacteria residing on their roots for the retention of nitrogen. Cyanobacteria are sensitive to UV radiation and would be affected by its increase. "Despite mechanisms to reduce or repair the effects of increased ultraviolet radiation, plants have a limited ability to adapt to increased levels of UVB, therefore plant growth can be directly affected by UVB radiation.

Effects on plant life

Over the years, the Arctic ozone layer has depleted severely. As a consequence the species that live above the snow cover or in areas where snow has melted abundantly, due to hot temperatures, are negatively impacted due to UV radiation that reaches the ground. Depletion of the ozone layer and allowing excess UVB radiation would initially be assumed to increase damage done to plant DNA. Reports have found that when plants are exposed to UVB radiation similar to stratospheric ozone depletion, there was no significant change in plant height or leaf mass, but showed a response in shoot biomass and leaf area with a small decrease. However, UVB radiation has been shown to decrease quantum yield of photosystem II. UVB damage only occurs under extreme exposure, and most plants also have UVB absorbing flavonoids which allow them to acclimatize to the radiation present. Plants experience different levels of UV radiation throughout the day. It is known that they are able to shift the levels and types of UV sunscreens (i.e. flavonoids), that they contain, throughout the day. This allows them to increase their protection against UV radiation. Plants that have been affected by radiation throughout development are more affected by the inability to intercept light with a larger leaf area than having photosynthetic systems compromised. Damage from UVB radiation is more likely to be significant on species interactions than on plants themselves.

Another significant impact of ozone depletion on plant life is the stress experienced by plants when exposed to UV radiation. This can cause a decrease in plant growth and an increase in oxidative stress, due to the production of nitric oxide and hydrogen peroxide. Reduction in plant growth will have important consequences in the long-term. It is projected that the plant productivity would decrease by 6% and there will be a reduction in the amount of carbon, plants would capture/sequester from the environment.

Moreover, if plants are exposed to high levels of UV radiation, it can elicit the production of harmful volatile organic compounds, like isoprenes. The emission of isoprenes into the air, by plants, can severely impact the environment by adding to air pollution and increasing the amount of carbon in the atmosphere, ultimately contributing to climate change.

9.8.1. Ozone Recovery:

The recognition of the dangers presented by chlorine and bromine to the ozone layer spawned an international effort to restrict the production and the use of CFCs and other halocarbons. The 1987 Montreal Protocol on Substances That Deplete the Ozone Layer began the phase out of CFCs in 1993 and sought to achieve a 50 percent reduction in global consumption from 1986 levels by 1998. A series of amendments to the Montreal Protocol in the following years was designed to strengthen the controls on CFCs and other halocarbons. By 2005 the consumption of ozone-depleting chemicals controlled by the agreement had fallen by 90–95 percent in the countries that were parties to the protocol.

During the early 2000s, scientists expected that stratospheric ozone levels would continue to rise slowly over subsequent decades. The size of the Antarctic ozone hole reached its greatest extent in 2000, when it spanned 29.9 million square km (11.5 million square miles); by 2021 its area had shrunk to 24.8 million square km (9.6 million square miles).

Indeed, some scientists contended that as levels of reactive chlorine and bromine declined in the stratosphere, the worst of ozone depletion would pass. Factoring in variations in air temperatures (which contribute to the size of ozone holes), scientists expected that continued reductions in chlorine loading would result in smaller ozone holes above Antarctica after 2040.

A 2018 United Nations report estimated that the Antarctic ozone hole would close slowly and stratospheric ozone concentrations would return to 1980 values by the 2060s. Above the Arctic, ozone levels are expected to return to 1980 values by the mid-2030s. The expected increases in ozone would be gradual primarily because of the long residence times of CFCs and other halocarbons in the atmosphere. Total ozone levels, as well as the distribution of ozone in the troposphere and stratosphere, would also depend on other changes in atmospheric composition—for example, changes in levels of carbon dioxide (which affects temperatures in both the troposphere and the stratosphere), methane which affects the levels of reactive hydrogen oxides in the troposphere and stratosphere that can react with ozone, and nitrous oxide (which affects levels of nitrogen oxides in the stratosphere that can react with ozone).

Scientists in 2014 observed a small increase in stratospheric ozone and they attributed this to worldwide compliance with international treaties regarding the phase out of ozone-depleting chemicals and to upper stratospheric cooling because of increased carbon dioxide. Upon more thorough study, however, scientists in 2016 announced that stratospheric ozone concentrations had actually been increasing in the upper stratosphere since 2000 while the size of the Antarctic ozone hole had been decreasing. Overall ozone concentrations away from the poles have continued to fall since 1998; however, a 2018 study showed that declines in ozone concentrations in the lower stratosphere contrasted with gains made in the upper stratosphere between 60° N and 60° S. Another sign of the ozone layer's recovery occurred in September 2019, when scientists recorded the smallest ozone hole since 1982 (some 16.3 million square km [6.3 million square miles] at its peak extent) above Antarctica. (In 1982 the ozone hole's peak extent was a little less than 16.1 million square km [6.2 million square miles].)

Studies note that continued reductions in ozone-depleting chemicals that follow the schedule proposed by the Montreal Protocol and its follow-up agreements are expected to result in a return to 1980-level ozone concentrations above the poles by the middle of the 21st century, perhaps as early as 2040. A 2023 report by the United Nations noted that the Antarctic and Arctic ozone holes are expected to recover by 2066 and 2045, respectively.

Since ozone is a greenhouse gas, the breakdown and anticipated recovery of the ozone layer affects Earth's climate. Scientific analyses show that the decrease in stratospheric ozone observed since the 1970s has produced a cooling effect—or, more accurately, that it has counteracted a small part of the warming that has resulted from rising concentrations of carbon dioxide and other greenhouse gases during this period. As the ozone layer slowly recovers in the coming decades, this cooling effect is expected to recede.

Ground level Ozone Pollution:

Ground-level ozone (**O_3**), also known as **surface-level ozone** and **tropospheric ozone**, is a trace gas in the troposphere (the lowest level of the Earth's atmosphere), with an average concentration of 20–30 parts per billion by volume (ppbv), with close to 100 ppbv in polluted areas. Ozone is also an important constituent of the stratosphere, where the ozone layer (2 to 8 parts per million ozone) exists which is located between 10 and 50 kilometers above the Earth's surface. The troposphere extends from the ground up to a variable height of approximately 14 kilometres above sea level. Ozone is least concentrated in the ground layer (or planetary boundary layer) of the troposphere. Ground-level or tropospheric ozone is created by chemical reactions between NOx gases (oxides of nitrogen produced by combustion) and volatile organic compounds (VOCs). The combination of these chemicals in the presence of sunlight form ozone. Its concentration increases as height above sea level increases, with a maximum concentration at the tropopause. About 90% of total ozone in the atmosphere is in the stratosphere, and 10% is in the troposphere.[5] Although tropospheric ozone is less concentrated than stratospheric ozone, it is of concern because of its health effects. Ozone in the troposphere is considered a greenhouse gas, and may contribute to global warming.

Photochemical and chemical reactions involving ozone drive of many chemical processes occur in the troposphere by day and by night. At abnormally high concentrations of emissions from combustion of fossil fuels, a pollutant, and a constituent of smog, its levels have increased significantly since the industrial revolution, A NOx gasses and VOCs are some of the by products of combustion. With more heat and sunlight in the summer months, more ozone is formed which is why regions often experience higher levels of pollution in the summer months. Although the same molecule, ground-level ozone can be harmful to human health, unlike stratospheric ozone that protects the earth from excess UV radiation.

Photolysis of ozone occurs at wavelengths below approximately 310–320 nanometres. This reaction initiates a chain of chemical reactions that remove carbon monoxide, methane, and other hydrocarbons from the atmosphere via oxidation. Therefore, the concentration of troposphere ozone affects how long these compounds remain in the air. If the oxidation of carbon monoxide or methane occurs in the presence of nitrogen monoxide (NO), this chain of reactions has a net product of ozone added to the system.

9.8.2. Ozone Formation

The majority of troposphere ozone formation occurs when nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs), react in the atmosphere in the presence of sunlight, specifically the UV spectrum. NOx, CO, and VOCs are considered ozone precursors. Motor vehicle exhaust, industrial emissions, and chemical solvents are the major anthropogenic sources of these ozone precursors. Although the ozone precursors often originate in urban areas. Winds can carry NOx hundreds of kilometres, causing ozone formation to occur in less populated regions as well. Methane, a VOC whose atmospheric concentration has increased tremendously during the last century, contributes to ozone formation on a global scale rather than in local or regional photochemical smog episodes. In situations where this exclusion of methane from the VOC group of substances is not obvious, the term Non-Methane VOC (NMVOC) is often used.

The chemical reactions involved in troposphere ozone formation are a series of complex cycles in which carbon monoxide and VOCs are oxidised to water vapour and carbon dioxide. The reactions involved in this process are illustrated here with CO but similar reactions occur for VOC as well. The oxidation begins with the reaction of CO with the hydroxyl radical ($^{\bullet}OH$).

The radical intermediate formed by this reacts rapidly with oxygen to give a peroxy radical $HO_2^{\bullet}$ An outline of the chain reaction that occurs in oxidation of CO, producing O_3.

The reaction begins with the oxidation of CO by the hydroxyl radical ($^{\bullet}OH$). The radical adduct (•HOCO) is unstable and reacts rapidly with oxygen to give a proxy radical, $HO_2^{\bullet}$:

$$\bullet OH + CO \rightarrow \bullet HOCO$$

$$\bullet HOCO + O_2 \rightarrow HO_2\bullet + CO_2$$

Peroxy-radicals then go on to react with NO to produce NO_2, which is photolysis by UV-A radiation to give a ground-state atomic oxygen, which then reacts with molecular oxygen to form ozone.[1]

$$HO_2^{\bullet} + NO \rightarrow {}^{\bullet}OH + NO_2$$

$$NO_2 + h\nu \rightarrow NO + O(^3P),\ \lambda<400\ nm$$

$$O(^3P) + O_2 \rightarrow O_3$$

Note that these three reactions are what forms the ozone molecule, and will occur the same way in the oxidation of CO or VOCs case.

The net reaction in this case is then:

$$CO + 2O_2 \rightarrow CO_2 + O_3$$

The amount of ozone produced through these reactions in ambient air can be estimated using a modified Leighton relationship. The limit on these interrelated cycles producing ozone is the reaction of •OH with NO_2 to form nitric acid at high NOx levels. If nitrogen monoxide (NO) is instead present at very low levels in the atmosphere (less than 10 approximately ppt), the peroxy radicals ($HO_2\bullet$) formed from the oxidation will instead react with themselves to form peroxides, and not produce ozone.

Health effects

Health effects depend on ozone precursors, which are a group of pollutants, primarily generated during the combustion of fossil fuels. Ground-level ozone is created by nitrous oxides reacting with organic compounds in the presence of sunlight. There are many man-made sources of these organic compounds including vehicle and industrial emissions, along with several other sources. Reaction with daylight ultraviolet (UV) rays and these precursors create ground-level ozone pollution (troposphere ozone). Ozone is known to have the following health effects at concentrations common in urban air:

- Irritation of the respiratory system, causing coughing, throat irritation, and/or an uncomfortable sensation in the chest. Ozone affects people with underlying respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer as well those who spend a lot of time being active outdoors.

- Reduced lung function, making it more difficult to breathe deeply and vigorously. Breathing may become more rapid and more shallow than normal, and a person's ability to engage in vigorous activities may be limited. Ozone causes the muscles in the airways to constrict which traps air in the alveoli leading to wheezing and shortness of breath.
- Aggravation of asthma. When ozone levels are high, more people with asthma have attacks that require a doctor's attention or use of medication. One reason this happens is that ozone makes people more sensitive to allergens, which in turn trigger asthma attacks.
- Increased susceptibility to respiratory infections. Examples of these respiratory complications include bronchitis, emphysema, and asthma.
- Inflammation and damage to the lining of the lungs. Within a few days, the damaged cells are shed and replaced much like the skin peels after sunburn. Animal studies suggest that if this type of inflammation happens repeatedly over a long time period (months, years, a lifetime), lung tissue may become permanently scarred, resulting in permanent loss of lung function and a lower quality of life.
- More recent data suggests that ozone can also have harmful effects via the inflammatory pathway leading to heart disease, type 2 diabetes, and other metabolic disorders.

9.9. Global Dimming:

Causes, Effects and Solutions to Global Dimming

Global dimming is the gradual reduction in the amount of global direct irradiance at the surface of the earth. It is a concept that has been observed since systematic measurements began in the 1950s. It was coined by an English scientist working in Israel, known as Gerry Stanhill, who first spotted these effects.

He compared Israeli sunlight records from the 50s with the current ones and was astonished to find a 22% drop in the sunlight. Intrigued by the records, he investigated the phenomenon further and found the same story almost everywhere he looked, with sunlight falling by about 10% over the US, 16% in parts of the British Isles and by up to 30% in parts of the Soviet Union.

Measurements taken between the 1960s and the early 1990s, in collaboration with a wide range of data and independent studies, have shown that there was a substantial decline in the amount of the sun's energy reaching the surface of the earth, hence global dimming. According to Gerry Stanhill, although global dimming effects varied from place to place, overall, the decline amounted to between 1% and 2% globally per decade between the 1950s and the 1990s. Global dimming is believed to be caused by the increase in particulates like sulphate aerosols in the atmosphere, all of which are attributed to human actions.

Global dimming, surprisingly, has an opposite effect to global warming as it produces cooling effects; so in essence, global dimming is beneficial to the environment, although it brings about elements of literal darkness on earth. The effects of global dimming vary by location, with some areas being badly affected than others.

For instance, the northern hemisphere saw much more significant declines with reductions of between 4% and 8% between 1961 and 1990. Since then, Europe and North America have seen partial recovery, or global brightening, with China and India seeing further, although regionally mixed declines.

The critical issue of Global Dimming was first raised through a documentary called Horizon by BBC on 15 January 2005.

Various regions observe different levels of global dimming. Till now, the Southern Hemisphere has seen very small amounts of global dimming while Northern Hemisphere has witnessed more significant reductions, to the tune of 4-8%. Regions such as parts of Europe and North America have observed partial recovery from dimming while parts of China and India have experienced an increase in global dimming.

Various Causes of Global Dimming

1. Aerosols

They are a colloid of fine solid particles or liquid droplets in the air and other gases, which are believed to be the major cause of global dimming. Most aerosols in the atmosphere, only scatter light from the sun, sending back to space some of the sun's radiant energy as well as exerting a cooling influence on the earth's climate. Sulfate aerosols in the atmosphere are due to human activities and they have interfered with the hydrological cycle by reducing evaporation and may have reduced rainfall in some areas.

2. Particulate matter

These include sulfur dioxide, ash and soot, which are by-products of burning fossil fuels as well as internal combustion engines. Once they enter the atmosphere, they directly absorb solar energy and reflect back into the space radiation from the sun, before it reaches the surface of the earth. By reflecting the radiation from the sun back, they cause a dimming in the energy and light from the sun that reaches parts of the earth.

3. Water droplets

Water droplets in the atmosphere may contain airborne particulates like sulfur dioxide, soot and ash, which form polluted clouds. These polluted clouds contain a heavier and larger number of droplets than normal clouds, which change the properties of a cloud, resulting in 'brown clouds'. These clouds reflect light and energy from the sun back into space, resulting in global dimming.

4. Vapours

Vapour in the atmosphere could result from numerous sources such as evaporation from bodies of water. Planes flying high in the sky, called contrails, reflect heat from the sun back into space, causing global dimming.

5. Wildfires

Over the last few years, wildfires have been more vicious than ever and in 2020 alone, wildfires have burnt more than a million acres in Oregon and more than 4 million acres in California. The wildfires have become so severe that entire cities are literally staying in some sort of dim light for days due to the amount of smoke in the atmosphere. Although the smoke will eventually clear, it adds to the causes of global dimming like particulate matter and the fine solid particles that cause global warming and global dimming

Effects of Global Dimming

1. Effects on water

As a result of the reflection of solar energy away from the surface of the earth, the water in the northern hemisphere is becoming colder. This is resulting in slow evaporation and the generation of far lesser water droplets. As a result of these, there is a reduction in the amount of rain reaching these areas of the globe causing drought and famine situations. The tragic consequences of these are miserable lives, disturbed marine life and deaths due to starvation

2. Drought in sub-Saharan Africa

It has been established that the drought and famine of The Sahel, which killed thousands in sub-Saharan Africa in the 1970s was largely due to global dimming. The profound drought was first blamed on farmers in the region for degradation of the land and desertification but that idea has since been disproved and global dimming is understood as the leading cause.

3. Change in overall land temperatures

Again, as a result of global dimming which reflects solar energy and heat that was meant for the planet's surface, the overall temperature on land goes down. Global dimming means there is a blanket in the atmosphere which prevents all the heat from the sun from reaching us. This results in colder days and an overall change in global temperatures.

4. Effects on plants

Plants depend on light for photosynthesis. A decrease in sunlight or solar radiation will negatively affect photosynthesis in plants. The process in green plants uses light energy and converts water, carbon dioxide and minerals into oxygen and energy-rich organic compounds. Humans rely on the oxygen for survival, and so do other animals as well as bodies of water

It counters global warming

Global dimming is believed to be counteracting the actual effects of carbon emissions on global warming. This creates a catch-22 situation from which in defeating one evil against the environment, means exposing ourselves to another. If efforts are made to reduce particulate emission causing global dimming, it will enhance global warming and increase the global temperatures to more than double, making the planet uninhabitable.

Ways to Reduce Global Dimming

1. Switching to alternative sources of energy: Many nations that have or had high levels of global dimming can be characterized by the fact that they produce or produced their energy through the burning of fossil fuels. Burning fossil fuels releases carbon dioxide and other greenhouse gases, which contribute to global warming. At the same time, these gases also produce aerosols as a by-product of burning fossil fuels such as coal. These aerosols account for global dimming and in switching to alternative sources of energy, will reduce these aerosols and global dimming

2. Reducing levels of pollution: Since the 1980s there have been campaigns and controls that have substantially reduced air pollution, a contributing factor to global dimming. Reducing pollution can control the amount of particulate matter and pollutants in the atmosphere which might bring about global dimming. Still, more needs to be done because airplane contrails are still providing some dimming

3. Controlling wildfires: Wildfires have an effect on the atmosphere by causing regional dimming, even if it is for some time. Wildfires occur all over the world throughout the year and minimizing or at least controlling them, will reduce dimming

. Switching to nuclear energy: Nuclear energy is a much better alternative to fossil energy as it is free from producing outputs of carbon, yet it produces more electricity than wind and solar power. It is the best alternative in highly industrialized countries like the US and China. In China and India, for instance, they are shutting down coal plants and building more nuclear energy plants, which will see them lower their levels of dimming.

5. Driving less: Vehicles produce a lot of emissions that are harmful to the environment. These particles are highly attributed to both global warming and global dimming. If we drive less, we might clear the environment and reduce dimming. The ongoing Coronavirus Pandemic has had a positive effect on the environment by increasing air quality all over the world as most nations instituted lockdown measures. Factories were shut down and people were forced off the roads, reducing emissions.

Difference between Global Dimming and Global Warming

1. Causes: Global warming is caused by the increase in the concentration of greenhouse gases like carbon dioxide as a result of the burning of fossil fuels. On the other hand, global dimming is mainly the result of aerosols produced as a by-product of burning fossil fuels. On a comparative front, both global warming and dimming are related to the burning of fossil fuels by industry and internal combustion engines and will continue to impact human societies if they continue unabated.

2. Effects on global temperature: Global warming, as the name suggests, results in warmer temperatures on earth because of the effect of the greenhouse gases. In contrast, global dimming results in lower temperatures as the sun’s heat, rays and energy is reflected away and does not reach the surface of the earth

3. Effects on rainfall: Global warming means the oceans evaporate more and as a result, it leads to more rainfall. Global dimming does the opposite as it reduces such evaporation, meaning there is less rainfall.

. Effects on the weather: Global warming results in more severe weather such as prolonged droughts, severe rainfall and floods, melting ice caps, rising ocean levels and strong winds which could bring about more typhoons and hurricanes. Global dimming leads to calmer weather as there is less energy in the water cycle, meaning fewer storms. However, both phenomena have been documented to ring about similar changes to the weather like droughts

5. Tackling the phenomena: Global dimming was identified several decades ago and has since been slowed, stopped or possibly been reversed in the 1980s. Unfortunately, global warming is a continuing problem and no efforts to stall, slow or end it have since been successful.

What is a carbon footprint – definition

A carbon footprint is defined as the total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO_2).

In other words: When we drive a car, the engine burns fuel which creates a certain amount of CO_2, depending on its fuel consumption and the driving distance. (CO_2 is the chemical symbol for carbon dioxide). When we heat our house with oil, gas or coal, then you also generate CO_2. Even if you heat your house with electricity, the generation of the electrical power may also have emitted a certain amount of CO_2. When you buy food and goods, the production of the food and goods also emitted some quantities of CO_2.

Your carbon footprint is the sum of all emissions of CO_2 (carbon dioxide), which was induced by your activities in a given time frame**.** Usually a carbon footprint is calculated for the time period of a year.

The best way is to calculate the carbon dioxide emissions based on the fuel consumption. In the next step you can add the CO_2 emission to your carbon footprint. Below is a table for the most common used fuels:

Examples of carbon dioxide (CO_2) emissions:

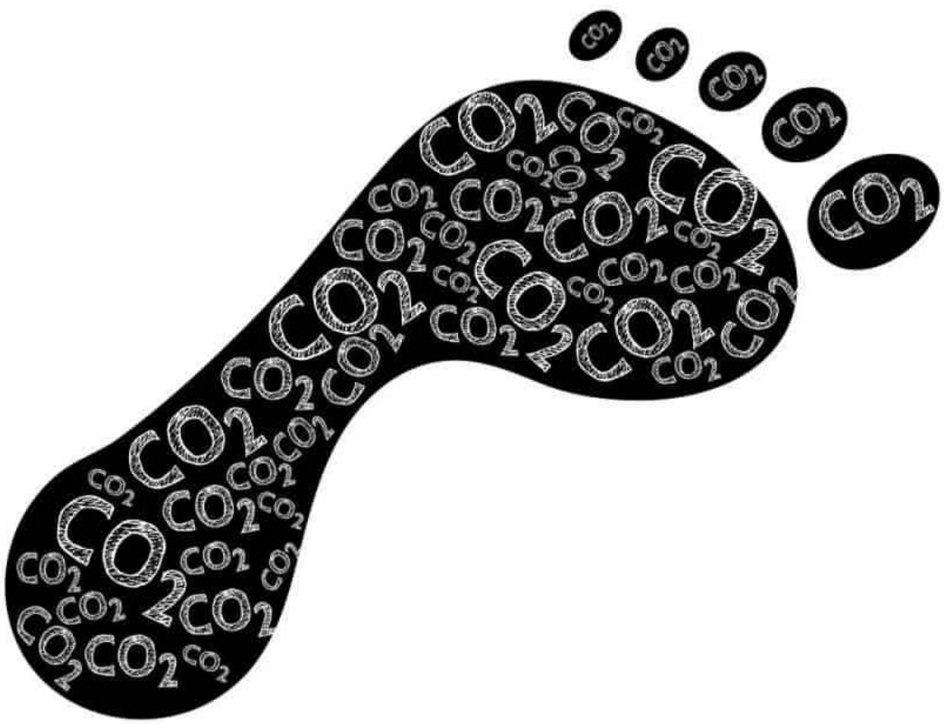
- For each (UK-) gallon of petrol fuel consumed, 10.4 kg carbon dioxide (CO_2) is emitted.

- For each (US-) gallon of gasoline fuel consumed, 8.7 kg carbon dioxide (CO_2) is emitted.
- If your car consumes 7.5 litter diesels per 100 km, then a drive of 300 km distance consumes 3 x 7.5 = 22.5 litter diesel, which adds 22.5 x 2.7 kg = 60.75 kg CO2 to your personal carbon footprint.
- A carbon footprint is the sum of all emissions of greenhouse gases (usually mainly CO2).
- Each of the following activities add 1 kg of CO2 to your personal carbon footprint:
- Travel by public transportation (train or bus) a distance of 10 to 12 km (6.5 to 7 miles)
- Drive with your car a distance of 6 km or 3.75 miles (assuming 7.3 litres petrol per 100 km or 39 mpg)
- Fly with a plane a distance of 2.2 km or 1.375 miles.
- Operate your computer for 32 hours (60 Watt consumption assumed)
- Production of 5 plastic bags (see article about carbon footprint of plastic bags)
- Production of 2 plastic bottles
- Production of 1/3 of an American cheeseburger (yes, the production of each cheeseburger emits 3.1 kg of CO2! It has a very large carbon footprint).

Examples for carbon footprint contributions:

fuel type	**unit**	**CO_2 emitted per unit**
Petrol	1 gallon (UK)	10.4 kg
Petrol	1 liter	2.3 kg
Gasoline	1 gallon (USA)	8.7 kg
Gasoline	1 liter	2.3 kg
Diesel	1 gallon (UK)	12.2 kg
Diesel	1 gallon (USA)	9.95 kg
Diesel	1 liter	2.7 kg

Oil (heating)	1 gallon (UK)	13.6 kg
Oil (heating)	1 gallon (USA)	11.26 kg



To calculate the above contributions to the carbon footprint, the current UK mix for electricity and trains was taken into account.

Carbon dioxide is a so called greenhouse gas causing global warming. Other greenhouse gases which might be emitted as a result of your activities are e.g. methane (CH4) and nitrous oxide [N2O]. These greenhouse gases are normally also taken into account for the carbon footprint. They are converted into the amount of CO2 that would cause the same effects on global warming within a certain time frame, usually 100 years (this is called equivalent CO2 amount).

Few people express their carbon footprint in kg carbon rather than kg carbon dioxide. You can always convert kg carbon dioxide in kg carbon by multiplying with a factor 0.27 (1’000 kg CO2 equals 270 kg carbon).

Why you should calculate your carbon footprint

The carbon footprint is a very powerful tool to understand the impact of personal behaviour on global warming. Most people are shocked when they see the amount of CO2 their activities create! If we personally want to contribute to stop global warming, the calculation and constant monitoring of our personal carbon footprint is essential.

In the web, we can find many carbon footprint calculators, which allow storing individual activities like, e.g. travelling by car, train, bus or air plane, fuel consumptions, electricity bills and so on. We can then see the amount of CO2 created for each individual activity. We can do this either in advance and use it as a help for decisions or afterwards to continually sum up our carbon dioxide emissions. Or we can estimate our carbon footprint of all our activities, an easy to use off-line carbon footprint and primary energy consumption calculator (Excel sheet) is available for free in the download section.

There are graphs available on this site for the CO2 emissions per capita by country (average carbon footprint by country). In the medium- and long term, the carbon footprint must be reduced to less than 600 kg CO2 per year and per person. This is the maximum allowance for a sustainable living .

9.10. Summary:

Gases that trap heat in **Green House Gases:** The atmospheres are called greenhouse gases. This section provides information on emissions and removals of the main greenhouse gases from the atmosphere. Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. The combustion of fossil fuels such as gasoline and diesel to transport people and goods was the largest source of CO_2 emissions in 2020. Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle. An **urban heat island** (**UHI**) is an urban or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. As a result of the reflection of solar energy away from the surface of the earth, the water in the northern hemisphere is becoming colder. This is resulting in slow evaporation and the generation of far lesser water droplets.

9.11. Terminal question

Q.1. What is Greenhouse gases (GHGs), discuss it source and effect in natural climate.

Answer:---

Q.2. What is the global warming; discuss the responsible factor of global warming.

Answer:---

Q.3. Discuss the role of Carbon Dioxide emission in global warming.

Answer:---

Q.4. Discuss about methane emissions and its role in nature.

Answer:---

Q.5. Discuss the sinks of Methane in the atmosphere.

Answer:---

Q.6. Discuss the human impact of greenhouse gases.

Answer:---

Q.7. What is the Urban Heat Island, writ the causes of urban heat island.

Answer:---

9.12.Further suggested Readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press. Godfrey,“ Renewable Energy Power For A Sustainable Future, Boyle, Oxford University Press.
5. Introduction to Energy and Climate , Developing a Sustainable Environment, Julie Kerr, Taylor & Francis eBooks

Block-4 **PGEVS-107N**

Rajarshi Tandon Open University, Prayagraj

Energy Resources and Climate Change

Block- 4

Climate Change and Policy Framework

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Introduction

This fourth block of Energy Resources and Climate Change, this consists of following three units:

Unit-10: this unit covers Impacts of Global Climate Change like change in global temperature, and insect outbreaks, vector borne/zoonotic diseases, forest fire, and reduced water availability etc. In addition the loss of biodiversity and extinction of species, sea level rise, and food security also discussed in this unit.

Unit-11: This unit covers the history of international climate change policies, united nation framework, convention on climate change (UNFCCC), and the intergovernmental panel on climate change (IPCC).

Unit-12: This unit covers the role of Ministry of environment, forests & climate change (MOEF&CC), national action plan on climate change (NAPCC) in reduction of green house gases and global warming. In addition, the agenda 21, the Kyoto protocol and Paris agreement also briefly discussed in this unit.

Unit-10: Impacts of Global Climate Change

Contents

10.1. INTRODUCTION

Climate change has occurred for as long as the earth existed. It happened any time earth's climate pattern change and remain in place for a measurable amount of time Global climate change, largely caused by human activities such as the burning of fossil fuels and deforestation, is resulting in arrange of impacts on the environment, economies, and societies around the world. This includes rising global temperatures, melting glaciers and sea ice, changes in precipitation patterns, impacts on ecosystems and human health and economic impacts. These impacts are expected to become increasingly severe in the coming decades unless significant action is taken to reduce greenhouse gas emissions and mitigate the effects of climate change. five main factors interacted with one another as climate change occurred. These five factor include 1) atmospheric (air), 2) Biosphere (living things), 3) Cryosphere (ice and permafrost) 4) hydrosphere (water) and 5) Lithosphere (earth crust and upper mantle).

- To understand the climate change
- To study effect of climate change on insect outbreak and waterborne diseases
- To study the effect of climate change on forest and biodiversity
- To study the effect of climate change on sea level rise and food security

10.2. Concept of Climate change

Climate change has always happened on Earth but its rapid rate and important magnitude occurring now are of great concern. Climate change occurs as a result of an imbalance between incoming and outgoing radiation in the atmosphere. The main cause of recent climate change is the release of greenhouse gases, particularly carbon dioxide, into the atmosphere as a result of human activities such as fossil fuel combustion and land use change. The global warming associated with climate change is different from past warming in its rate. It is anticipated that there will be a rise in global mean temperatures of up to 5.4°C by 2100.Climate change is recognized as a serious threat to ecosystem, biodiversity, and health. It is associated with alterations in the physical environment of the planet Earth and affects life around the globe. Climate change assign to the changes in prolonged changes in the climate. Climate change happens over decades and century's .It brings about by burning of greenhouse gases in the Earth's atmosphere due fundamentally to ignited fossil fuels (e.g., coal, oil, and natural gas).

These gases raise the Temperature of the Earth and the oceans resulting in rising sea levels, alternations in storm patterns, altered ocean currents, changes in rainfall, melting snow and ice melting glacier and warming oceans more extreme heat events, fires, and drought.. These impacts are projected to continue and in some cases, intensify, affecting human health, infrastructure, forests, agriculture, freshwater supplies, coastlines, and marine systems.

Climate Variability

The natural variation in climate that occurs from month to month, season to season, year to year and decade to decade is referred to as climate variability (e.g., yearly cycle of wet and dry seasons in the western tropical Pacific). as climate change worsens dangerous weather events are becoming more frequently or severe.

Climate variability between years is caused by natural variations in the atmosphere and ocean, such as the El Niño Southern Oscillation (ENSO). ENSO has two extreme phases: El Niño and La Niña. El Niño tends to bring weaker trade winds and warmer ocean conditions near the equator across much of the Pacific, whereas La Niña tends to bring stronger trade winds and cooler ocean conditions.

Natural climate variability occurs in parallel with climate change (i.e., droughts and floods caused by ENSO will continue to occur and may intensify due to climate change). Therefore, these natural fluctuations must also be taken into account while planning for future. Various fluctuations are seen in the environment due to climatic change. It is a major concern for the environment. a slight change in the earth can lead to climatic changes. while less tilt means cooler summers and milder winters. These small and slow changes can lead important change in the seasons over ten of thousands of year.

How do we know the world's climate is changing?

The world's average temperature has changed throughout the existence of earth. Sometimes the world's temperature has been warmer and sometimes it has been colder. Ice age happens when the Earth experiences colder temperatures. Factors like ocean currents and volcanic eruptions caused these shifts. These changes are part of a natural cycle of heating and cooling. This usually happens over tens of thousands of years.

But now Earth's climate is changing faster than it ever has during human history. Earth's average temperature has increased by 1 °C over the past 100 years. In fact, 2015 to 2020 were the hottest on record. Global warming refers to this trend of rising global temperatures. Global warming is one of the ways that Earth's climate is changing. Global warming is one aspect of climate change. Climate change also involves changing global weather patterns, ocean currents, and other systems.

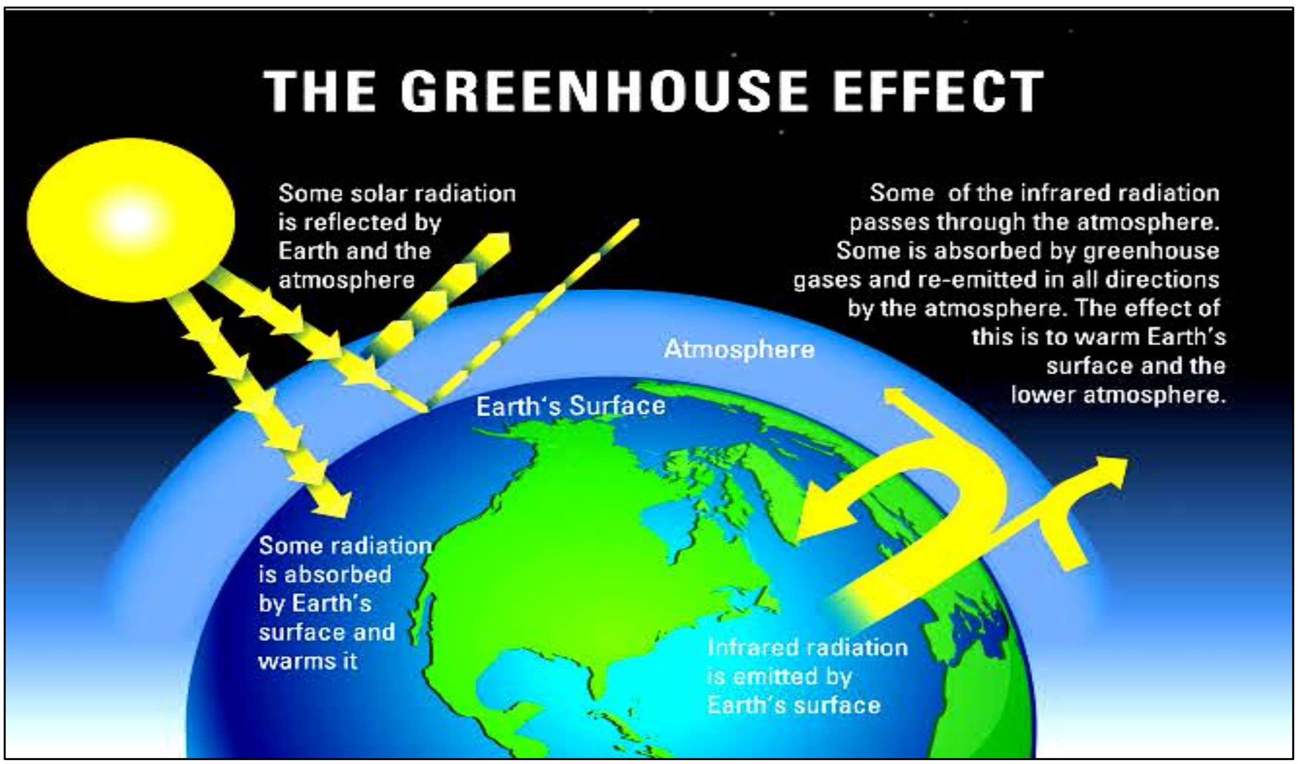
Rising sea levels, melting ice and increasing extreme weather events affect each region differently. For example, snow and ice are melting so quickly that the Arctic could have no summer sea ice by 2035. Coastal areas are experiencing more flooding. These are all evidence of climate change. Change to weather is perhaps the most noticeable effect of climate change which includes extreme weather events like. 1) Stronger storms and hurricanes, 2) Heat waves, 3) Wildfires,4) More loading, 5) Heavier drought.

Why is the climate changing?

These changes to Earth's climate are not natural shifts. Scientists are confident that human activities are leading to climate change. Human activities release gases that change the makeup of Earth's atmosphere. These gases are of atmosphere traps at trapping the Sun's heat. The warming of our atmosphere is actually happening because the atmosphere is continuing to trap heat that radiates form the earth and traps it between earth and space. This is the greenhouse effect. The greenhouse effect is the main cause of rising temperatures.

So what is the greenhouse effect? Plants can grow better in a greenhouse because it stays warmer than the outside air. This is because heat from the Sun is able to enter the clear glass or plastic. The heat warms the air inside. The heat from the trapped air keeps the greenhouse warm.

Earth's atmosphere also acts like a greenhouse. Sunlight reaches our planet and warms it. Some of the heat is reflected back into space. Some of the heat is trapped by gases in Earth's atmosphere. These greenhouse gases include carbon dioxide (CO_2), water vapour, methane, and nitrous oxide.



The greenhouse gases in our atmosphere help keep our planet warm enough for us to survive. Too little greenhouse gas would make the Earth too cold for humans. But, too much greenhouse gas in the atmosphere makes the Earth too warm. Over the past century, humans have added a lot of greenhouse gases to our atmosphere.

Carbon dioxide is the most common greenhouse gas in our atmosphere. Carbon moves between the Earth, living things, and the atmosphere in the carbon cycle. Like all animals, humans add carbon dioxide to the atmosphere when we breathe. We also emit a lot more carbon dioxide when we burn fossil fuels. These are fuels we dig up like oil, gas and coal which are made of plant and animal remains from millions of years ago. We burn fossil fuels when we drive cars, heat our homes, and generate electricity. Humans have burned large amounts of fossil fuels over the last century.

Methane (CH4) is the next most common greenhouse gas. Methane traps roughly 30 times more heat than carbon dioxide. This makes methane an important gas to keep an eye on. The main sources of methane in Canada are from fossil fuels use, farming, and waste and lot of domestic livestock.

What are the impacts of climate change?

Rising global temperatures have complex and sometimes unexpected impacts that affect us all. Even one more degree of increase could be disastrous for the world. The impacts of climate change are complex and different for every region. In some places, higher temperatures could lead to more droughts and heat waves. Rising temperatures could also increase the amount of water that evaporates. This could lead to more frequent and intense storms in some areas. Climate change could continue to lead to melting ice and glaciers, warming oceans, and rising sea levels. These changes impact people, plants, and animals The amount of carbon dioxide in the air is now nearly 50% more than at the start of the industrial age. Carbon dioxide concentrations haven’t been so high for over three million years.

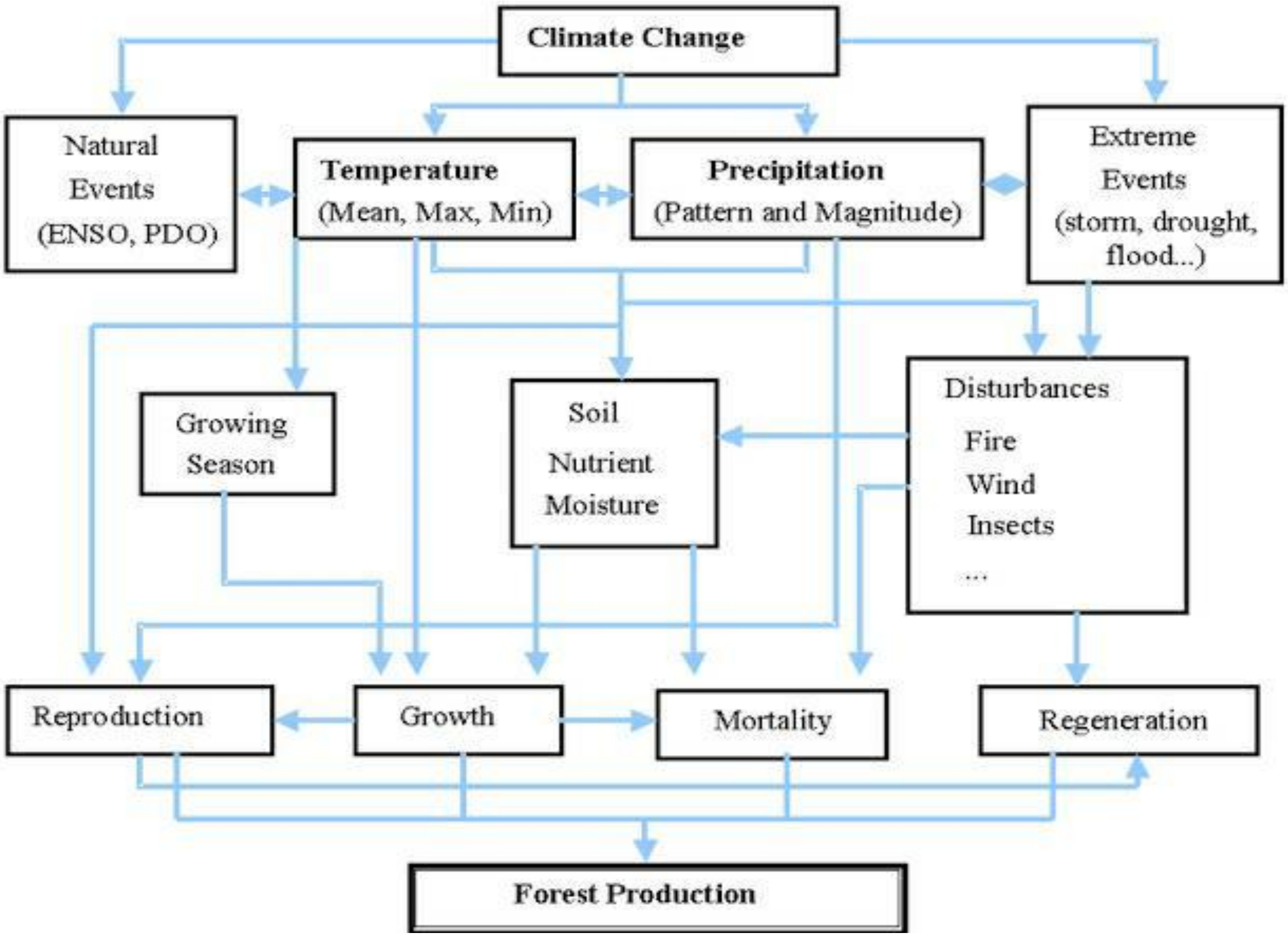
The Impacts of climate change affects the physical environment, ecosystems and human societies. The environmental Impacts of climate change are diversed and far-reaching. They affect various things in our Environment like - the water cycle, oceans, sea and land ice (glaciers), sea level, as well as weather and climate extreme events. the regional changes vary: at high latitudes it is the average temperature that is increasing, while for the oceans and tropics it is in particular the rainfall and the water cycle where changes are observed. These all are due to Climate change and it is commonly known as Global Warming.

Human-induced climate change is continuous process and effects. Ecosystems and communities in and around the world. Global temperatures rose about 1.98°Foffsite link (1.1°C) from 1901 to 2020, but climate change refers to more than an increase in temperature. It also includes sea level rise, changes in weather patterns like drought and flooding, and much more. There is wide impact upon as water, energy, transportation, wildlife, agriculture, ecosystems, and human health due to changing climate.

10.3. A Complex Issue

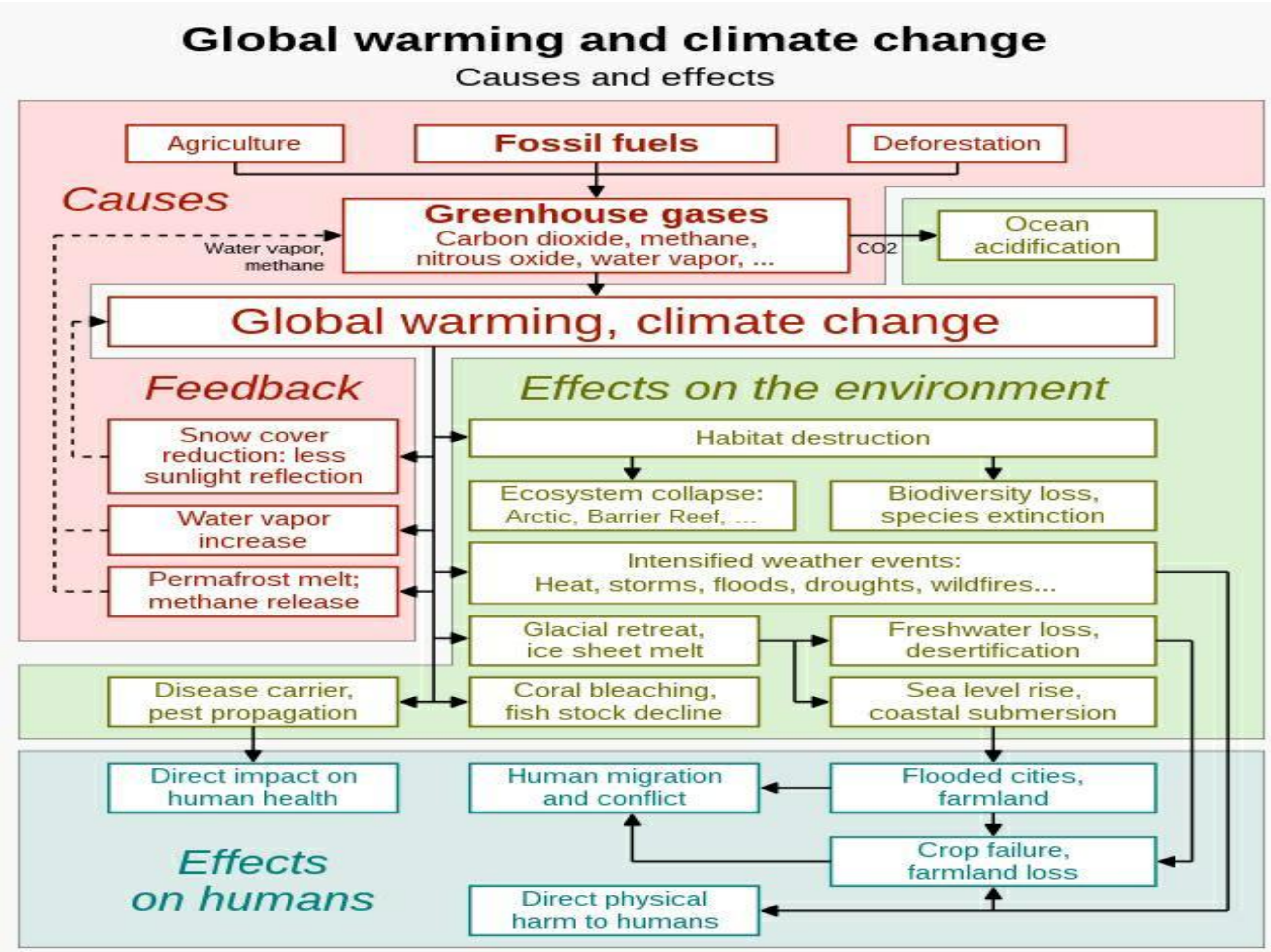
The impacts of climate change on different sectors of society are inter related. Drought can harm food production and human health. Flooding can lead to disease spread and damages to ecosystems and infrastructure. Human health issues can increase mortality, induce food availability, and limit workers productivity. Climate change impacts are seen throughout every aspect of the world we live in. However, climate change impacts are uneven across the country and the world even within a single community, climate change impacts can differ between neighbourhoods or individuals. Long-standing socioeconomic inequities can make negative impact on underserved groups, who often have the highest exposure to hazards and the fewest resources to respond.

Experts believe that there is still hope to avoid negative outcomes by limiting warming offsets link and reduce emissions to zero as quickly as possible. Reducing our emissions of green house gases will require investment on new technology and infrastructure, which will create Jons. Additionally, lowering emissions will lessen harmful impacts on human health, saving countless lives and will save billions of dollars in health-related expenses.



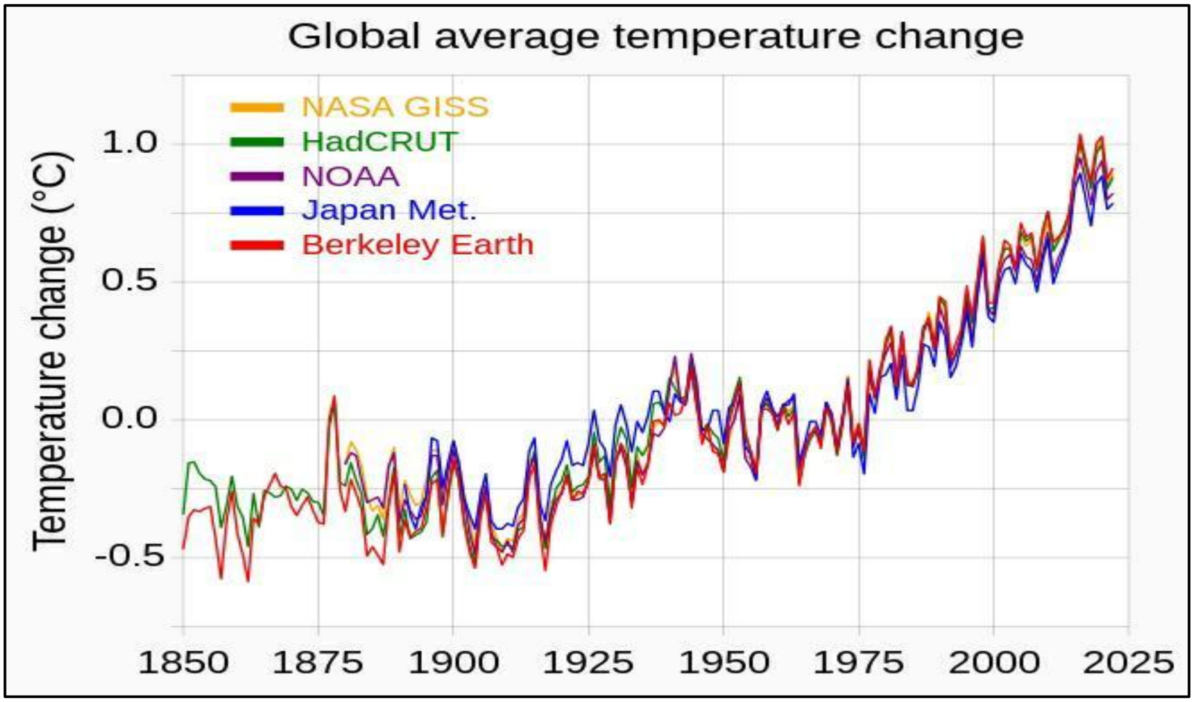
Climate Change
Natural Events (ENSO, PDO)
Temperature (Mean, Max, Min)
Precipitation (Pattern and Magnitude)
Extreme Events (storm, drought, flood...)
Growing Season
Soil Nutrient Moisture
Disturbances Fire Wind Insects ...
Reproduction
Growth
Mortality
Regeneration
Forest Production

Following are Some Common Major impacts of Climate Change :-



Global Climate change degraded land by Increasing Surface Mean Temperature

In earth science, global surface temperature (GST; sometimes referred to as global mean surface temperature, GMST, or global average surface temperature) is calculated by averaging the temperature at the surface of the sea and air temperature over land. In technical writing, scientists call long-term changes in GST global cooling or global warming.



Periods of both have happened regularly throughout earth's history.

The reliable measurement of the global temperature started in 1880. Between that year and 1940 the average annual temperature increased by 0.2 °C. The temperature was stable between 1940 and 1970. Since 1970, it has increased by 0.18 °C at each decade. The average global temperature has increased by 0.9 °C (33.6 °F) compared to the baseline temperature which is about 14 °C. Although a pause has been observed between 1998 and 2013, there after the global warming continues to rise since at the same pace as earlier.

Scientists point out that in the earth's 4.6 billion years of history; sea levels have risen and fallen sharply. However, recent global sea level rise rate has deviated from the average rate of the past two to three thousand years, and is rising at a rate of one-tenth of an inch per year. The continuation or acceleration of this trend will cause significant changes in the world's coastlines.

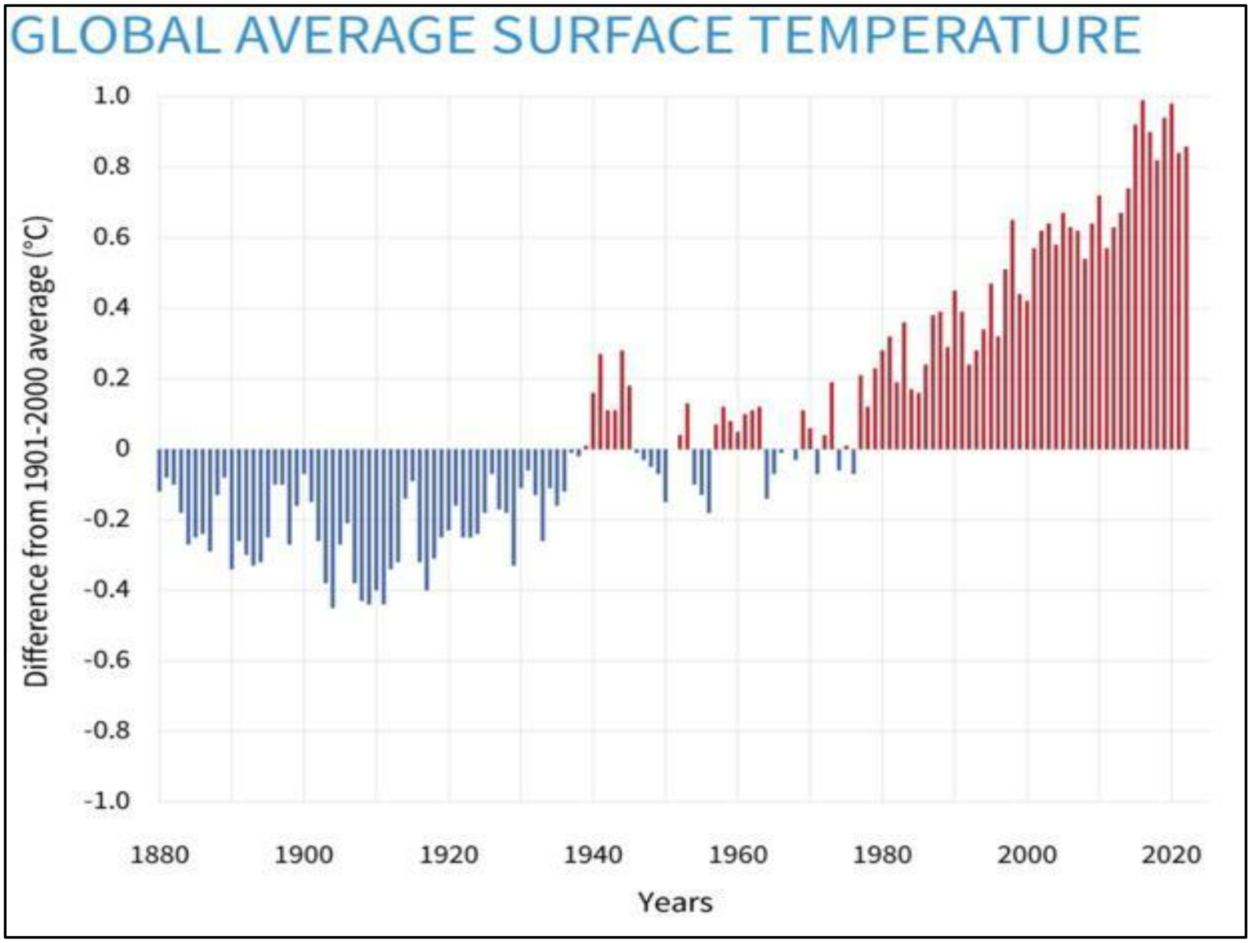
Earth's temperature has risen by an average of 0.14° Fahrenheit (0.08° Celsius) per decade since 1880, or about 2° F in total.

The rate of warming since 1981 is more than twice as fast: 0.32° F (0.18° C) per decade.

2022 was the sixth-warmest year on record based on NOAA's temperature data.

At 2022, the surface temperature was 1.55 °F (0.86 °Celsius) warmer than the 20th-century average of 57.0 °F (13.9 °C) and 1.90 ˚F (1.06 ˚C) warmer than the pre-industrial period (1880-1900). The 10 warmest years were recorded which occurred since 2010.

Yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years.

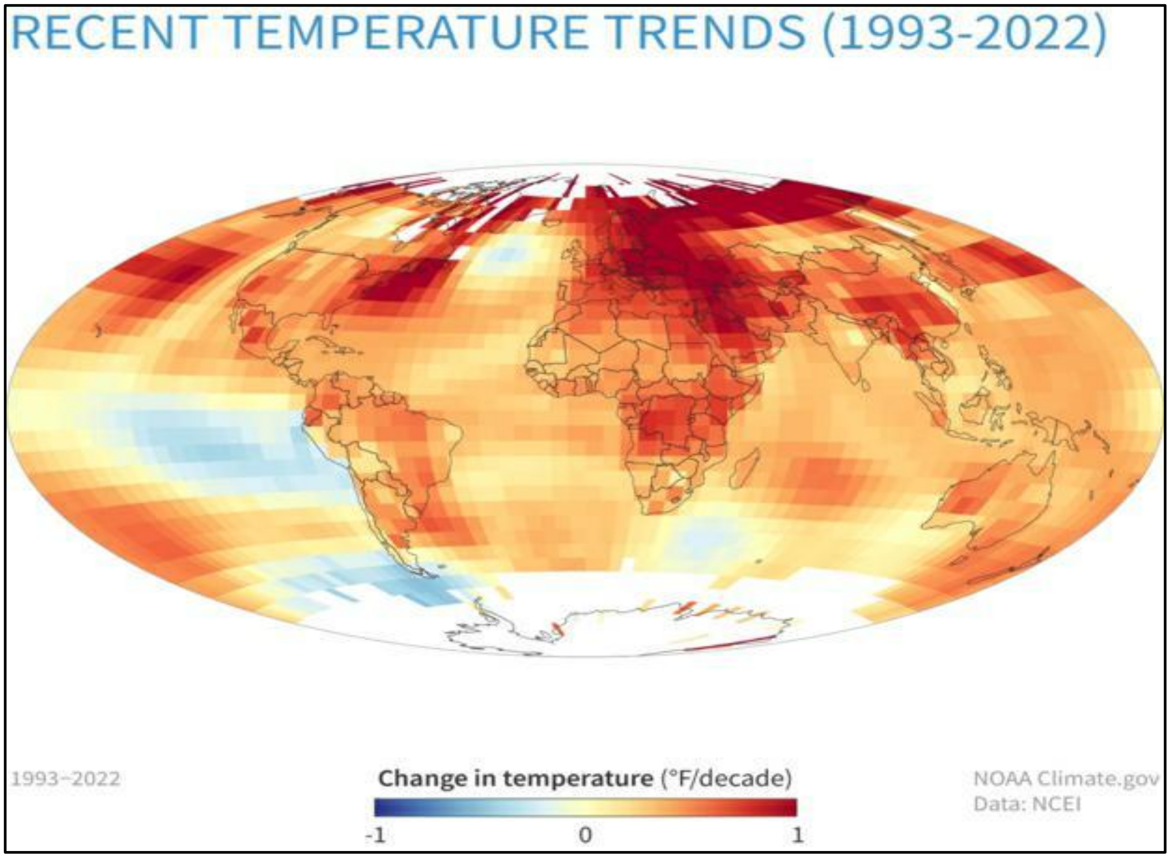


NOAA Climate.gov graph, based on data from the National Centers for Environmental Information.

Given the tremendous size and heat capacity of the global oceans, it takes a massive amount of heat energy to raise Earth's average yearly surface temperature even a small amount. The roughly 2-degree Fahrenheit (1 degrees Celsius) increase in global average surface temperature that has occurred since the pre-industrial era (1880-1900) might seem small, but it means a significant increase in accumulated heat.

That extra heat is driving regional and seasonal temperature to its extremes, reducing snow cover and sea ice, intensifying heavy rainfall, and changing habitat ranges for plants and animals—expanding some and shrinking others. As the map below shows, most land areas have warmed faster than most ocean areas, and the Arctic is warming faster than most other regions.

Recent Temperature Trends (1993-2022)



About surface Temperature

The concept of an average temperature for the entire globe may seem odd. After all, at this very moment, the highest and lowest temperatures on Earth are likely more than 100°F (55°C) apart. Temperatures vary from night to day and between seasonal extremes in the Northern and Southern Hemispheres. This means that some parts of Earth are quite cold while other parts are downright hot. To speak of the "average" temperature, then, may seem like nonsense. However, the concept of a global average temperature is convenient for detecting and tracking changes in earth's energy budget how much sunlight Earth absorbs minus how much it radiates to space as heat over time.

To calculate a global average temperature, scientists begin with temperature measurements taken at locations around the globe, because changes in temperature, measurements are converted from absolute temperature readings to temperature anomalies. The difference between the observed temperature and the long-term average temperature for each location and date are recommended. Across inaccessible areas, scientists use surrounding temperatures and other information to estimate the missing values. Each value is then used to calculate a global temperature average. This process provides a consistent, reliable method for monitoring changes in Earth's surface temperature over time.

Global temperature in 2022

According to the 2022 Global Climate Report from NOAA National Centres for Environmental Information, despite the cooling influence from the La Niña climate pattern in the tropical Pacific, the "coolest" month was November, which was 1.35 ˚F (0.75 ˚C) warmer than average.

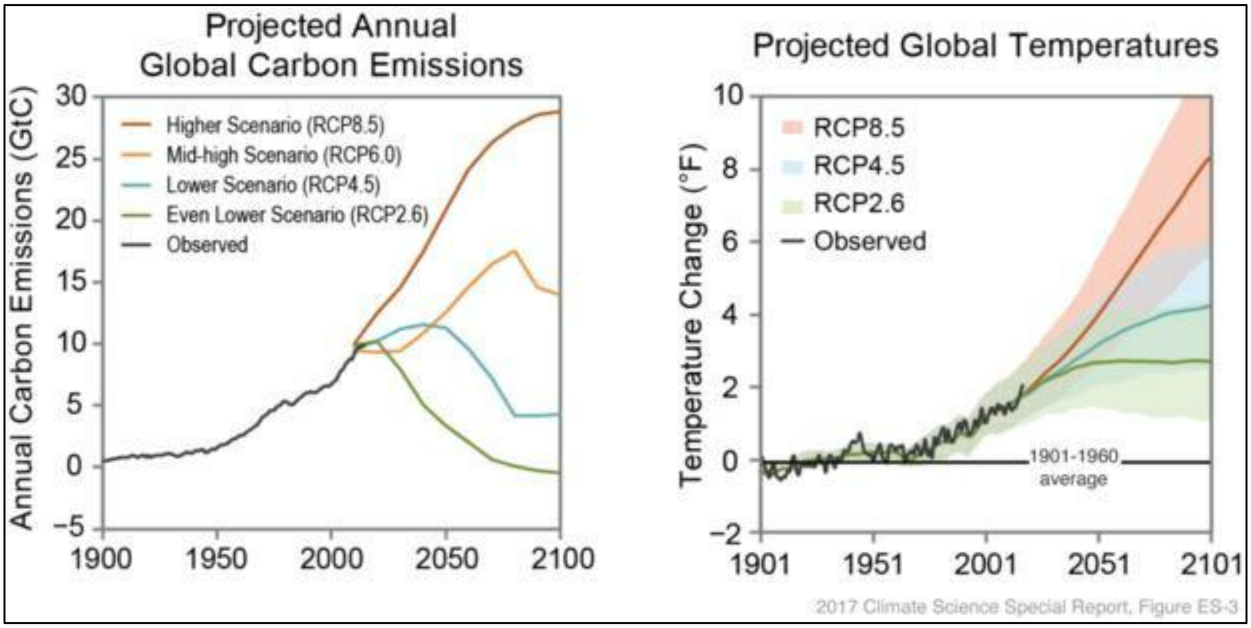
According to NCEI,

The year 2022 was the sixth warmest year since global records began in 1880 at 0.86°C (1.55°F) above the 20th century average of 13.9°C (57.0°F). This value is 0.13°C (0.23°F) less than the record set in 2016 and it is only 0.02°C (0.04°F) higher than the last year's (2021) value, which now ranks as the seventh highest. The 10 warmest years in the 143-year record have all occurred since 2010, with the last nine years (2014–2022) ranking as the nine warmest years on record.

Past and future change in global temperature

Though warming has not been uniform across the planet, the upward trend in the globally averaged temperature shows that more areas are warming than cooling. According to NOAA's 2021 Annual Climate Report the combined land and ocean temperature has increased at an average rate of 0.14 degrees Fahrenheit (0.08 degrees Celsius) per decade since 1880; however, the average rate of increase since 1981 has been more than twice as fast: 0.32 °F (0.18 °C) per decade.

The future warming of earth will depends on how much carbon dioxide and other greenhouse gases we emit in coming decades. Today, our activities such as burning fossil fuels and clearing forests add about 11 billion metric tons of carbon (equivalent to a little over 40 billion metric tons of carbon dioxide) to the atmosphere each year. Because more carbon is generated than natural processes can remove resulting atmospheric carbon dioxide increase every year.



(left) Hypothetical pathways of carbon emissions ("representative concentration pathways," or RCPs) throughout the twenty-first century based on different possible energy policies and economic growth patterns. (right) Projected temperature increase relative to the 1901-1960 average depending on which RCP we eventually follow. Image by Katharine Hayhoe, from the 2017 Climate Science Special Report by the U.S. Global Change Research Program.

According to the 2017 U.S. Climate Science Special Report, if yearly emissions continue to increase rapidly, the global temperature will be increased at least 5 degrees Fahrenheit warmer than the 1901-1960 average, and possibly as much as 10.2 degrees warmer. If annual emissions increase more slowly and begin to decline significantly by 2050, models project temperatures would still be at least 2.4 degrees warmer than the first half of the 20th century, and possibly up to 5.9 degrees warmer.

Impacts of climate change on insect pests

Insects are cold-blooded organisms – the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing insect behaviour, distribution, development, survival, and reproduction.

Anthropogenic CO_2 is almost twice more important for temperature increase than other long-lived greenhouse gases combined. Although increased CO_2 should not directly deleteriously affects insects, the temperature increase due to increase in anthropogenic CO_2 affects insects in their distribution, nutrition, phenology and role as disease vectors.

Effects of elevated CO2 on insect pests

In general, host plants grown under elevated CO2 are less nutritious to herbivores insect it affects their behaviour and performance. Phenotypic host-plant changes typically make leaf material eaten by insects less nutritious. As a consequence, insects have a more difficult time to convert the food eat into biomass. In order to mitigate the effects of less nutritious food, insect herbivores insects often consume more.

Herbivore insect performance is positively correlated with leaf nitrogen concentrations. It has been reported that the leaf nitrogen content decreased for mustard and collard grown under elevated CO_2. Leaf chewing herbivore insects performance is positively correlated with leaf water content. Decrease in leaf water contents was observed under elevated CO_2 for both mustard and collard.

Plants can also defend themselves mechanically, either by having tough leaves or by structures such as leaf trichomes. Levels of mechanical defense are negatively correlated with herbivore performance. Elevated CO_2 increased trichome densities on radish. Several studies, mostly considering leaf toughness, leaf thickness, and specific leaf weight, have also been observed to increase the mechanical defence due to elevated CO_2. Higher percent leaf damage or consumption has been observed due to cabbage white butterfly fed either mustard or collard grown under elevated CO_2. Similar results have been obtained in leaf miners on a variety of woody species. It has been detected a significant negative effect of elevated CO_2 on herbivore insects performance. They observed that overall herbivore communities were lower on plants grown under elevated CO_2 vs. Ambient CO_2. This is likely imparts higher mortality rates due to both parasitoids and other natural enemies. Natural enemies are thought to have better success under elevated CO2 because their prey is more apparent. Insects typically take longer to develop, making them more apparent natural enemies. Higher consumption rates also cause increased leaf damage and increased grass production, both due to natural enemies.

10.4. Effects of elevated temperature on insect pests

Increased temperatures on insect performance directing effects on insects. Because insects are exothermic, they tend to be more active under warmer conditions. A typical effect of elevated temperature is therefore, to increase consumption rates and decrease the time of pupation, making them less apparent to natural enemies and in some cases increasing the potential number of generations per season. It has been estimated that with a 20 °C temperature increase insects might experience one to five additional life cycles per season. Elevated temperatures increase gypsy moth performance, both by decreasing its development time and increasing its survival. However survival rate of another member of its genus, the nun moth, is very different under increased temperatures. If gypsy moths react more favorably to future environments than competitors, they may become more prone to outbreak. Elevated temperatures (on the scale of expected global warming) can also have direct effects on plant phenotypes, and affected total nonstructural carbohydrates, starches, and sugars production.

Effect of changes in rainfall pattern on insect pests

Early and timely planting become more uncertain under climate change. During the 2009 rainy season, delay in onset of monsoons by 45 days resulted in delayed plantings of pigeon pea that are prone to damage by Helicoverpaarmigera and caused heavy damage .As with temperature, precipitation changes can impact insect pest predators, parasites, and diseases resulting in a complex dynamic. Fungal pathogens of insects are favoured by high humidity and their incidence would be increased by climatic changes that lengthen periods of high humidity and reduced result in drier conditions. Some insects are sensitive to precipitation and are killed or removed from crops by heavy rains.

10.5. Vector Borne /Zoonotic Diseases

How climate change affects vector-borne diseases?

As climate change alters temperatures and weather patterns around the world, the risk of vector-borne diseases like dengue fever and Zika virus will increase.

Virtually all vector-borne diseases have a climate dimension. There are three key ways climate change which affects vectors:

More places will become suitable for vectors. Warmer temperatures can increase the geographic spread of vectors- like mosquitoes and ticks- on survival and breeding. Increased rainfall can increase the amount of stagnant water, creating more breeding areas for many vectors. Droughts can also support breeding by forming pools of standing water from previously flowing water.

Warmer climates extend the disease transmission season. This may lead to an increase in the duration of disease transmission seasons.

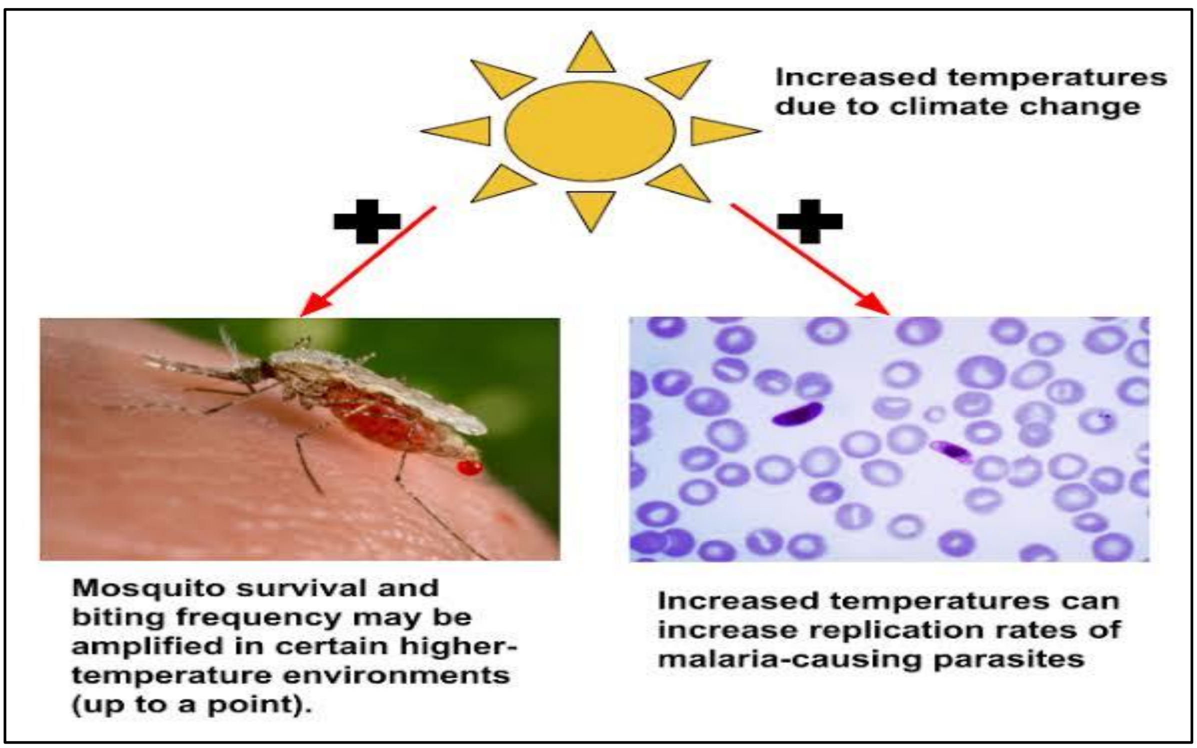
Temperature change can affect the behaviour of vectors. For example, increased temperatures change affects biting behaviour of mosquitoes, reducing the effectiveness of barriers such as bed nets.

Climate change is already affecting vector-borne disease transmission and spread, and its impacts are likely to worsen. In the face of ongoing climate change, we must intensify efforts to prevent and control vector-borne diseases.

The rapid warming of the Earth, caused by anthropogenic greenhouse gas emissions, has profound long-term implications for the prevention and control of vector-borne diseases. Ectotherms cold-blooded animals vectors do better in a warmer world. To address the adverse impacts of climate change, urgent and rapid reductions in greenhouse gas emissions, as well as adaptation to ongoing climate change through intensification of vector-borne disease prevention and control efforts one needed.

Vector-borne diseases

A vector is an organism (most often an arthropod) that transmits an infectious pathogen from an infected human or animal host to an uninfected human. The World Health Organization



identifies the major global vector-borne diseases as malaria, dengue, chikungunya, yellow fever, Zika virus disease, lymphatic filariasis, schistosomiasis, onchocerciasis, Chagas disease, leishmaniasis and Japanese encephalitis . Other vector-borne diseases of regional importance include African trypanosomiasis, Lyme disease, tick-borne encephalitis and West Nile fever. Tropical and subtropical low- and middle-income countries bear the highest burden of vector-borne diseases. Eight vector-borne diseases are considered to be neglected tropical diseases.

10.6. Climate Change Results In Forest Fire

Climate change affects wildfires by exacerbating the hot, dry conditions that help these fires catch and spread.As global temperatures rise, we expect the size, frequency and severity of wildfires to increase in the years ahead. Already, the average wildfire season in the western U.S. is over three months longer than it was a few decades back. In places from California to the Siberian Arctic, we're seeing record-breaking wildfires.

What causes wildfires?

Wildfires are unplanned fires that burn in forests, grasslands and other ecosystems, and they can start with a natural event like a lightning strike, or as the result of human activity. Campfires, discarded cigarettes, and electrical equipment like downed power lines all spark wildfires. the hot and dry conditions cause wildfires to spread across dense forests and make it a perfect recipe for disaster. They not only reduce green cover bt also push forest animals toward higher altitudes. An animal that cold not survive because extinct and gets their name registered in the list of endangered species.

But climate change can make environments more susceptible to burning. Increasing severe heat and drought due to climate change can fuel wildfires.

Hotter temperatures evaporate more moisture from soil and vegetation, drying out trees, shrubs and grasses and turning leaf litter and fallen branches into kindling. In times of drought, trees that are stressed by a lack of water may also become more vulnerable to insects and diseases that can weaken or kill them, creating more fuel for fires. Fire is a natural phenomenon that serves important ecological purposes, clearing dead and diseased plants from some forests, for example, and even helping some plants reproduce.

But a rapidly warming planet — along with a history of short-sighted forest management practices and land use decisions that push development into the wilderness — is contributing to more destructive wildfires.

Fighting wildfires by fighting climate change

Extreme wildfires are devastating communities and ecosystems. Climate change has been a key factor in increasing the risk and extent of wildfires in the Western United States. Wildfire risk depends on a number of factors, including temperature, soil moisture, and the presence of trees, shrubs, and other potential fuel. All these factors have strong direct or indirect ties to climate variability and climate change. Climate change enhances the drying of organic matter in forests (the material that burns and spreads wildfire), and has doubled the number of large fires.

Researches show that changes in climate create warmer, drier conditions. Increased drought and a longer fire season are boosting these increases in wildfire risk.

Wildfires are caused by lighting-ignited wildfire people, warmer temperatures and drier conditions can help fires spread and make them harder to put out. Warmer, drier conditions also contribute to the spread of the mountain pine beetle and other insects that can weaken or kill trees, building up the fuels in a forest.

Land use and forest management also affect wildfire risk. Changes in climate add to these factors and are expected to continue to increase the area affected by wildfires in the United States.

Wildfire can affect:

Federal and State Budgets: U.S. Forest Service fire suppression expenditures had increased from about 15 percent of the agency's appropriated budget to more than 50 percent in 2017. Nationwide suppression costs in 2017 and 2018 ballooned to $2.9 billion and $3.1 billion respectively, while state wildfire expenditures have also increased substantially.

Public Health: The growing number of people in wild lands is increasing the risk to life, property and public health. Smoke reduces air quality and can cause eye and respiratory illness, especially among children and the elderly. Wildfires that burn in residential areas can melt plastic water pipes and cause contamination of water systems with a known carcinogen.

Natural Environment: Wildfires are a natural part of many ecosystems. Although wildfires produce a number of greenhouse gases and aerosols including carbon dioxide, methane, and black carbon, the plants that re-colonize burned areas remove carbon from the atmosphere, generally leading to a net neutral effect on climate. However, when fires burn more frequently and consume larger areas, as they are doing with climate change, the released greenhouse gases may not be completely removed from the atmosphere even if plants can't grow to maturity. The plants that re-colonize are less efficient at carbon uptake.

10.7. Climate Change Reduced Water Availability

Climate change is already affecting water access for people around the world, causing more severe droughts and floods. Increasing global temperatures are one of the main contributors to this problem. Climate change impacts the water cycle by influencing when, where, and how much precipitation falls. It also leads to more severe weather events. Increasing global temperatures cause water to evaporate in larger amounts, which will lead to higher levels of atmospheric water vapour and more frequent, heavy, and intense rains in the coming years.

Climate scientists predict that this shift will lead to more floods since more water will fall than vegetation and soil can absorb. The remaining water, or runoff, drains into nearby waterways, picking up contaminants like fertilizer on the way. Excess runoff eventually travels to larger bodies of water like lakes, estuaries, and the ocean, polluting the water supply and limiting water access for humans and ecosystems.

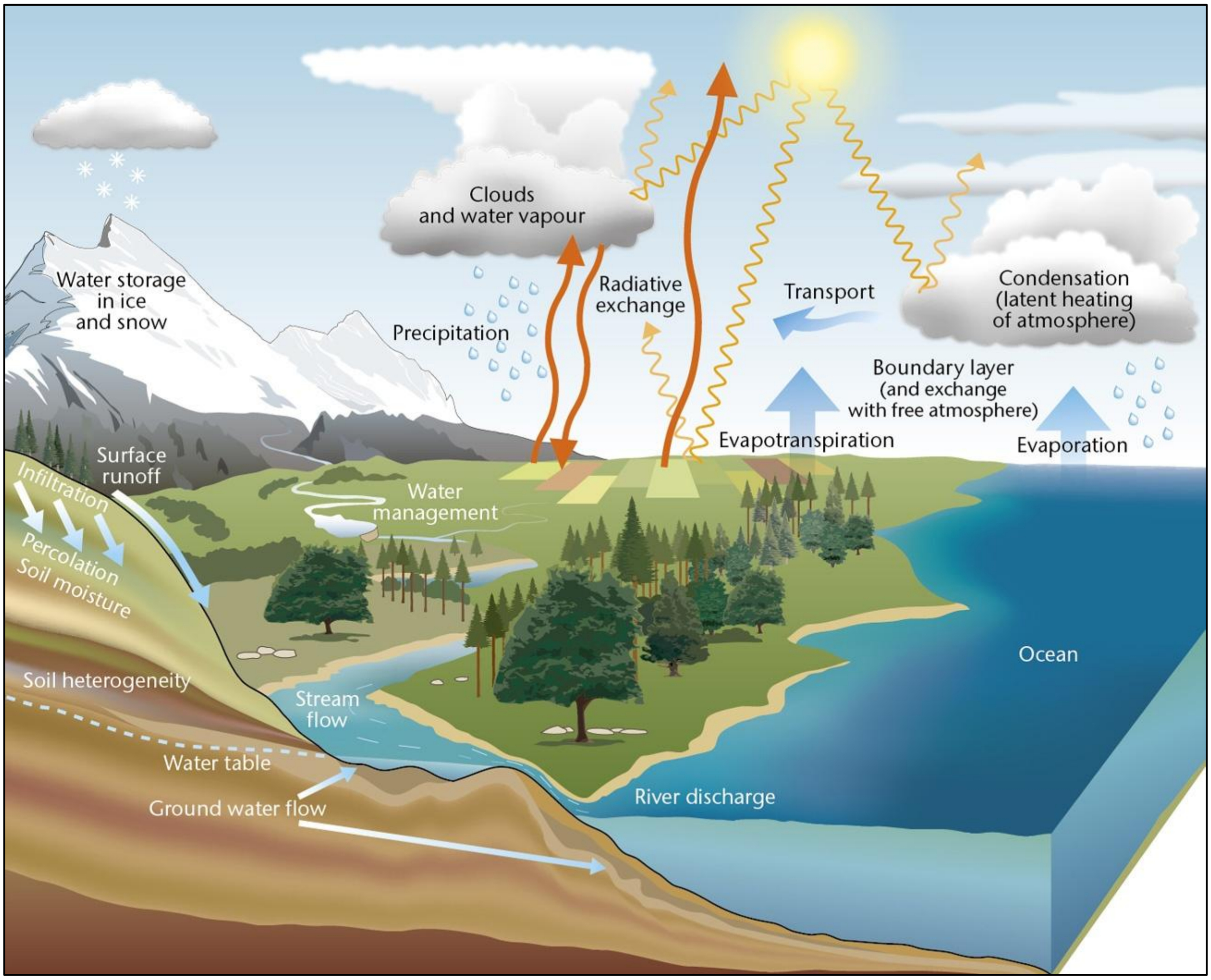
Fertilizers from farming wash into lakes and the ocean, promote rapid growth of algae. These resulting algal blooms clog coasts and waterways with clouds of green, blue-green, red, or brown algae. The blooms block sunlight from reaching underwater life and diminish oxygen levels within the water. Toxins from the blooms can kill fish and other aquatic animals, make people sick, and even kill humans. These toxins are especially dangerous because they can survive purification processes, making tap water unfit for consumption once contaminated. Algal blooms also impact industries that rely on the water for business, and often cause local waterfronts to shut down during blooms. As the climate warms, harmful algal blooms happen more often and become more severe.

As the ocean warms, freshwater glaciers around Earth begin to melt at an unsustainable rate, which results in rising sea levels. The freshwater from the melted glaciers eventually runs into the ocean. With the rising of sea levels, salt water can more easily contaminate underground freshwater-bearing rocks, called aquifers. A process called desalination removes salt from salt water, but it is a last-resort, energy-intensive, costly process for places where there are persistent droughts and freshwater is lacking. The Middle East, North Africa, and the Caribbean use desalination to produce freshwater out of necessity.

In the Northern Hemisphere—where snow, a freshwater source, typically accumulates—warmer temperatures mean less snowfall, which leaves less water available in local reservoirs after winter. This negatively impacts farmers, who are left without enough water to irrigate their crops in the growing season.

There are many things that everyone can do to lessen the impact of climate change. Some measures include growing your own fruits and vegetables or buying locally grown produce, since produce is often transported to grocery stores from far away by trucks, which add more carbon dioxide to the atmosphere. You could also walk or ride a bike instead of driving a car. On a larger scale, industries that are dependent on fossil fuels need to the switch to renewable, cleaner energy sources to influence our planet for the better.

Climatic change affects the world's water in complex ways. Consider a water cycle diagram, like the one below; global warming is altering nearly every stage in the diagram. These changes will put pressure on drinking water supplies, food production, property values, and more, in the U.S. and all around the world.



Evaporation

Warmer air can hold more moisture than cool air. As a result, in a warmer world, the air will suck up more water from oceans, lakes, soil and plants. The drier conditions this air leaves behind could negatively affect drinking water supplies and agriculture.

On the flip side, the warmer, wetter air could also endanger human lives. A study out of

Precipitation

When all that extra warm, extra wet air cools down, it drops extra rain or snow to the ground. Thus, a warmer world means we get hit with heavier rain and snowstorms. The north-eastern largest increase in the intensity and frequency of heavy precipitation events and clusters of thunderstorms have been becoming more frequent and dropping more precipitation since 1979.

By changing air temperatures and circulation patterns, climate change will also change where precipitation falls.

The Southwest, southern Great Plains, and Southeast are predicted to see more intense and prolonged droughts, according to the National Climate Assessment. And most of the rest of the country is at risk of experiencing more severe short-term droughts, too. Researchers within the Earth Institute have found that climate change may already have exacerbated past and present droughts, and that drier conditions are making wildfires worse. The drought scenario could be mitigated by having more water storage in dams. Changes in precipitation patterns will challenge many farmers, as well as natural ecosystems.

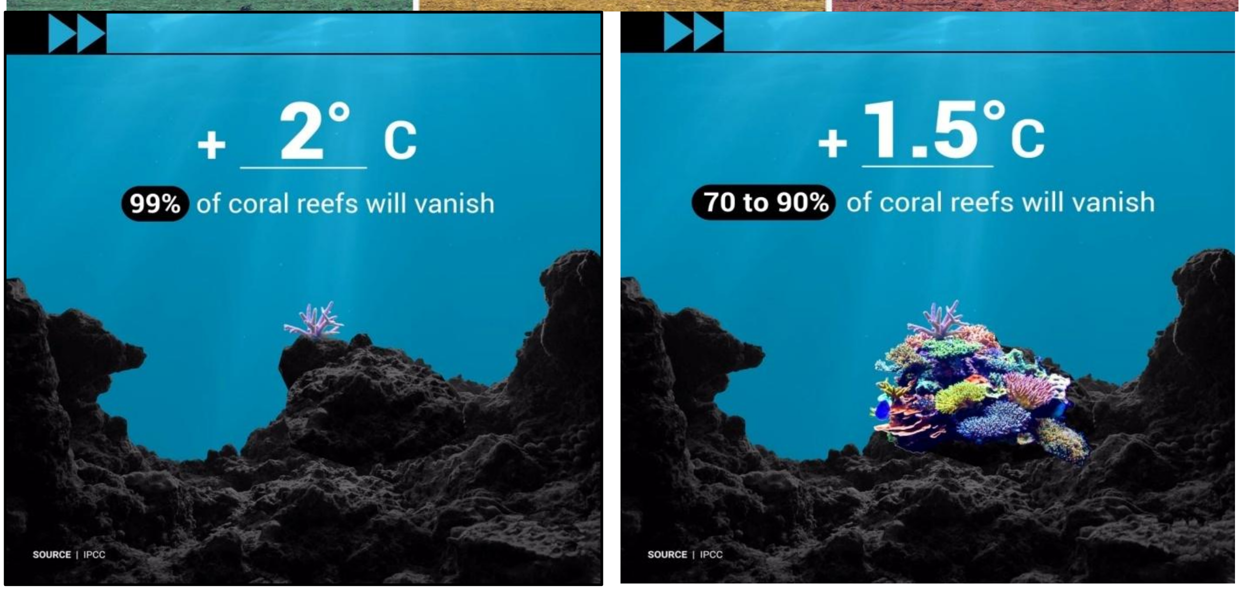
Effect of climate change on biodiversity

The main driver of biodiversity loss remains humans' use of land – primarily for food production. Human activity has already altered over 70 per cent of all ice-free land. When land is converted for agriculture, some animal and plant species may lose their habitat and face extinction.

But climate change is playing an increasingly important role in the decline of biodiversity. Climate change has altered marine, terrestrial, and freshwater ecosystems around the world. It has caused the loss of local species, increased diseases, and driven mass mortality of plants and animals, resulting in the first climate-driven extinctions.

On land, higher temperatures have forced animals and plants to move to higher elevations or higher latitudes, many moving towards the Earth's poles, with far-reaching consequences for ecosystems. The risk of species extinction increases with every degree of warming.

In the ocean, rising temperatures increase the risk of irreversible loss of marine and coastal ecosystems. Live coral reefs, for instance, have nearly halved in the past 150 years, and further warming threatens to destroy almost all remaining reefs.



Overall, climate change affects the health of ecosystems, influencing shifts in the distribution of plants, viruses, animals, and even human settlements. This can create increased opportunities for animals to spread diseases and for viruses to spill over to humans. Human health can also be affected by reduced ecosystem services, such as the loss of food, medicine and livelihoods provided by nature.

The environmental changes being driven by climate change are disturbing natural habitats and species in ways that are still only becoming clear. There are signs that rising temperatures are affecting biodiversity, while changing rainfall patterns, extreme weather events, and ocean acidification are putting pressure on species already threatened by other human activities.

The threat posed by climate change to biodiversity is expected to increase, yet thriving ecosystems also have the capacity to help reduce the impacts of climate change.

If current rates of warming continue, by 2030 global temperatures could increase by more than 1.5°C (2.7°F) compared to before the industrial revolution. A major impact of climate change on biodiversity is the increase in the intensity and frequency of fires, storms or periods of drought. In Australia at the end of 2019 and start of 2020, 97,000km2 of forest and surrounding habitats were destroyed by intense fires that are now known to have been made worse by climate change. This adds to the threat to biodiversity which has already been placed under stress by other human activities. It is thought that the number of threatened species in the area may have increased by 14% as a result of the fires.

Rising global temperatures also have the potential to alter ecosystems over longer periods by changing what can grow and live within them. There is already evidence to suggest that reductions in water vapour in the atmosphere since the 1990s has resulted in 59% of vegetated areas showing pronounced browning and reduced growth rates worldwide.

Rising temperatures in the oceans affect marine organisms. Corals are particularly vulnerable to rising temperatures and ocean acidification can make it harder for shellfish and corals in the upper ocean to form shells and hard skeletons. We have also seen changes in occurrence of marine algae blooms.

Despite the threats posed by climate change to biodiversity, we also know that natural habitats play an important role in regulating climate and can help to absorb and store carbon. Mangroves are significant sinks for carbon and the Amazon is one of the most biologically diverse places on the planet and is an enormous store of carbon – up to 100 billion tons, although a recent study has suggested that the Amazon may now be emitting more carbon than it absorbs. Safeguarding these natural carbon sinks from further damage is an important part of limiting climate change

What is causing biodiversity loss?

Since the Industrial Revolution, human activities, such as logging, pollution, commercial fishing and the development of large urban settlements, have damaged and degraded precious landscapes. Today, the destruction of forests and grasslands for agriculture is the single biggest driver of biodiversity loss. Every minute, deforestation destroys a wooded area the size of 27 football pitches.

Climate change is currently the second biggest cause of biodiversity loss in the ocean and the fourth biggest cause on land, though it's likely to play a greater role in the future.

If the current trends in biodiversity loss continue, one million animal and plant species will be threatened with extinction – more than at any other point in human history. This trend is so stark, some are calling it the sixth mass extinction. This ecological crisis is already impacting millions of people around the world. Overfishing is affecting food supplies and livelihoods in coastal communities. Air pollution contributes to 7 million deaths every year. Human disturbance of ecosystems can help infectious diseases spread more easily. Coastal habitats, which can help reduce the impact of extreme weather events, are also being lost, putting 100-300 million people at an increased risk of floods and hurricanes.

Often, the places and communities suffering the most because of this biodiversity crisis – poorer countries, island nations, Indigenous peoples and the polar regions – are not those most responsible for causing it.

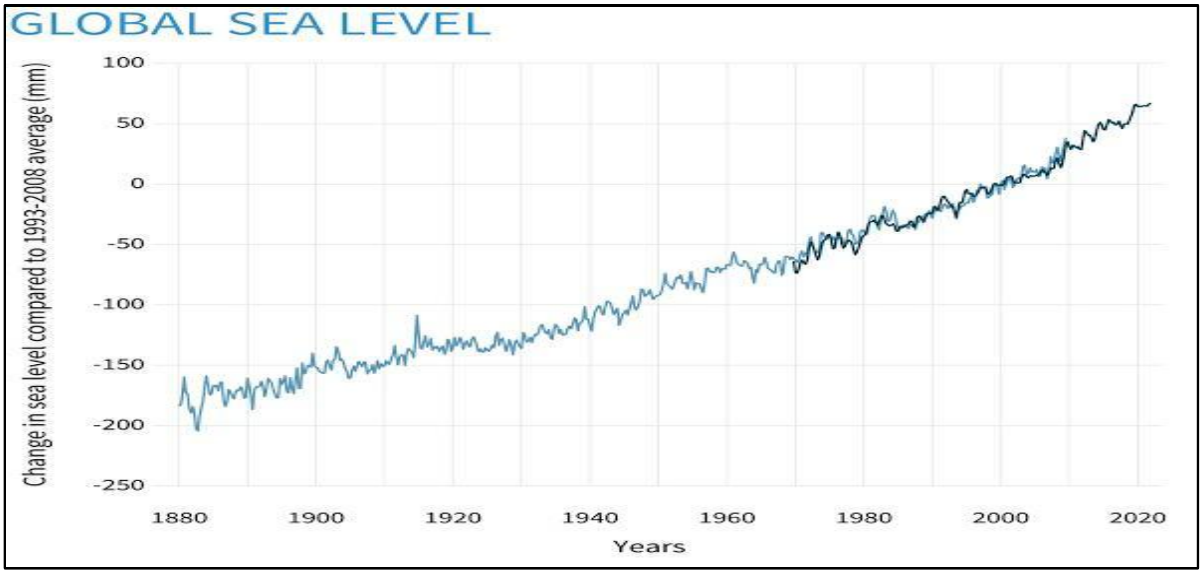
Species and ecosystems have evolved to thrive under specific conditions. The range of temperatures a species can withstand, which is called the species' climate envelope, govern their mating and migration patterns. Global temperatures are likely to rise by more than 1.5°C within the next 20 years. This is a very sudden and serious shock for many species and will either force them to adapt or push them towards extinction.

Populations that can't migrate or adapt, such as some plant and insect species, are at risk of becoming locally extinct. In turn, this will reduce the genetic diversity of the entire species, making it more vulnerable to pests, diseases and other pressures. If this happens to a food crop, it could damage our food system, putting millions at risk of malnutrition and famine.

While many species will be negatively affected by climate change, some species may find the range of available habitat increases. This, coupled with the increased movement of people and goods around the world, is leading to an increase in the number of species being introduced and becoming established outside of their natural range. Some of these species, which are called invasive species, aggressively compete with the local native species for resources. They negatively affect the biodiversity of the area.

It's not just the rising temperatures which present risk to biodiversity. But mounting climate crisis is also causing ice and snow to melt, raising sea levels and eroding vital coastal ecosystems, extreme weather events, such as hurricanes, are happening more frequently, in some cases causing catastrophic flooding that sweeps away homes and vegetation and threatens the lives of humans and animals. Wildfires are also becoming worse.

10.8. Climate Change Causes Sea Level Rise



What's causing sea level to rise?

Global warming is causing sea level to rise in two ways. First, glaciers and ice sheets worldwide are melting and adding water to the ocean. Second, the volume of the ocean is expanding as the water warms. A third, much smaller contributor to sea level rise is a decline in the amount of liquid water on land aquifers, lakes and reservoirs, rivers, soil moisture. This shift of liquid water from land to ocean is largely due to groundwater pumping. From the 1970s up through the last decade or so, melting and heat expansion were contributing roughly equally to observed sea level rise. But the melting of mountain glaciers and ice sheets has been accelerated. As a result, the amount of sea level rise due to melting (with a small addition from groundwater transfer and other water storage shifts) from 2005–2013 was nearly twice the amount of sea level rise due to thermal expansion.

Oceans

Warmer temperatures and increasing acidity are making life difficult for sea creatures. These changes are transforming food chains from the bottom-up. In addition, many fish are moving pole ward in search of cooler waters, which has implications for the fishing industry and people who like to eat fish.

Temperature changes also have the potential to alter major ocean currents. Because ocean temperatures drive atmospheric circulation patterns, this could change weather patterns all over the world. Climate scientist Richard Seager from Columbia's Lamont-Doherty Earth Observatory has found that higher ocean surface temperatures could make rainfall more variable, and thus less predictable, from year to year. End of course, as ice sheets and mountaintop glaciers melt, they're dumping extra water into the oceans; the resulting sea level rise jeopardizes coastal properties around the world.

Snowpack

Ordinarily, as winter snowpack melts in the springtime, it slowly adds fresh water to rivers and streams and helps to replenish drinking water supplies.

However, as the air warms, many areas are receiving more of their precipitation as rain rather than snow. This means less water is being stored for later as snowpack. In addition, the rain actually accelerates the melting of snow that's already on the ground.The lack of snowpack can lead to drier conditions later in the year, which can be bad news for regions that rely on snowmelt to refill their drinking water supplies. Changes in snowpack can also negatively impact wildlife and income from skiing and winter tourism.

10.9. Impact of Climate Change on Food Security

One of the most significant impacts of climate change is on our food system. The impact is even more on a predominantly agrarian economy like India, creating ripple effects on the entire food production chain. On Sunday, the mercury level in several states of north India touched 49 degrees Celcius, making it one of the hottest days in recent history. The damage caused to agriculture and food security by the ongoing heat wave is multi-dimensional. It damaged the wheat crop, and affe-c-ted the food supply, prompting a phenomenal rise in the price of wheat products. The loss to wheat is both qualitative as well as quantitative as besides the low output, the grain is also of poor quality. It should be seen in the light of the fact that food security is as much about the quantity of food, as it is about the nutritional value.

The Global Food Policy Report 2022 by the International Food Policy Research Institute has warned that climate change may push many Indians towards hunger by 2030 due to a decline in agricultural production and disruption in the food supply chain.

The report states that globally, around 65 million people are at risk due to climate change-induced hunger, with 17 million people in India facing hunger by 2030, the highest among all countries. The report further notes that although global food production may increase by 60 per cent by 2050, 50 crores of Indians would still be at the risk of going hungry. Of these 50 crores, seven crore people would suffer from hunger due to climate change.

Higher temperatures, changing precipitation patterns, sea-level rise, and growing frequency and intensity of extreme weather events such as droughts, floods, extreme heat, and cyclones are already reducing agricultural productivity, disrupting food supply chains, and displacing communities," the report noted.

Climate change has added to the enormity of India's food security challenges. While the relationship between climate change and food security is complex, most studies focus on one dimension of food security, i.e., food availability. The impact of climate change on India's food security depends on availability, access, and absorption. It finds that ensuring food security in the face of climate change will be a formidable challenge. It recommends, the adoption of sustainable agricultural practices, greater emphasis on urban food security and public health, provision of livelihood security, and long-term relief measures in the event of natural disasters

Climate change affects livelihoods of poor and rich alike by impacting basic human needs, including food, clothing and shelter requirements. The four components of food security—food availability, food access, food utilization and food production system stability—are the heart of the mandate of the Food and Agriculture Organization of the United Nations (FAO). All four components are affected by climate but food availability is most intimately associated with climate and its changes, from crops to animal products, marine and aquaculture products and wood and non-wood products from forests. Even when production is sufficient food access is impaired and food security is compromised. Urbanization is rapidly taking place in many countries of the world, creating a category of urban poor who do not themselves farm and are very vulnerable to climate change.

Projections of increased pests and diseases due to climate change have an important implication for nutrition. New risks will affect crops, livestock, fish and humans. When human health is compromised, particularly that of women who prepare foods for household members, the capacity to utilize food effectively is dramatically lowered. Food safety may also be compromised with degraded hygiene in preparing food under limited fresh-water availability or food-storage ability due to warmer climate. Mal-nutrition may also increase, due to shrinking food biodiversity and excessive dependence on a few staple foods.

The changes in climate variability have a direct implication on food-production system stability. Increased frequency and intensity of extreme events such as drought and flood would be a great threat to stability, whether the impact is domestic or through the global food market. The frequency and magnitude of food emergencies might increase, resulting from complex interrelations between political conflicts and migration in a context of increased competition for limited resources.

Global impacts on potential agricultural production

In general, crop yields will increase in cold areas where low temperature currently limits crop growth. On the other hand, heat stress on crop and water availability will lead to a decrease in yields in warm environments. Globally, food production may increase but a net negative impact is expected if night temperatures increase and averages rise by more than a few degrees Celsius.

In addition to the potential negative impact on global food production, there is pressure from the projected increase in population in most developing countries. This is illustrated in a plot of net primary production of biomass, a biophysical indicator of potential agricultural production, from a recent FAO study which produced a typology of vulnerable countries to climate change (Figure 1). Net primary production per capita in 2030 was calculated from temperature, precipitation and population projections. From purely biophysical, geophysical and demographical factors, it appears that only parts of Europe, the Russian Federation and Japan may benefit from increased productivity due to warming in the next couple of decades.

In short, climate change is putting food production at risk.Yield growth for wheat, maize, and other crops has been declining in many countries due to extreme heat, severe weather, and droughts. By some estimates, in the absence of effective adaptation, global yields could decline by up to 30 percent by 2050. Countries that are already grappling with conflict, pollution, deforestation, and other challenges are likely to suffer the brunt of these impacts. The 2 billion people already without access to sufficient food, including smallholder farmers and other people living in poverty, will be hit hardest.

Unless urgent action is taken, climate change will increase food prices, decrease food availability, and exacerbate instability and conflict because of competition over water and fertile land.

10.10 Climate Solutions from Sustainable Agriculture

Agriculture is a major contributor and a potential solution to climate change. The Intergovernmental Panel on Climate Change found that more than a third of global greenhouse gas emissions come from the production, distribution, and consumption of food. When it comes to producing food, the majority of agricultural emissions are related to raising livestock, followed by rice cultivation and the production of synthetic fertilizers. Moreover, as forests and grasslands are converted for agriculture, the world is losing vitally important ecosystems that remove greenhouse gases from the atmosphere.

To avoid the most devastating impacts of climate change and meet the goals of the Paris Agreement, we must radically transform our agricultural systems. The good news is that a number of sustainable practices offer significant climate mitigation opportunities, some of which will also help farmers build resilience against future environmental and economic shocks:

Reducing food loss and waste, which account for 8% of greenhouse gas emissions globally, is low-hanging fruit to reduce heat-trapping emissions. Adopting more sustainable diets, in particular shifting away from meat consumption, while difficult for social and cultural reasons, could lead to an 80% reduction in greenhouse gas emissions from the agriculture sector.

Agroforestry (incorporating the cultivation and conservation of trees in croplands or pastures) can cut emissions by creating additional “carbon sinks” on farms. Widely practiced across Central and Latin America since pre-Columbian times, this practice also protects farms from soil erosion and provides habitat to a diversity of species.

Better soil management on farms, including such practices as reduced tillage, can keep carbon in the soil while increasing productivity. Higher per hectare yields could, in turn, help ease the pressure for more deforestation, thereby avoiding emissions — not to mention biodiversity and ecosystem loss — from land use change. Sustainable farming practices that maintain soil health can also increase farmers’ incomes, providing an important buffer against climate shocks for rural populations.

Degraded and abandoned farmlands present climate opportunities as well. Restoring degraded farmlands not only reduces emissions, but also can decrease the risk of soil erosion and landslides and restore the availability of clean water and other critical ecosystem services.

Working to achieve improved soil fertility and higher productivity while lessening greenhouse gas emissions could significantly reduce agriculture's contribution to climate change while helping achieve more sustainable and resilient communities.

10.11. Summary

Climate change refers to the long-term changes in the Earth's climate patterns, including temperature, precipitation, and wind. These changes are primarily caused by human activities such as burning fossil fuels, deforestation, and industrial processes, which release large amounts of greenhouse gases into the atmosphere. These gases trap heat from the sun and cause the Earth's temperature to rise, leading to a range of impacts, including rising sea levels, more frequent and severe weather events, and changes in the distribution of plant and animal species. The impacts of climate change are already being felt around the world, and urgent action is needed to reduce greenhouse gas emissions and limit the extent of future warming. This requires a global effort to transition to clean, renewable energy sources, increase energy efficiency, and make other changes to reduce emissions and adapt to the changing climate. Global climate change, caused mainly by human activities, is having significant impacts on the environment, economies, and societies around the world. Some of the key impacts include rising global temperatures, melting of glaciers and sea ice, changes in precipitation patterns, impacts on ecosystems and human health, and economic impacts. Unless significant action is taken to reduce greenhouse gas emissions and mitigate the effects of climate change, the impacts are expected to become increasingly severe in the coming decades.

10.12. Terminal questions

Q.1. What is climate change and its variability

Answer:---

Q.2. Define the effects of image change in natural diversity.

Answer:---

Q.3. Discuss the impact of temperature change on climatic conditions.

Answer:---

Q.4. What is the role of climate change in natural water resources and its quality?

Answer:--

Q.5. Discuss the climates change on food security and its role on human health.

Answer:--

Q.6. How climatic change affects vector-borne diseases?

Answer:--

10.13. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non-conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press.
5. Godfrey, Renewable Energy Power fora Sustainable Future, Boyle, Oxford University Press.

Unit -11: Climate Change and Policy Framework

11.1. Introduction

Climate change is a global issue that requires collective action from governments, businesses, and individuals to reduce greenhouse gas emissions and mitigate its impacts. A policy framework is needed to guide and support these efforts. The intergovernmental panel on climate change (IPCC) was created to provide policymakers with regular scientific assessments on climate change; it is implications and potential future risk, as well. Mainstreaming affective and equitable climate action will not only reduce loses and damages for nature and people, it will also provide wider benefits. In 2018, IPCC highlighted the unprecedented scale of the challenge required to keep warming to 1.5 °C. the pace and scale of what has been done so for, and current plans are insufficient to tackle climate change.

At the international level, the United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 to address global climate change. The UNFCCC has led to several agreements, including the Paris Agreement in 2015, which aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels and pursue efforts to limit it to 1.5 degrees Celsius. The Paris Agreement also includes provisions for countries to regularly report on their progress in reducing emissions and adapting to the impacts of climate change. At the national level, governments can implement policies to reduce greenhouse gas emissions and promote clean energy, such as carbon pricing, renewable energy incentives, and energy efficiency standards. Governments can also provide support for adaptation measures, such as building sea walls or developing drought-resistant crops. Emerging efficiency strategies can be applied across multiple sectors in our power plants, electrical grids, factories, vehicles, buildings, home appliance and more. Transitioning form fissile fuels to clean energy is the key wining the fight against climate change.

At the local level, cities and communities can implement measures to reduce emissions and promote resilience, such as improving public transportation, increasing energy efficiency in buildings, and developing green spaces to reduce the urban heat island effect. Businesses can also play a crucial role in addressing climate change by adopting sustainable practices, investing in clean energy, and reporting on their greenhouse gas emissions. In summary, addressing climate change requires a comprehensive policy framework at the international, national, and local levels, as well as collective action from governments, businesses, and individuals. Almost half of the world population lives in regions that are highly vulnerable to climate change. Meanwhile, keeping warming to 1.5 °C above pre-industrial levels required deep rapid and sustained green house gas emissions reductions in all sectors. Emissions need to be cut by most half by 2023, if warming is to be limited to 1.5 °C.

Objectives

- To study the history of International climate change policies
- To understand the different International climate change policies
- To study the convention on climate change (UNFCCC)
- To study about the Intergovernmental Panel on Climate Change (IPCC)

11.2. Climate change

Climate change refers to the long-term changes in the Earth's climate, including temperature, precipitation, and weather patterns. These changes are caused by natural and human factors, such as greenhouse gas emissions from burning fossil fuels, deforestation, and changes in land use. The impacts of climate change include rising sea levels, more frequent and severe weather events, and changes in ecosystems and biodiversity. Climate change is considered one of the greatest global challenges of our time and requires immediate action to reduce emissions and mitigate its impacts. Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil and gas.

Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures. Every increment of warming results in rapidly escalating hazardous. More intense heat waves, heavier rainfall and other weather extreme further increase risk for human health and ecosystems. in every region people are dying form extreme heat climate driven food and water insecurity is expected to increase with increased warming. When the risks combine with other adverse events, pandemics default to manage.

Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane. These come from using gasoline for driving a car or coal for heating a building, for example. Clearing land and forests can also release carbon dioxide. Landfills for garbage are a major source of methane emissions. Energy, industry, transport, buildings, agriculture and land use are among the main emitters.

History of climate change policy

The history of the scientific discovery of climate change began in the early 19th century when ice ages and other natural changes in paleoclimate were first suspected and the natural green house effect was first identified. In the late 19th century, scientists first argued than human. The Earth's climate has fluctuated between cold and warm periods throughout its history, with the most recent ice age ending about 11,700 years ago.

The industrial revolution, which began in the 18th century, marked the beginning of significant human-caused emissions of greenhouse gases (GHGs) from burning fossil fuels and other activities. in the 1960, the evidence for the warming effect of carbon dioxide gas become increasing convincing.

The 20th century saw a rapid increase in GHG emissions, leading to a rise in global average temperature by about 1°C (1.8°F) compared to pre-industrial times.

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to assess the science of climate change and its impacts on society and the environment.

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted as an international treaty to address climate change.The Kyoto Protocol, adopted in 1997, was the first international agreement to reduce GHG emissions, but it was not ratified by all countries.

The Paris Agreement, adopted in 2015, is the most recent global climate agreement, in which countries pledged to limit global warming to well below 2°C (3.6°F) above pre-industrial levels and to pursue efforts to limit it to 1.5°C (2.7°F). During the 1970s, the scientific opinion increasingly favored the warming view point. By the 1990s, as the result of improving the fidelity of computer models and observation work confirming the Milankovitch theory of the ice ages, a consensus position formed. Since the 1990s, scientific research are on climate change has include multiple disciplines and expanded. Research has expanded our understanding of causal relations likes with historic data and abilities to measure and model climate change. it has been summarized in assessment report by IPCC.

The scientific consensus is that climate change is happening and is largely caused by human activities, and that urgent action is needed to reduce emissions and mitigate its impacts. The history of climate change policy and politics refers to the continuing history of policies, trends, controversies and activist efforts as they pertain to the issue of global warming and other environmental anomalies.

International policy regarding climate change has focused on cooperation and the establishment of international guidelines to address global warming. The United Nations Framework Convention on Climate Change (UNFCCC) accepted international agreement that has continuously developed to meet new challenges.

Domestic policy on climate change has focused on both establishing internal measures to reduce greenhouse gas emissions and incorporating international guidelines into domestic law.

In the late 20th and 21st century, climate change policy moved away from attempts to mitigate the impact of global warming and towards adapting to unavoidable changes to the human environment. There has also been a shift towards vulnerability based policy for those most impacted by environmental anomalies. Over the history of climate policy, concerns have been raised about the treatment of developing nations and a lack of gender specific action.

Activism

Since the early 1970s, climate activists have called for more effective political action regarding global warming and other environmental anomalies. In 1970, Earth Day was the first large-scale environmental movement that called for the protection of all life on earth. The Friends of Earth organisation was also founded in 1970. Between 2006 and 2009, the Campaign against Climate Change and other British organisations staged a series of demonstrations to encourage governments to make more serious attempts to address climate change.

In 2019, activists, most of whom were young people, participated in a global climate strike to criticise the lack of international and political action to address the worsening impacts of climate change. Greta Thunberg, a 19-year-old activist from Sweden, became a figurehead for the movement.

Continuing in the spirit of young activists such as Greta Thunberg, the abandoned village of Lutzerath in North Rhine Westphalia, Germany has seen a growing army of at least 700 protesters from the country itself and around the world (estimated on 10 January 2023) taking over. They are there in defiance of coal mining company RWE who are intent on extracting coal from the Garzweiler Open Cast Brown Coal Mine near the village. There has been conflict between the protesters and the company since at least 2013, when RWE asked to extend its scope of operation to include Lutzerath and surrounding villages.

With the recent illegal invasion of Ukraine by Russia seeing gas supplies to Europe being curtailed by the Russian government in retaliation to Western sanctions, it seems there is no choice but to increase coal extraction, which flies in the face of recent promises made at the COP26 summit in 2022, held in Glasgow UK. The German government remains steadfast in its promise of reducing greenhouse gas emissions by 2030 and reducing global warming by 1.5 degrees as internationally agreed at COP26, stating it actually wants to reduce coal extraction but is being forced to perform short term extraction to deal with Germany's energy shortage due to the Russian invasion of Ukraine. Germany's Green Party is in agreement with the government's decision to extend mining operations after brokering a compromise that would spare five villages scheduled for demolition. This would appear to be seemingly in opposition to the reason the activists are protesting against the coal extraction.

11.3. International policy on climate change

There are several international policies and agreements on climate change, with the primary goal of reducing greenhouse gas emissions and mitigating the impacts of climate change. Some of the most significant policies include:

United Nations Framework Convention on Climate Change (UNFCCC): This agreement was signed in 1992, and its objective is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human interference with the climate system.

Kyoto Protocol: This protocol was adopted in 1997 and came into force in 2005. It committed developed countries to reduce their greenhouse gas emissions by an average of 5% below their 1990 levels by 2012.

Paris Agreement: This agreement was adopted in 2015 and aims to keep the global temperature rise below 2°C above pre-industrial levels and to pursue efforts to limit it to 1.5°C. It also aims to increase the ability of countries to adapt to the impacts of climate change and provide financial support for developing countries.

Sustainable Development Goals (SDGs): These goals were adopted by the United Nations in 2015 and include a goal on climate action, which aims to "take urgent action to combat climate change and its impacts."

These policies and agreements work together to reduce emissions and mitigate its impacts. Through the creation of multilateral treaties, agreements, and frameworks, international policy on climate change seeks to establish a worldwide response to the impacts of global warming and environmental anomalies.

11.3.1. Parties to the UNFCCC as of 2016

In 2016, 197 countries participated in United Nations Framework Convention on Climate Change (UNFCCC), It is a global treaty aimed at addressing climate change. These Parties include 196 countries and the European Union. Each Party is represented at the annual Conference of the Parties (COP), where they negotiate and make decisions on global climate action. The most recent COP was held in Madrid, Spain in 2019. The United States, has withdrawn from the Paris Agreement. However, it was a Party to the UNFCCC in 2016.

In 1992, the United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro. The UNCED introduced the Rio Declaration on Environment and Development, Agenda 21, the Forestry Principles and the Convention on Biological Diversity.

The United Nations Framework Convention on Climate Change (UNFCCC) has established the concept of common but differentiated responsibilities. Defined Annex 1 and Annex 2 countries, highlighted the needs of vulnerable nations, and established a precautionary approach to climate policy. The first Conference of the Parties (COP-1) was held in Berlin in 1995 in accordance with the convention.

In 1997, the third Conference of the Parties (COP-3) passed the Kyoto Protocol, It contained the first legally binding greenhouse gas reduction targets. The Kyoto Protocol required Annex 1 countries to reduce greenhouse gas emissions by 5% from 1990 levels between 2008 and 2012.

11.3.2. Adoption of Paris Agreement in 2015

The Paris Agreement is a legally binding international treaty on climate change adopted in 2015. The agreement was negotiated by representatives of 196 countries at the United Nations Climate Change Conference (COP21) in Paris, France.

The main goal of the Paris Agreement is to limit global warming to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius. To achieve this, the agreement sets out a framework for countries to make voluntary commitments to reduce their greenhouse gas emissions and to report on their progress regularly.

The Paris Agreement is significant because it marks the first time that almost all countries in the world have agreed to take action to combat climate change. It represents a historic moment of global cooperation and commitment to addressing one of the most pressing issues of our time.

At the 13th Conference of the Parties (COP-13) in 2007, the Bali Action Plan was implemented to promote a shared vision for the Copenhagen Summit.The Action Plan called for Annex 2 nations to adopt Nationally Appropriate Mitigation Actions (NAMAs). The Bali Conference also raised awareness for the 20% of global greenhouse gas emissions caused by deforestation.

In 2009, the Copenhagen Accord was created at the 15th Conference of the Parties (COP-15) in Copenhagen, Denmark. Although not legally binding, the Accord established an agreed-upon goal to keep global warming below two degrees Celsius.

The Paris Agreement was adopted at the 21st Conference of the Parties (COP-21) on the 12th of December 2015. It entered into force on the 4th of November 2016. The agreement addressed greenhouse-gas-emissions mitigation, adaptation, and finance. Its language was negotiated by representatives of 196 state parties at COP-21. As of March 2019, 195 UNFCCC members have signed the agreement and 187 have become party to the agreement.

In November 2019, a coalition of 11,000 scientists declared that a worldwide climate emergency exists.

Domestic action

Domestic policy regarding climate change has historically combined the incorporation of international guidelines and creation of state-specific goals, legislation and programs to address global warming and environmental anomalies a state level.

11.4. Climate change policy in Australia

Domestic action to address climate change in Australia began in 1989, when Senator Graham Richardson proposed the first greenhouse gas emission reduction target of 20% by 2005. The Australian Government rejected this target. In 1990, Ros Kelly and Jon Kerin announced that the Australian Government would adhere to the goals initially proposed by Richardson but not to any economic detriment.

Australia signed the UNFCCC in 1992. This was followed by the release of the National Greenhouse Response Strategy (NGRS), which provided states and territories with the mechanisms to adhere to UNFCCC emission guidelines. Australia attended the first UNFCCC Conference in Berlin in March 1995, but throughout the 1990s, Australia failed to meet its own emission targets.

In 1997, Prime Minister John Howard announced that by 2010, an additional 2% of electricity would be sustainably sourced. The Australian Greenhouse Office (AGO) was established to monitor greenhouse gas reductions. This later combined with the Department of Environment and Heritage. Australia became a party to the Kyoto Declaration in 1998. The Declaration was ratified in 2007 under Prime Minister Kevin Rudd.

In the Renewable Energy (Electricity) Act 2000, the Federal Government introduced the Mandatory Renewable Energy Target program, which aimed to sustainably source 10% of electrical energy by 2010. In 2011, the Mandatory Renewable Energy Target program was divided into the Large-Scale Renewable Energy Target and the Small-Scale Renewable Energy Scheme. The New South Wales State Government implemented the Greenhouse Gas Reduction Scheme (GGRS), in January 2003, which allowed carbon emissions to be traded.

11.4.1. Protests against the CPRS in 2009

Under Rudd, the Labor Government proposed the Carbon Pollution Reduction Scheme, It was intended to take effect in 2010.This scheme was rejected by the Greens for being too permissive by Tony Abbott's Coalition for being economically detrimental. The Prime Minister Julia Gillard of Labor Party passed the Clean Energy Act 2011 to establish a carbon tax and put a price on greenhouse gas emissions. This carbon tax was a divisive partisan issue.

In 2012, the Coalition ran a campaign to repeal the carbon tax. Upon election victory in September 2013, Prime Minister Tony Abbott passed the Clean Energy Legislation (Carbon Tax Repeal) Bill. In replacement of the carbon tax, Abbott introduced the Direct Action Scheme to financially reward businesses for voluntarily reducing their carbon emissions. This was followed by a decision not to participate in the 19th Conference of UNFCCC Parties (COP-19). Australia became a party to the Paris Agreement in 2015. In the agreement, Australia committed to reducing its emissions by 26% by 2030. Prime Minister Scott Morrison was (2019) criticized for a lack of commitment to addressing climate change while taking a vacation during the 2019 bushfires.

11.5. Climate change policy in the USA

From the mid-1980s, the United States attempted to promote climate action at an international level. The US ratified the Montreal Protocol of 1987 in a 1990 amendment to the Clean Air Act. The Clinton (1993) Administration commissioned the Climate Change Action Plan, It lacked both funding and parliamentary support and relied on voluntary compliance.

President Trump criticizing the Paris Accord in 2017

The Kyoto Protocol was never submitted for ratification in the US.This was because the previous Senate resolution suggested that it would not be ratified. President George W. Bush (2001) cited economic concerns as a reason for his withdrawal from the Kyoto Protocol. Instead, the administration set an 18% reduction target over the next 10 years.

The Obama (2013) Administration created the Climate Action Plan, which aimed to cut 32% of carbon emissions from electrical power plants.

The USA became a party to the Paris Agreement in December 2015. President Trump announced his intention to withdraw from the agreement in 2017. This was formalised in 2019, when Trump officially notified the United Nations of the impending US withdrawal. In 2017, 20 states have pledged to abide with the terms of the Paris Agreement regardless of federal withdrawal.

Trends

Adaptation

In the early 21st century, policy approaches shifted from mitigation, aiming to reduce the environmental impact of human behaviour, to adaptation. Adaptation based policy focuses on adjusting environmental and human systems to respond to the predicted impacts of global warming. According to Klein, Schipper and Dessai, adaptation is necessary to accommodate permanent changes to the human environment that, regardless of mitigation attempts which cannot be reversed. Haibach and Schneider suggest that climate policy continues to move towards 'crisis management and plans for preventative measures'. Ford also states that the UNFCCC has evolved to address 'exposure to predicted climate change impacts' by stressing the need to adapt.

Vulnerability based policy

Vulnerability based policy is regionally or socioeconomically specific policy aimed at reducing the disproportionate impacts of climate change on certain groups. This policy is emerging in developing countries where communities are more affected by climate change and environmental disasters. In the Kyoto Protocol, the Least Developed Country fund and Special Climate Change fund were established to improve development and adaptation in regions who are least equipped to manage the consequences of climate change. This form of policy has also been linked to sustainable development in developing countries.

In vulnerable arctic regions, climate policy has increasingly focused on addressing changing weather patterns, animal demography and sea ice levels.

Controversy

Disproportionate impact on developing nations

Developing nations have commented that climate change and climate change policy disproportionately impact vulnerable states. Ford mentions that international climate policy does not adequately address the different needs and capacities of Annex 1 and Annex 2 states. The New Delhi Declaration of Principles of International Law relating to Sustainable Development (2002) suggests that developing countries are both more impacted by and less equipped to address climate change. The Declaration also stress on common but differentiated responsibilities. Gupta suggests that these disproportionate impacts justify lowering emission reduction targets for developing nations. Critics of equity-based policy have argued that it is “unfair” to create differentiated emission targets.

11.6. United Nations Framework Convention on Climate Change (UNFCCC)

Source: https://iispmun.com/committees/unfccc-2022/

The United Nations Framework Convention on Climate Change (UNFCCC) established an international environmental treaty to combat "dangerous human interference with the climate system", by stabilizing greenhouse gas concentrations in the atmosphere. It was signed by 154 states at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held at Rio de Janeiro from 3 to 14 June 1992. Its original secretariat was in Geneva but relocated to Bonn in 1996. It entered into force on 21 March 1994. The treaty called for ongoing scientific research and regular meetings, negotiations, and future policy agreements designed to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The Kyoto Protocol, which was signed in 1997 and ran from 2005 to 2020, was the first implementation of measures under the UNFCCC. The Kyoto Protocol was superseded by the Paris Agreement, which entered into force in 2016. By 2022, the UNFCCC had 198 parties. Its supreme decision-making body, at Conference of the Parties (COP), annually meets to assess progress of climate change as signatory states were not adhering to their individual commitments. The UNFCCC has been criticized as being unsuccessful in reducing the emission of carbon dioxide since its adoption.

The treaty assigned the different responsibilities under three categories for signatory states. First developed countries, second developed countries with special financial responsibilities, and third developing countries. The developed countries, also called Annex 1 countries, originally consisted of 38 states, 13 of which were Eastern European states in transition to democracy and market economies, and the European Union. All belong to the Organization for Economic Co-operation and Development (OECD).

Annex 1 countries were assigned to adopt national policies and take corresponding measures on the mitigation of climate change. They have to limit their anthropogenic emissions of greenhouse gases and to report on steps adopted to their 1990 emissions levels. The developed Annexure II countries having special financial responsibilities. They include the entire Annex I countries with the exception of those in transition to democracy and market economies. Annex II countries have to provide new and additional financial resources to meet the costs incurred by developing countries. they have to with their obligation to produce national inventories of their emissions and their removals by sinks not covered under the Montreal Protocol submit their inventories to the UNFCCC Secretariat.

Treaties

11.6.1. Convention Agreement in 1992

The text of the Framework Convention was produced during the meeting of an Intergovernmental Negotiating Committee in New York from 30 April to 9 May 1992. The Convention was adopted on 9 May 1992 and opened for signature on 4 June 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (known by its popular title, the Earth Summit). On 12 June 1992, 154 nations signed the UNFCCC, which upon ratification committed signatories' governments to reduce atmospheric concentrations of greenhouse gases with the goal of "preventing dangerous anthropogenic interference with Earth's climate system". This commitment would require substantial reductions in greenhouse gas emissions (see the later section, "Stabilization of greenhouse gas concentrations"). The parties to the convention have met annually from 1995 in Conferences of the Parties (COP) to assess progress in dealing with climate change.

Article 3(1) of the Convention states that Parties should act to protect the climate system on the basis of "common but differentiated responsibilities and respective capabilities", and that developed country Parties should "take the lead" in addressing climate change. Under Article 4, all Parties make general commitments to address climate change through, for example, climate change mitigation and adapting to the eventual impacts of climate change. Article 4(7) states:

- The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology and will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties.

The Framework Convention specifies the aim of Annex I Parties stabilizing their greenhouse gas emissions (carbon dioxide and other anthropogenic greenhouse gases not regulated under the Montreal Protocol) at 1990 levels, by 2000.

"UNFCCC" is also the name of the United Nations Secretariat charged with supporting the operation of the convention, with offices in HausCarstanjen, and the UN Campus (known as Langer Eugen) in Bonn, Germany. From 2010 to 2016 the head of the secretariat was Christiana Figueres. In July 2016, Patricia Espinosa succeeded Figueres. The Secretariat, augmented through the parallel efforts of the Intergovernmental Panel on Climate Change (IPCC), aims to gain consensus through meetings and the discussion of various strategies. Since the signing of the UNFCCC treaty, Conferences of the Parties (COPs) have discussed how to achieve the treaty's aims.

11.6.2. Action for Climate Empowerment (ACE)

Action for Climate Empowerment (ACE) is a term adopted by the UNFCCC in 2015 to have a better name for this topic than "Article 6". It refers to Article 6 of the convention's original text (1992), focusing on six priority areas: education, training, public awareness, public participation, public access to information, and international cooperation on these issues. The implementation of all six areas has been identified to understand and participate in solving the challenges presented by climate change. ACE calls on governments to develop and implement educational and public awareness programmes, train scientific, technical and managerial personnel, foster access to information, and promote public participation in addressing climate change and its effects. It also urges countries to cooperate in this process, by exchanging good practices and lessons learned, and strengthening national institutions. This wide scope of activities is guided by specific objectives for effectively implementing climate adaptation and mitigation actions, for achieving the ultimate objective of the UNFCCC.

11.6.3. Kyoto Protocol

The 1st Conference of the Parties (COP-1) decided that the aim of Annex I Parties stabilizing their emissions at 1990 levels by 2000 was "not adequate", and further discussions at later conferences led to the Kyoto Protocol in 1997. The Kyoto Protocol was legally binding obligations under international law, for developed countries to reduce their greenhouse gas emissions in the period 2008–2012. The 2010 United Nations Climate Change Conference produced an agreement stating that future global warming should be limited to below 2 °C (3.6 °F) relative to the pre-industrial level. The Kyoto Protocol had two commitment periods, the first of which lasted from 2008 to 2012. The Protocol was amended in 2012 to encompass the second one for the period 2013–2020 in the Doha Amendment.

The first tasks set by the UNFCCC was for signatory nations to establish national greenhouse gas inventories of greenhouse gas (GHG) emissions and removals, it was used to create the 1990 benchmark levels for accession of Annex I countries to the Kyoto Protocol and for the commitment of those countries to GHG reductions. Updated inventories must be submitted annually by Annex I countries.

The US did not ratify the Kyoto Protocol, while Canada denounced it in 2012. The Kyoto Protocol was ratified by all the other Annex I Parties.

All Annex I Parties, excluding the US, participated in the 1st Kyoto commitment period. 37 Annex I countries and the EU agreed to second-round Kyoto targets. These countries are Australia, all members of the European Union, Belarus, Iceland, Kazakhstan, Norway, Switzerland, and Ukraine.Belarus, Kazakhstan and Ukraine stated that they might withdraw from the Protocol or not put into legal force the Amendment with second round targets. Japan, New Zealand, and Russia participated in Kyoto's first round but did not take on new targets in the second commitment period. Other developed countries without second-round targets were Canada (which withdrew from the Kyoto Protocol in 2012) and the United States.

All countries that remained parties to the Kyoto Protocol met their first commitment period targets.

11.6.4. National communication

A "National Communication" is a type of report submitted by the countries that have ratified the United Nations Framework Convention on Climate Change (UNFCCC). Developed countries are required to submit National Communications every four years and developing countries should do so. Some Least Developed Countries have not submitted National Communications in the past 5–15 years, largely due to capacity constraints.

National Communication reports are often several hundred pages long and cover a country's measures to mitigate greenhouse gas emissions as well as a description of its vulnerabilities and impacts from climate change. National Communications are prepared according to guidelines that have been agreed by the Conference of the Parties to the UNFCCC. The (Intended) Nationally Determined Contributions (NDCs) that form the basis of the Paris Agreement are shorter and less detailed but also follow a standardized structure and are subject to technical review by experts.

Parties

As of 2022, the UNFCCC has 198 parties including all United Nations member states, United Nations General Assembly observers the State of Palestine and the Holy See, UN non-member states Niue and the Cook Islands, and the supranational union European Union.

11.6.5. Classification of Parties and their commitments

Parties to the UNFCCC are classified as:

Annex I: There are 43 Parties to the UNFCCC listed in Annex I of the convention, including the European Union. These Parties are classified as industrialized (developed) countries and "economies in transition" (EITs). The 14 EITs are the former centrally-planned (Soviet) economies of Russia and Eastern Europe.

Annex II: Of the Parties listed in Annex I of the convention, 24 are also listed in Annex II of the convention, including the European Union. These Parties are made up of members of the Organisation for Economic Co-operation and Development (OECD): these Parties consist of the members of the OECD in 1992, minus Turkey, plus the EU.

Annex II Parties are required to provide financial and technical support to the EITs and developing countries to assist them in reducing their greenhouse gas emissions (climate change mitigation) and manage the impacts of climate change (climate change adaptation).

Least-developed countries (LDCs): 49 Parties are LDCs, and are given special status under the treaty in view of their limited capacity to adapt to the effects of climate change.

Non-Annex I: Parties to the UNFCCC not listed in Annex I of the convention are mostly low-income developing countries. Developing countries may volunteer to become Annex I countries when they are sufficiently developed.

11.6.6. Conferences of the Parties (CoP)

The United Nations Climate Change Conference are yearly convened conferences held in the framework of the UNFCCC. They serve the formal meeting of the UNFCCC Parties (Conferences of the Parties) (COP) to assess progress in dealing with climate change, and beginning in the mid-1990s, to negotiate the Kyoto Protocol to establish legally binding obligations for developed countries to reduce their greenhouse gas emissions. Since 2005 the Conferences also served as the Meetings of Parties of the Kyoto Protocol (CMP) and since 2016 the Conferences also serve as Meeting of the Parties to the Paris Agreement (CMA).

The first conference (COP1) was held in 1995 in Berlin. The 3rd conference (COP3) was held in Kyoto and resulted in the Kyoto protocol, which was amended during the 2012 Doha Conference (COP18, CMP 8). The COP21 (CMP11) conference was held in Paris and resulted in adoption of the Paris Agreement. The COP26 (CMA3) was held in Glasgow, Scotland, United Kingdom. The COP28 is taking place at the United Arab Emirates and Sultan al-Jaber has been nominated by the ruler to lead the same.

Subsidiary bodies

A subsidiary body is a committee that assists the Conference of the Parties. Subsidiary bodies include:

Permanents:

- The Subsidiary Body of Scientific and Technological Advice (SBSTA) is established by Article 9 of the convention to provide the Conference of the Parties and, as appropriate, its other subsidiary bodies with timely information and advice on scientific and technological matters relating to the convention. It serves as a link between information and assessments provided by expert sources (such as the IPCC) and the COP, which focuses on setting policy.

- The Subsidiary Body of Implementation (SBI) is established by Article 10 of the convention to assist the Conference of the Parties in the assessment and review of the effective implementation of the convention. It makes recommendations on policy and implementation issues to the COP and, if requested, to other bodies.

Temporary:

- Ad hoc Group on Article 13 (AG13), active from 1995 to 1998;

- Ad hoc Group on the Berlin Mandate (AGBM), active from 1995 to 1997;
- Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP), established in 2005 by the Parties to the Kyoto Protocol to consider further commitments of industrialized countries under the Kyoto Protocol for the period beyond 2012; it concluded its work in 2012 when the CMP adopted the Doha Amendment;
- Ad Hoc Working Group on Long-term Cooperative Action (AWG-LCA), established in Bali in 2007 to conduct negotiations on a strengthened international deal on climate change;
- Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP), established at COP 17 in Durban in 2011 "to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties." The ADP concluded its work in Paris on 5 December 2015.

11.7. Intergovernmental Panel on Climate Change (IPCC)

Source: https://images.app.goo.gl/dvj3gQnDo3vE4mm47

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations charged with advancing scientific knowledge about anthropogenic climate change. It was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) and endorsed by the UN later that year. It has a secretariat in Geneva, Switzerland, hosted by the WMO, and is governed by 195 member states.

The IPCC informs governments about the state of knowledge on climate change, including possible response options and the natural, economic, and social impacts and risks. It does not conduct original research but undertakes periodic and systematic reviews of all relevant scientific publications by enlisting thousands of volunteer scientists and experts; observers have described this work as the biggest peer review process in the scientific community.Key findings are compiled into periodic "Assessment Reports" for policymakers and the general public.

The IPCC is governed by its member state, which elects a bureau of scientists to serve through an "assessment cycle" of six to seven years. The bureau selects experts to prepare IPCC reports, drawing from nominations by governments and observer organisations. The IPCC carries out its activities through three working groups and a task force.

The IPCC is an internationally accepted authority on climate change. Its findings are endorsed by leading climate scientists and all member governments, while its reports are regularly cited by media, governments, civil society organisations and businesses. IPCC reports play a key role in the annual climate negotiations held by the United Nations Framework Convention on Climate Change (UNFCCC); the Fifth Assessment Report influenced the landmark Paris Agreement in 2015.The IPCC shared the 2007 Nobel Peace Prize with Al Gore for contributions to the understanding of climate change.

In 2015, the IPCC began its sixth assessment cycle, to be completed in 2023.In August 2021, the IPCC published its Working Group I contribution to the Sixth Assessment Report (IPCC AR6) on the physical science basis of climate change.The Guardian described this report as the "starkest warning yet" of "major inevitable and irreversible climate changes". Many newspapers around the world echoed this theme.

Origins

The predecessor of the IPCC was the Advisory Group on Greenhouse Gases (AGGG). Three organizations set up the AGGG in 1986. These were the International Council of Scientific Unions, the United Nations Environment Programme (UNEP), and the World Meteorological Organization (WMO). The AGGG reviewed scientific research on greenhouse gases. It also studied increases in greenhouse gases. Climate science was becoming more complicated and covering more disciplines. This small group of scientists lacked the resources to cover climate science.

The United States Environmental Protection Agency sought an international convention to restrict greenhouse gas emissions. The Reagan Administration worried that independent scientists would have too much influence. The WMO and UNEP therefore created the IPCC as an intergovernmental body in 1988. Scientists take part in the IPCC as both experts and government representatives. The IPCC produces reports backed by all leading relevant scientists. Member governments must also endorse the reports by consensus agreement. So the IPCC is both a scientific body and an organization of governments. Its job is to tell governments what scientists know about climate change. It also examines the impacts of climate change and options for dealing with it. The IPCC does this by assessing peer-reviewed scientific literature.

The United Nations endorsed the creation of the IPCC in 1988. The General Assembly resolution noted that human activity could change the climate. This could lead to severe economic and social consequences. It said increasing concentrations of greenhouse gases could warm the planet. This would cause the sea level to rise. The effects for humanity would be disastrous if timely steps were not taken.

Organization

Way of working

The IPCC does not conduct original research. It produces comprehensive assessments on the state of knowledge of climate change. It prepares reports on special topics relevant to climate change. It also produces methodologies. These methodologies help countries estimate their greenhouse gas emissions and removals through sinks. Its assessments build on previous reports and scientific publications. Over the course of six assessments the reports reflect the growing evidence for a changing climate. And they show how this is due to human activity.

Rules and governing principles

The IPCC has adopted its rules of procedure in the "Principles Governing IPCC Work". These state that the IPCC will assess:

- The risk of climate change caused by human activities,
- Its potential impacts, and

- Possible options for prevention.

Under IPCC rules its assessments are comprehensive, objective, open and transparent. They cover all the information relevant to the scientific understanding of climate change. This draws on scientific, technical and socioeconomic information. IPCC reports must be neutral regarding policy recommendations. However, they may address the objective factors relevant to enacting policies.

Structure

The IPCC has the following structure:

IPCC Panel: Meets in plenary session about twice a year. It may meet more often for the approval of reports. It controls the IPCC's structure, procedures, work program and budget. It accepts and approves IPCC reports. The Panel is the IPCC corporate entity.

Chair: Elected by the Panel. Chairs the Bureau and other bodies. Represents the organization.

Bureau: Elected by the Panel. It currently has 34 members from different geographic regions. Besides the Chair and three IPCC Vice-Chairs, they provide the leadership for the IPCC's three Working Groups and Task Force. It provides guidance to the Panel on the scientific and technical aspects of its work.

Working Groups: Each has two Co-Chairs, one from a developed country and one from a developing country. A technical support unit supports each Working Group. Which approve the Summary for Policymakers of assessment and special reports. Each Working Group has a Bureau. This consists of its Co-Chairs and Vice-Chairs, who are also members of the IPCC Bureau.

- **Working Group I:** Assesses scientific aspects of the climate system and climate change. Co-Chairs: Valérie Masson-Delmotte and PanmaoZhai
- **Working Group II**: Assesses the impacts of climate change on human and natural systems. Assesses adaptation options. Co-Chairs: Hans-Otto Pörtner and Debra Roberts

- **Working Group III:** Assesses how to stop climate change by limiting greenhouse gas emissions. (Known as "mitigation".) Co-Chairs: Priyadarshi R. Shukla and Jim Skea

Task Force on National Greenhouse Gas Inventories.Develops methodologies for estimating greenhouse gas emissions. Co-Chairs: Kiyoto Tanabe and Eduardo CalvoBuendía

- **Task Force Bureau:** Comprises the two Co-Chairs, who are also members of the IPCC Bureau, and 12 members.

Executive Committee: Comprises the Chair, IPCC Vice-Chairs and the Co-Chairs of the Working Groups and Task Force. It addresses urgent issues that arise between sessions of the Panel.

Secretariat: Administers activities, supports the Chair and Bureau, point of contact for governments. Supported by UNEP and the WMO.

Chair

The chair of the IPCC is Korean economist Hoesung Lee. Lee has served since 8 October 2015 with the election of the new IPCC Bureau. His predecessor Rajendra K. Pachauri, elected in 2002, resigned in February 2015.Vice-Chair Ismail El Gizouli served as acting chair until the election of the new Bureau. The previous chairs were Robert Watson, elected in 1997, and Bert Bolin, elected in 1988.

Panel

The Panel consists of representatives appointed by governments. They take part in plenary sessions of the IPCC and its Working Groups. Non-governmental and intergovernmental organizations may attend as observers.Meetings of IPCC bodies are by invitation only. About 500 people from 130 countries attended the 48th Session of the Panel in Incheon, Republic of Korea. This took place in October 2018. They included 290 government officials and 60 representatives of observer organizations. The opening ceremonies of sessions of the Panel and of Lead Author Meetings are open to media. Otherwise, IPCC meetings are closed.

Funding

The IPCC receives funding through a dedicated trust fund. UNEP and the WMO established the fund in 1989. The trust fund receives annual financial contributions from member governments. The WMO, UNEP and other organizations also contribute. Payments are voluntary and there is no set amount required. The WMO covers the operating costs of the secretariat. It also sets the IPCC's financial regulations and rules. The Panel sets the annual budget.

Activities other than report preparation

The IPCC bases its work on the decisions of the WMO and UNEP, which established the IPCC. It also supports the work of the UNFCCC. The main work of the IPCC is to prepare assessment and other reports. It also supports other activities such as the Data Distribution Centre. This helps manage data related to IPCC reports.

The IPCC has a "Gender Policy and Implementation Plan" to pay attention to gender in its work. It aims to carry out its work in an inclusive and respectful manner. The IPCC aims for balance in participation in IPCC work. This should offer all participants equal opportunity.

Communications and dissemination activities

The IPCC enhanced its communications activities for the Fifth Assessment Report. For instance it made the approved report and press release available to registered media under embargo before the release. And it expanded its outreach activities with an outreach calendar.The IPCC held an Expert Meeting on Communication in February 2016, at the start of the Sixth Assessment Report cycle. Members of the old and new Bureaus worked with communications experts and practitioners at this meeting. This meeting produced a series of recommendations.The IPCC adopted many of them. One was to bring people with communications expertise into the Working Group Technical Support Units. Another was to consider communications questions early on in the preparation of reports.

Following these steps in communications, the IPCC saw a significant increase in media coverage of its reports. This was particularly the case with the Special Report on Global Warming of 1.5 °C in 2018 and Climate Change 2021: The Physical Science Basis, the Working Group I contribution to the Sixth Assessment Report, in 2021. There was also much greater public interest, reflected in the youth and other movements that emerged in 2018.

IPCC reports are important for public awareness of climate change and related policymaking. This has led to a number of academic studies of IPCC communications, for example in 2021.

Archiving

The IPCC archives have reports on electronic files on its website. They include the review comments on drafts of reports. The Environmental Science and Public Policy Archives are the Harvard Library who also archives them..

Assessment reports

Between 1990 and 2022, the IPCC has published six comprehensive assessment reports reviewing the latest climate science. The IPCC has also produced 14 special reports on particular topics. Each assessment report has four parts. These are a contribution from each of the three working groups, plus a synthesis report. The synthesis report integrates the working group contributions. It also integrates any special reports produced in that assessment cycle.

Review process of scientific literature

The reports by IPCC assess scientific papers and independent results from other scientific bodies. The IPCC sets a deadline for publication of scientific papers that a report will cover. That report will not include new information that emerges after this deadline. However, there is a steady evolution of key findings and levels of scientific confidence from one assessment report to the next. Each IPCC report record areas where the science has improved since the previous report. It also notes areas that would benefit from further research.

Selection and role of authors

The IPCC Bureau or Working Group Bureau selects the authors of the reports from government nominations. Lead authors of IPCC reports assess the available information about climate change based on published sources. According to IPCC guidelines, authors should give priority to peer-reviewed sources. Authors may refer to non-peer-reviewed sources ("grey literature"), if they are of sufficient quality. These could include reports from government agencies and non-governmental organizations. Industry journals and model results are other examples of non-peer-reviewed sources.

Authors prepare drafts of a full report divided into chapters. They also prepare a technical summary of the report, and a summary for policymakers.

Each chapter has a number of authors to write and edit the material. A typical chapter has two coordinating lead authors, ten to fifteen lead authors and a larger number of contributing authors. The coordinating lead authors assemble the contributions of the other authors. They ensure that contributions meet stylistic and formatting requirements. They report to the Working Group co-chairs. Lead authors write sections of chapters. They invite contributing authors to prepare text, graphs or data for inclusion.

The Bureau aims for a range of views, expertise and geographical representation in its choice of authors. This ensures that the author team may include experts from both developing and developed countries. The Bureau also seeks a balance between male and female authors. And it aims for a balance between those who have worked previously on IPCC reports and those new to the process.

Scientists who work as authors on IPCC reports do not receive any compensation for this work. They depend on the salaries they receive from their home institutions or other work. The work is labour-intensive with a big time commitment. It can disrupt participating scientists' research. This has led to concern that the IPCC process may discourage qualified scientists from participating.

Review process for assessment reports

Expert reviewers comment at different stages on the drafts. Reviewers come from member governments and IPCC observers. Also, anyone may become an IPCC reviewer by stating they have the relevant expertise.

There are generally three stages in the review process.First comes expert review of the first draft of the chapters. The next stage is a review by governments and experts of the revised draft of the chapters and the first draft of the Summary for Policymakers. The third stage is a government review of the revised Summary for Policymakers. Review comments and author responses remain in an open archive for at least five years. Finally government representatives together with the authors review the Summary for Policymakers. They go through the Summary for Policymakers line by line to ensure it is a good summary for the underlying report. This final review of the Summary of Policymakers takes place at sessions of the responsible working group or of the Panel.

There are several types of endorsement which documents receive:

- **Approval -** Material has been subject to detailed, line by line discussion and agreement. (The relevant Working Groups approve Working Group Summaries for Policymakers. The Panel approves the Synthesis Report Summary for Policymakers.)
- **Adoption -** Endorsed section by section (not line by line). (The Panel adopts the full IPCC Synthesis Report. It also adopts Overview Chapters of Methodology Reports.)
- **Acceptance -** Not been subject to line by line discussion and agreement. But it presents a comprehensive, objective and balanced view of the subject matter. (Working Groups accept their reports. The Panel accepts Working Group Summaries for Policy makers after working group approval. The Panel accepts Methodology Reports.)

Key findings and impacts

Assessment reports one to five (1990 to 2014)

- The IPCC's First Assessment Report (FAR) appeared in 1990. The report gave a broad overview of climate change science. It discussed uncertainties and provided evidence of warming. The authors are in agreement that greenhouse gases are increasing in the atmosphere because of human activity. Which result in more warming of the Earth's surface. The report led to the establishment of the United Nations Framework Convention on Climate Change (UNFCCC).
- The Second Assessment Report (SAR), was published in 1995. It strengthened the findings of the First Assessment Report. The evidence suggests that there is a discernible human influence on the global climate, it said.[58] The Second Assessment Report provided important material for the negotiations leading to the UNFCCC's Kyoto Protocol.
- The Third Assessment Report (TAR) was completed in 2001. It found more evidence that most of the global warming seen over the previous 50 years was due to human activity. The report includes a graph reconstructing global temperature since the year 1000. The sharp rise in temperature in recent years gave it the name "hockey stick". This became a powerful image of how temperature is soaring with climate change. The report also shows how adaptation to the effects of climate change can reduce some of its ill effects.
- The IPCC's Fourth Assessment Report (AR4) was published in 2007. It gives much greater certainty about climate change. It states: "Warming of the climate system is unequivocal...". The report helped make people around the world aware of climate change. The IPCC shared the Nobel Peace Prize in the year of the report's publication for this work.
- The Fifth Assessment Report (AR5) was published in 2013 and 2014. This report again stated the fact of climate change and warned of the dangerous risks. It emphasized how the world can counter climate change. Three key findings were for example: Firstly, human influence on the climate system is clear. Secondly, the more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts. And thirdly, we have the means to limit climate change and build a more prosperous, sustainable future. The report's findings were the scientific foundation of the UNFCCC's 2015 Paris Agreement.

Sixth assessment report (2021/2022)

The IPCC's most recent report is the Sixth Assessment Report (AR6). The first three installments of AR6 appeared in 2021 and 2022. The final synthesis report was completed in March 2023.

The IPCC published the Working Group I report, Climate Change 2021: The Physical Science Basis, in August 2021. It confirms that the climate is already changing in every region. Many of these changes have not been seen in thousands of years. Many of them, such as sea-level rise, are irreversible over hundreds of thousands of years. Strong reductions in greenhouse gas emissions would limit climate change. But it could take 20-30 years for the climate to stabilize.This report attracted enormous media and public attention. U.N. Secretary-General AntónioGuterres described it as "code red for humanity".

The IPCC published the Working Group II report, Climate Change 2022: Impacts, Adaptation and Vulnerability, in February 2022.Climate change due to human activities is already affecting the lives of billions of people, it said. It is disrupting nature. The world faces unavoidable hazards over the next two decades even with global warming of 1.5ºC, it said.

The IPCC published the Working Group III report, Climate Change 2022: Mitigation of Climate Change, in April 2022. It will be impossible to limit warming to 1.5ºC without immediate and deep cuts in greenhouse gas emissions. It is still possible to halve emissions by 2050, it said.

Special reports

The IPCC also publishes other types of reports. It produces Special Reports on topics proposed by governments or observer organizations. Between 1994 and 2019 the IPCC published 14 special reports. Now usually more than one working group cooperates to produce a special report. The preparation and approval process is the same as for assessment reports.

Special reports in 2011

During the fifth assessment cycle the IPCC produced two special reports. It completed the Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) in 2011. Working Group III prepared this report. The report examined options to use different types of renewable energy to replace fossil fuels. The report noted that the cost of most renewable technologies had fallen. It was likely to fall even more with further advances in technology. It said renewable could increase access to energy. The report reviewed 164 scenarios that examine how renewable could help stop climate change. In more than half of these scenarios, renewable would contribute more than 27% of primary energy supply in mid-century. This would be more than double the 13% share in 2008. In the scenarios with the highest shares for renewable energy, it contributes 77% by 2050.

Later in 2011 the IPCC released the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). This was collaboration between Working Groups I and II. It was the first time two IPCC working groups worked together on a special report. The report shows how climate change has contributed to changes in extreme weather. It shows how can policies make to avoid and prepare for extreme weather events and can reduce their impact. In the same way policies may respond to events and recover from them and can make societies more resilient.

Special reports 2018-2019

During the sixth assessment cycle the IPCC produced three special reports. This made it the most ambitious cycle in IPCC history. The UNFCCC set a goal of keeping global warming well below 2ºC while trying to hold it at 1.5ºC, when it reached the Paris Agreement at COP21 in 2015. But time there was little understanding about 1.5ºC warming. There was little scientific research explanation that how the impacts of 1.5ºC would differ from 2ºC.and keeps the warming at 1.5ºC stagnant. So the UNFCCC invited the IPCC to prepare a report on global warming of 1.5ºC. All three IPCC working groups collaborated to produce the report. The IPCC released the Special Report on Global Warming of 1.5 °C (SR15) in 2018. The report showed that it was possible to keep warming below 1.5ºC during the 21st century. But this would mean deep cuts in emissions. It would also mean rapid, far-reaching changes in all aspects of society. The report showed warming of 2ºC would have much more severe impacts than 1.5ºC. In other words: every bit of warming matters. SR15 had an unprecedented impact for an IPCC report in the media and with the public. It put the 1.5ºC target at the center of climate activism.

In 2019 the IPCC released two more special reports which examine different parts of the climate system. The Special Report on Climate Change and Land (SRCCL) decodes the way that how land use affects the climate. It looked at emissions from activities such as farming and forestry rather than from energy and transport. It also looked at how climate change is affecting land. All three IPCC working groups and its Task Force on National Greenhouse Gas Inventories collaborated on the report. The report found that climate change is adding pressures to live on and grow our food. It will only be possible to keep warming well below.

The Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) show that how the ocean and frozen parts of the planet interact with climate change. (The cryosphere includes frozen systems such as ice sheets, glaciers and permafrost.) IPCC Working Groups I and II prepared the report. The report highlighted the need to tackle unprecedented changes in the ocean and cryosphere. It also showed that how adaptation could help sustainable development.

- **Methodology Reports**

The IPCC has a National Greenhouse Gas Inventories Programme. It develops methodologies and software for countries to report their greenhouse gas emissions. The IPCC's Task Force on National Greenhouse Gas Inventories (TFI) has managed the program since 1998.Japan's Institute for Global Environmental Strategies (IGES) hosts the TFI's Technical Support Unit.

The IPCC approves its methodology reports at sessions of the Panel. The Panel adopts the Methodology Report's Overview Chapter by endorsing it section by section.

Revised 1996 IPCC Guidelines

The IPCC released its first Methodology Report for National Greenhouse Gas Inventories, in 1994. Two "good practice reports" complete these guidelines. First is Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The second is Good Practice Guidance for Land Use, Land-Use Change and Forestry. Parties to the UNFCCC and its Kyoto Protocol use the 1996 guidelines and two good practice reports for their annual submissions of inventories.

2006 IPCC Guidelines

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories further update these methodologies. They include a large number of "default emission factors". These are factors to estimate the amount of emissions for an activity. The IPCC prepared this new version of the guidelines at the request of the UNFCCC. The UNFCCC accepted them for use at its 2013 Climate Change Conference, COP19, in Warsaw. The IPCC added further material in its 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The TFI has started preparations for a methodology report on short-lived climate forcers (SLCFs). It will complete this report in the next seventh assessment cycle.

Challenges and controversies

IPCC reports also attract criticism. Criticisms come from both people who say that the reports exaggerate the risks and people who say they underestimate them. The IPCC consensus approach has faced internal and external challenges.

Conservative nature of IPCC reports

Some critics have argued that IPCC reports tend to be conservative. They say the reports consistently underestimate the pace and impacts of global warming. This leads to findings that are the "lowest common denominator", they say. Stefan Rahmstorf, professor of physics and oceanography at Potsdam University, stated in 2007: "In a way, it is one of the strengths of the IPCC to be very conservative and cautious and not overstate any climate change risk". IPCC reports aim to inform policymakers about the state of knowledge on climate change. They do this by assessing the findings of the thousands of scientific papers available on the subject at a given time. Individual publications may have different conclusions to IPCC reports. This includes those appearing just after the release of an IPCC report. This can lead to criticism that the IPCC is either alarmist or conservative. New findings must wait for the next assessment for consideration.

Potential political influence

A memo by ExxonMobil to the Bush administration in the United States in 2002 was an example of possible political influence on the IPCC. The memo led to strong Bush administration lobbying to oust Robert Watson, a climate scientist, from IPCC chair. They sought to replace him with Rajendra Pachauri. Many considered Pachauri at the time as more mild-mannered and industry-friendly.

Governments form the membership of the IPCC. They are the prime audience for IPCC reports. IPCC rules give them a formal role in the scoping, preparation and approval of reports. For instance governments take part in the review process and work with authors to approve the Summary for Policymakers of reports. But some activists have argued that governments abuse this role to influence the outcome of reports.

Controversy and review after Fourth Assessment Report in 2007

The IPCC came under unprecedented media scrutiny in 2009 in the run-up to the Copenhagen climate conference. This "Climatic Research Unit email controversy" involved the leak of emails from climate scientists. Many of these scientists were authors of the Fourth Assessment Report which came out in 2007. The discovery of an error in this report states that the Himalayan glaciers would melt by 2035. It put the IPCC under further pressure. Scientific bodies upheld the general findings of the Fourth Assessment Report and the IPCC's approach. But many people thought the IPCC should review the way it works.

Inter Academy Council review in 2010

The United Nations Secretary-General and the Chair of the IPCC asked the Inter Academy Council (IAC) in March 2010 to review the IPCC's processes for preparing its reports. The IAC panel, chaired by Harold Tafler Shapiro, released its report on 1 September 2010. The IAC panel made seven formal recommendations for improving the IPCC's assessment process. The IPCC implemented most of the review's recommendations by 2012. One of these was the introduction of a protocol to handle errors in reports. Other recommendations included strengthening the science-review process and improving communications. But the IPCC did not adopt the proposal to appoint a full-time executive secretary.

Issues with consensual approach

Michael Oppenheimer, a long-time participant in the IPCC, has said the IPCC consensus approach has some limitations. Oppenheimer, a coordinating lead author of the Fifth Assessment Report, called for concurring, smaller assessments of special problems instead of the large-scale approach of previous IPCC assessments. Others see "mixed blessings" in the drive for consensus within the IPCC. They suggest including dissenting or minority positions. Others suggest improving statements about uncertainties.

Endorsements and awards

IPCC reports are the benchmark for climate science. There is widespread support for the IPCC in the scientific community. Publications by other scientific bodies and experts have issued official statements which endorse the findings of the IPCC. For example:

For the Third Assessment Report in 2001 endorsements came from the Canadian Foundation for Climate and Atmospheric Sciences, United States National Research Council and European Geosciences Union.

For the Fourth Assessment Report in 2007 endorsements came from the International Council for Science (ICSU), and the Network of African Science Academies.

Nobel Peace Prize in 2007

In December 2007, the IPCC received the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change". It shared the award with former U.S. Vice-president Al Gore for his work on climate change and the documentary An Inconvenient Truth.

Gulbenkian Prize for Humanity in 2022

In October 2022, the IPCC and IPBES shared the Gulbenkian Prize for Humanity. The two intergovernmental bodies won the prize because they "produce scientific knowledge, alert society, and inform decision-makers to make better choices for combating climate change and the loss of biodiversity".

11.8. Summary

According to the Intergovernmental Panel on Climate Change (IPCC), to keep global warming below 2 °C, emissions of carbon dioxide (CO2) and other greenhouse gases (GHGs) must be halved by 2050 (compared with 1990 levels). Developed countries will need to reduce more – between 80 % and 95 % by 2050; advanced developing countries with large emissions (e.g. China, India and Brazil) will have to limit their emission growth. Climate change is a global problem that requires global cooperation to address. The objective of the United Nations Framework Convention on Climate Change (UNFCCC), which virtually all nations, including the U.S., have ratified, is to stabilize greenhouse gas (GHG) concentrations at a level that will not cause "dangerous anthropogenic (human-induced) interference with the climate system. Due to the persistence of some GHGs in the atmosphere, significant emissions reductions must be achieved in coming decades to meet the UNFCCC objective.

11.9. Terminal Questions

History of international climate change policies, united nation framework, convention on climate change (UNFCCC), intergovernmental panel on climate change (IPCC)

Q.1. What is climate change and its policies? Discuss briefly.

Answers ---

Q.2. Describe in detail about International climate change policies.

Answers ---

Q.3. Discuss the objectives of United Nation Framework, Convention on Climate Change (UNFCCC).

Answers ---

Q.4. How countries are classified as parties in UNFCCC?

Answers ---

Q.5. What is Kyoto protocol? Describe its key findings?

Answers ---

Q.6. Discuss in detail about the IPCC. Discuss its structure and objectives.

11.10. Suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non-conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press.
5. Godfrey, Renewable Energy Power fora Sustainable Future, Boyle, Oxford University Press.

Unit-12: Indian Climate Panel

12.1. Introduction

The union government has set up two high level scientific panels to put together an advanced agricultural weather information system. The first panel on a proposed advances system will recommend a string of high tech automatic weather stations to monitor changes in temperature drought and extreme rainfall with. Second panel tasked with putting in place faster calculation of yield losses due to extreme weather for quicker farm insurance payouts under the flagship Pradhanmantri Fasal Bima Yogna. Scientist will work on satellite based data and technologies such as artificial intelligence for yield calculation. The Ministry of Environment, Forest and Climate Change (MoEFCC) is an Indian government ministry. This ministry is headed by Secretary Rank, senior most IAS officer. The ministry portfolio is currently held by Bhupender Yadav, Union Minister of Environment, Forest and Climate Change. The Ministry of Environment, Forests and Climate Change (MOEFCC) is a nodal agency of the administrative structure of the central government for the planning, promotion, co-ordination. It over's the implementation of India's environmental and forestry policies and programmes. The main activities include conservation survey flora and fauna of India, forests and other wilderness areas and its prevention and control of pollution of Indian Himalayan Environment its sustainable development, aforestation, and land degradation mitigation. It is responsible for the administration of the 1947 national parks of India. The Ministry of Environment, Forest and Climate Change is the cadre controlling authority of the Indian Forest Service (IFS). it's one of the three All India Services.

Objectives

- To study about the Ministry of environment, forests & climate change (MOEF&CC)
- To understand the National Action Plan on Climate Change (NAPCC)
- To understand the agenda 21
- To study the Kyoto protocol
- To study the Paris agreement.

12.2. The Ministry of Environment, Forest and Climate Change at a glance

Formed 1985; 38 years ago

Jurisdiction = Government of India

Headquarters = Indira Paryavaran Bhavan, Jorbagh Road, New Delhi

Annual budget. ₹ 3,079 crore (2023–24 est.)

Ministers responsible = Bhupender Yadav, Cabinet Minister, Ashwini Kumar Choubey, **Minister of State Agency executives =** Leena Nandan, IAS, Secretary (EF&CC) C. P. Goyal, IFS, Director General of Forests and Special Secretary

Slogan we make the world we live in and save the nature

Website = moef.gov.in

History:-

Environmental debates were first introduced into the national political agenda during Indira Gandhi's first term as Prime Minister of India. The 4th Five-Year Plan (1969–74), for example, proclaimed "harmonious development on the basis of a comprehensive appraisal of environmental issues." In 1977 (during the Emergency) Mrs. Gandhi added Article 48A to the constitution stating that: "The State shall endeavor to protect and improve the environment and to safeguard the forests and wildlife of the country." The same decree transferred wildlife and forests from state list to concurrent list of the constitution, thus giving the central government the power to overrule state decisions on that matter. Such political and constitutional changes prepared the groundwork for the creation of a federal Department of Environment in 1980, turned into the Ministry of Environment and Forests in 1985. Although tackling climate change which was already a responsibility of the ministry, its priority was raised, when in May 2014, the ministry was renamed to the current title of Ministry of Environment, Forest and Climate Change.

Administration:-

The forest administration is based on demarcation of states into Forest Divisions which consists of Forest Ranges. Forest Beats under Ranges are the smallest unit of administration hierarchy. Natural features on the field form the boundaries of each beat which has an average area of around 16 km square.

Organization:-

Indian Forest Service (IFS)

Authorities

- Central Zoo Authority of India, New Delhi
- National Biodiversity Authority, Chennai
- National Tiger Conservation Authority, New Delhi

Subordinate offices

- Andaman & Nicobar Islands Forest and Plantation Development Corporation (Public Sector Undertaking)
- Animal Welfare Board of India, Chennai
- Botanical Survey of India (BSI), Kolkata
- Central Pollution Control Board
- Environmental Information System (ENVIS)[7]

- Odisha State Pollution Control Board
- Delhi Pollution Control Committee
- Directorate of Forest Education
- Forest Survey of India
- Mrs Indira Gandhi National Forest Academy
- National Afforestation and Eco-Development Board
- National Board of Wildlife
- National Institute of Animal Welfare
- National Museum of Natural History (NMNH), New Delhi
- National Zoological Park (NZP), New Delhi
- Zoological Survey of India (ZSI), Kolkata

Centers of excellence

- Centre for Environment Education, Ahmedabad
- C. P. R. Environmental Education Centre, Chennai
- Centre for Animals and Environment, Bangalore
- Centre of Excellence in Environmental Economics, Chennai
- Foundation for Revitalisation of Local Health Traditions, Bangalore
- Centre for Ecological Sciences, Bangalore
- Centre for Environmental Management of Degraded Ecosystem, New Delhi
- Center for Mining Environment, Dhanbad
- Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore
- Tropical Botanic Garden and Research Institute,Thiruvananthapuram

Autonomous institutions

- G. B.Pant Institute of Himalayan Environment and Development, Almora
- Indian Institute of Forest Management, Bhopal
- Indian Plywood Industries Research and Training Institute, Bengaluru
- Indian Council of Forestry Research and Education (ICFRE), Dehradun
- Wildlife Institute of India (WII), Dehradun

Initiatives

In August 2019 the Ministry of Environment released the Draft National Resource Efficiency Policy. It is a set of guidelines which envisions, a future with environmentally sustainable and equitable economic growth. The policy is guided by the principle of reduction in primary resource consumption, creation of higher value with less material through resource efficient circular approach, waste minimization, material security and creation of employment opportunities and business model beneficial to the cause of environment protection and restoration. It was based on the report of NITI Aayog and European Union titled, The strategy on resource efficiency. The policy seeks to set up a National Resource Efficiency Authority with a core working group housed in the Ministry. It also plans to offer tax benefits on recycled materials and soft loans to set up waste disposal and material recovery facilities.

Some states have received more than Rupees 47,000 crore for afforestation on 8th December 2021. The states were directed to channel this amount as compensatory afforestation which shall be used for plantations, assisted natural forest regeneration, forest fire-prevention, pest and disease control in forest, and expedite soil and moisture conservation works.

12.3. National action plan on climate change (NAPCC)

National Action Plan for Climate Change (NAPCC) is a Government of India's programme launched in 2008 to mitigate and adapt to the adverse impact of climate change. The action plan was launched in 2008 with 8 sub-missions. The plan aims at fulfilling India's developmental objectives with focus on reducing emission intensity of its economy. The plan will rely on the support from the developed countries with the prime focus of keeping its carbon emissions below the developed economies at any point of time.The 8 missions under NAPCC are as follows:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining Himalayan Ecosystem
- Green India Mission
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change

12.3.1. National Solar Mission

The National Solar Mission was launched as Jawaharlal Nehru National Solar Mission in 2010. It has been revised two times since then. The Mission was launched with a target of producing

20,000 Megawatts of solar power in three phases of (2010-2013); (2013-2017); and (2017-2022). In the 2015 Budget speech, a revised target of 100,000 Megawatts was fixed, which was to be achieved till 2022. The Ministry of New and Renewable Energy has also set up a target of producing 40 Gigawatts of solar power by 'Rooftop Solar Power Projects' while the rest 60 Gigawatts is planned to be obtained from large and medium scale grid connected solar power projects.

The Ministry will provide capital subsidy in the form of viability gap funding to the Solar Energy Corporation of India (SECI). The Government of India also planned to leverage the funding from bilateral donors like Green Climate Fund under United Nations Framework Convention on Climate Change (UNFCCC), as the solar power production could reduce greenhouse gas emissions from coal based power plants. The target of 100 GW solar energy capacity generations was part of production of 175 GW of energy through renewable sources by 2022. In 2019, speaking at the United Nations Secretary General's Climate Action Summit, Prime Minister, Mr. Narendra Modi announced the target of 175 GW renewable energy production to be extended beyond its ceiling to reach an ambitious target of 450 GW till 2022.

To fulfill the targets set up under the mission, the Government launched several schemes in order to promote solar power and reduce dependency on the traditional power sources. One such scheme called Kisan Urja Suraksha Evam Uthhan Mahabhiyan (KUSUM) which was approved by the Cabinet Committee on Economic affairs in 2019. The program aims for, installation of off-grid solar pumps in rural areas and reducing dependence on grid, in grid connected areas. The Domestic Content Requirement provision for the procurement of components used in the solar power projects has remained a disputed step for foreign players who have often complained of discrimination against their manufacturers.

12.3.2. National Mission for Enhanced Energy Efficiency (NMEEE)

The National Mission for Enhanced Energy Efficiency was developed from the Energy Conservation Act of 2001. The Mission document, which was approved in 2010, established the immense energy efficiency potential of India, which was about Rs. 74,000 crores. The Mission, upon its complete execution, aims to achieve total avoided capacity addition of 19,598 MW, fuel savings of around 23 million tonnes per year and greenhouse gas emissions reductions of 98.55 million tonnes per year. A 2016 World Bank study has estimated the country's energy efficiency market to be at 1.6 lakh crores. India has the fifth lowest energy efficiency in the world, and has a poor ratio of GDP to energy consumption. The NMEEE addresses sustainable economic growth and a reduction in energy and carbon intensity.

NMEEE has four components:

- Perform, Achieve, Trade (PAT)
- Energy Efficiency Financing Platform
- Market Transformation For Energy

Efficiency (MTEE)

- Framework For Energy Efficiency

Economic Development

The Perform Achieve and Trade (PAT) component assigns targets to energy-intensive industries and also allots energy saving certificates (Escerts). These certificates are tradable amongst the candidates who have either breached their targets or remained unsuccessful in achieving them. As in 2021, it remains unclear whether PAT is doing enough to lower India's carbon footprint or not.

The Energy Efficiency Financing Platform encourages financial institutions and investors to support energy efficiency initiatives.

The Framework For Energy Efficiency Economic Development promotes energy efficient initiatives by hedging against investment risks.

The Market Transformation for Energy Efficiency component promotes the use and adoption of energy efficient equipment. One 2009 campaign, "Bachat Lamp Yojana", was designed to replace incandescent light bulbs with the CFL bulbs. CFL bulbs were distributed at reduced prices, and the government was able to recover the cost through sale of Certified Emission reduction certificates.

"Bachat Lamp Yojna" was later replaced by the "Unnat Jyoti Affordable LED for All" (UJALA) scheme in 2015, in which LED bulbs were distributed to replace the comparatively more efficient CFL bulbs.

The UJALA scheme is implemented by Energy Efficiency Services Limited (EESL); which is a joint venture of Public Sector Undertakings (PSUs) under the power ministry.

Under the same component of MTEE, the Government also launched the "Super Efficient Equipment Program", which was supported by the World Bank. The scheme aimed at transfer of the assistance from the World Bank to the energy equipment manufacturers to enable them to produces the products that consume less electricity. The "Super Efficient Equipment Program" is implemented by the Bureau of Energy Efficiency.

In order to hedge the financial institutions providing loans for the energy efficiency projects against credit risks, the Bureau of Energy Efficiency has also institutionalized two funds namely "Partial Risk Guarantee Fund for Energy Efficiency" and "Venture Capital Fund for Energy Efficiency". Both these funds have been launched under the "Framework for Energy Efficient Economic Development" component of the NMEEE.

12.3.3. National Mission on Sustainable Habitat:-

The transport sector along with urban buildings is major consumers of energy in India. one of the most important mission is to pave the way for a shift to public transport. The National Mission on Sustainable Habitat is an umbrella programme to reduce the energy consumption and hence the risk of climate changes due to the urban settlement pattern. The mission envisages a shift to Energy Conservation Building Code (ECBC) to design new commercial buildings as well as solid and liquid waste management. The mission also covers the water resource management as well as drinking water management. It important component of the mission is to promote the waste water use and sewage utilization along with Waste Management.

National Water Mission is a comprehensive programme for equitable distribution of water across the country as well as for enhancing the capacity building process for the management of over exploited blocs. It is focused upon tackling the issues related to water availability and pollution which is owed to global warming and climate change. The mission promotes research and development and reviews National Water Policy. The mission, while promoting the traditional water conservation system, also promotes the expeditious implementation of the multipurpose water projects. It has a target of increasing water use efficiency by 20%. The convergence of various water conservation schemes for a better outcome and implementation of water resource management program via the MNREGA route with participation of the elected representatives of the over exploited water blocks is the central theme of the mission.

The program has focused on a decentralized approach which is reflected in its plan of "basin level" integrated water resource management and sensitization of the urban local youths. The National Water Mission has an identified a goal of putting a comprehensive water resource database in the public domain. The onus of implementation lies on the Ministry of Jal Shakti.

12.3.4. National Mission for Sustainable Himalayan Ecosystem:-

The Himalayas are one of the most important ecosystems of India with millions of people depending upon it. The adverse impact of climate change has remained detrimental to the Himalayan Ecosystem which provides a variety of Ecosystem Services. To ensure the provisions from the Himalayas, the mission has a multi-pronged approach to understand the impact of climate change on the Himalayan Ecosystem for the Sustainable Development to other parts of the country. The Ministry of Science and Technology is the nodal Ministry for its implementation but the collaboration of "Himalayan states" as well as the Ministry of Environment, Forest and Climate Change is instrumental in the success of the Mission.

One of the primary objectives of the mission is to assess the health of Himalayan Ecosystem, for which the scheme was released with an outlay of Rs.550 Crores during the 12th "Five Years Plan" period.

12.3.5. Green India Mission

The Green India Mission is aimed at protecting, restoring and enhancing India's green cover in response to climate change. The mission has a cumulative target of increasing forest cover on 5 million hectares and improving the forest cover to additional 5 hectares. The mission also has a target of providing livelihood to 3 million people through the forest based activities and enhancing the provisioning capacity of the Indian forests along with their carbon sequestration capacity. The scheme was proposed for 10 years with an outlay of 60,000 crores but it has remained grossly underfunded. Due to the investment crunch, the scheme which was planned to be launched in 2012 was delayed for its final launch in 2015. The scheme also has an important goal of fulfilling India's Nationally Determined Contribution (NDC) target of sequestering 2.5 Billion tonnes of "Carbon emissions" by 2020-30, which it submitted to UNFCCC. We are planting with massive plantation drives i.e. UP in 2017,18,19 and Maharashtra (under Green Maharashtra mission) and MP that later converted into a disputed drive. But the result is not visible anywhere, because of faulty execution everywhere. there is an immediate need of improvement and officials strict attitude about this aspect. The here the "One Tree My Duty" probably is the best solution, provided by Ek Kadam Sansthan.

12.3.6. National Mission for Sustainable Agriculture (NMSA)

The National Mission for Sustainable Agriculture includes multiple programmes for the sustainable growth of the agriculture sector. It includes interventions like Soil Health Card Scheme, Paramparagat Krishi Vikas Yojana, Mission organic value chain development for

North-East region, Rain fed Area Development program, National Bamboo Mission and Sub Mission on Agroforestry. These programs along with others like "Pradhan Mantri Krishi Sinchai Yojana " aims to promote judicious use of natural resources. The NMSA has four components, namely "Rainfed Area Development Program", "On Farm Water Management Program", "Soil Health Management Program" and "Climate Change and Sustainable Agriculture Monitoring, Modeling and Networking Program".

Under NMSA, the Cabinet Committee on Economic affairs released the restructured "National Bamboo Mission" in 2018 to last till the end of 14th Five Year Plan period. The Mission is a centrally sponsored scheme in which the funding pattern for General states is in 60:40 ratio with the central government while for North-East and hilly areas it is 90:10. The Union Territories will get 100% funding from the center. The goal of the scheme is to promote Bamboo cultivation on non-forest government land and on the private lands of farmers in the states where it has social, commercial and economic importance.

The government had amended the Indian Forest Act, 1927 to remove the Bamboo plant from the category of trees to enable its cultivation market development and commercial cultivation of Bamboo and feeling without permit in non-forest areas for the livelihood improvement of tribal's and formers.

12.4. National Mission on Strategic Knowledge for Climate Change

This sub-mission involves formation of knowledge networks among the existing knowledge institutions involved in research and development relating to climate science and facilitating data sharing and exchange through a suitable policy framework and institutional support.

Drawbacks

As per news reports, the council heading NAPCC has no accountability. There is not much information available in the public domain regarding the meetings' help or the decisions taken in them. In total 10 ministries are involved in implementation and they took 6 years just to approve the 8 missions.

Status

According to a news report, It has been hard to track the status of different missions. While on one hand the officers are unwilling to give out details and on the other hand the budget heads and schemes are seeing constant changes which make tracking very difficult.

12.4.1. Agenda 21

Agenda 21 is a non-binding action plan of the United Nations with regard to sustainable development. It is a product of the Earth Summit (UN Conference on Environment and Development) held in Rio de Janeiro, Brazil, in 1992. It is an action agenda for the UN, other multilateral organizations, and individual governments around the world that can be executed at local, national, and global levels. One major objective of the Agenda 21 initiative is that every local government should draw its own local Agenda 21. Its aim initially was to achieve global sustainable development by 2000, with the "21" in Agenda 21 referring to the original target of the 21st century.

Agenda 21 is grouped into 4 sections:

Section I: Social and Economic Dimensions two is directed toward combating poverty, especially in developing countries, changing consumption patterns, promoting health, achieving a more sustainable population, and sustainable settlement in decision making.

Section II: Conservation and Management of Resources for Development includes atmospheric protection, combating deforestation, protecting fragile environments, conservation of biological diversity (biodiversity), control of pollution and the management of biotechnology, and radioactive wastes.

Section III: Strengthening the Role of Major Groups includes the roles of children and youth, women, NGOs, local authorities, business and industry, and workers; and strengthening the role of indigenous peoples, their communities, and farmers.

Section IV: Means of Implementation includes science, technology transfer, education, international institutions, and financial mechanisms.

Development and evolution

The full text of Agenda 21 was made public at the UN Conference on Environment and Development (Earth Summit), held in Rio de Janeiro on 13 June 1992, where 178 countries voted to adopt the program. The final text was the result of drafting, consultation, and negotiation. It begain began in 1989 and culminating at the two-week conference.

Rio+5 (1997)

In 1997, the UN General Assembly held a special session to appraise the status of Agenda 21 (Rio +5). The Assembly recognized progress as "uneven" and identified key trends, including increasing globalization, widening inequalities in income, and continued deterioration of the global environment. A new General Assembly Resolution (S-19/2) promised further action

Rio+10 (2002)

The Johannesburg Plan of Implementation, agreed to at the World Summit on Sustainable Development (Earth Summit 2002), affirmed UN commitment to "full implementation" of Agenda 21, alongside achievement of the Millennium Development Goals and other international agreements.

Agenda 21 for culture (2002)

The first World Public Meeting on Culture, held in Porto Alegre, Brazil, in 2002, came up with the idea to establish guidelines for local cultural policies, something comparable to what Agenda 21 was for the environment.[3] They are to be included in various subsections of Agenda 21 and will be carried out through a wide range of sub-programs beginning with G8 countries.

Rio+20 (2012)

In 2012, at the United Nations Conference on Sustainable Development the attending members reaffirmed their commitment to Agenda 21 in their outcome document called "The Future We Want". Leaders from 180 nations participated.

12.5. Sustainable Development Summit (2015)

Agenda 2030, also known as the Sustainable Development Goals, was a set of goals decided upon at the UN Sustainable Development Summit in 2015.[4] It takes all of the goals set by Agenda 21 and re-asserts them as the basis for sustainable development, saying, "We reaffirm all the principles of the Rio Declaration on Environment and Development…" Adding onto those goals from the original Rio document, a total of 17 goals have been agreed on, revolving around the same concepts of Agenda 21; people, planet, prosperity, peace, and partnership.

Implementation

The Commission on Sustainable Development acts as a high-level forum on sustainable development and has acted as preparatory committee for summits and sessions on the implementation of Agenda 21. The UN Division for Sustainable Development acts as the secretariat to the Commission and works "within the context of" Agenda 21.

Implementation by member states remains voluntary, and its adoption has varied.

Local level

The implementation of Agenda 21 was intended to involve action at international, national, regional and local levels. Some national and state governments have legislated or advised that local authorities should take steps to implement the plan locally, as recommended in Chapter 28 of the document. These programs are often known as "Local Agenda 21" or "LA21".For example, in the Philippines, the plan is "Philippines Agenda 21" (PA21). The group, ICLEI-Local Governments for Sustainability was formed in 1990. Its members come from over 1,000 cities, towns, and counties from 88 countries and are widely regarded as a paragon of Agenda 21 implementation.

Europe turned out to be the continent where LA21 was best accepted and most implemented.In Sweden, for example, four small- to medium-sized municipalities in the south-east of Sweden were chosen for a 5-year study of their Local Agenda 21 (LA21) processes.

Regional levels

The UN Department of Economic and Social Affairs' Division for Sustainable Development monitors and evaluates progress, nation by nation, towards the adoption of Agenda 21, and makes these reports available to the public on its website.

The Rio+10 report identified over 6400 local governments of 113 countries were engaged in Local Agenda 21 (LA21) activities. A more than three-fold increase over less than five years about 80% = 5120 of these local governments were located in Europe. A significant increase has been noted in the number of countries in which one or more LA21 processes are underway.

Australia

Australia is a signatory to Agenda 21 and 88 of its municipalities and subscribe to ICLEI. It is an organization that promotes Agenda 21 globally. Australia's membership is second only to that of the United States.

Africa

In Africa, national support for Agenda 21 is strong and most countries are signatories. But support is often closely tied to environmental challenges specific to each country; for example, in 2002 Sam Nujoma, who was the President of Namibia, spoke about the importance of adhering to Agenda 21 at the 2002 Earth Summit, noting that as a semi-arid country, Namibia sets a lot of store in the United Nations Convention to Combat Desertification (UNCCD). Furthermore, there is little mention of Agenda 21 at the local level in indigenous media. Only major municipalities in sub-Saharan African countries are members of ICLEI. Agenda 21 participation in North

African countries mirrors Middle Eastern countries, with most countries being signatories but little to no adoption on the local-government level. Countries in sub-Saharan Africa and North Africa generally have poorly documented Agenda 21 status reports. By contrast, South Africa's participation in Agenda 21 mirrors modern Europe, with 21 city members of ICLEI and support of Agenda 21 by national-level governments.

North America

United States

The national focal point in the United States is the Division Chief for Sustainable Development and Multilateral Affairs, Office of Environmental Policy, Bureau of Oceans and International Environmental and Scientific Affairs, U.S. Department of State. A June 2012 poll of 1,300 United States by the American Planning Association found that 9% supported Agenda 21, 6% opposed it, and 85% thought they didn't have enough information to form an opinion.

Support

The United States is a signatory country to Agenda 21, but because Agenda 21 is a legally non-binding statement of intent and not a treaty, the United States, Senate did not hold a formal debate or vote on it. It is therefore not considered to be law under Article Six of the United States Constitution. President George H. W. Bush was one of the 178 heads of government who signed the final text of the agreement at the Earth Summit in 1992, and in the same year Representatives Nancy Pelosi, Eliot Engel and William Broomfield spoke in support of United States House of Representatives Concurrent Resolution 353, supporting implementation of Agenda 21 in the United States. Created by Executive Order 12852 in 1993, the President's Council on Sustainable Development (PCSD) is explicitly charged with recommending a national action plan for sustainable development to the President. The PCSD is composed of leaders from government and industry, as well as from environmental, labor and civil rights organizations. The PCSD submitted its report, "Sustainable America: A New Consensus", to the President in early 1996. In the absence of a multi- sectoral consensus on how to achieve sustainable development in the United States, the PCSD was conceived to formulate recommendations for the implementation of Agenda 21. Executive Order 12852 was revoked by Executive Order 13138 in 1999.

The PCSD set 10 common goals to support the Agenda 21 movement:

1. Health and the environment
2. Economic Prosperity

3. Equity
4. Conservation of nature
5. Stewardship
6. Sustainable communities
7. Civic engagement
8. Population
9. International responsibility
10. Education.

In the United States, over 528 cities are members of ICLEI, an international sustainability organization that helps to implement the Agenda 21 and Local Agenda 21 concepts across the world. The United States has nearly half of the ICLEI's global membership of 1,200 cities promoting sustainable development at a local level.The United States also has one of the most comprehensively documented Agenda 21 status reports.In response to the opposition, Don Knapp, U.S. spokesman for the ICLEI, has said "Sustainable development is not a top-down conspiracy from the U.N., but a bottom-up push from local governments".

Opposition

Agenda 21 fears have played a role in opposition to local government's efforts to promote resource and land conservation, build bike lanes, and construct hubs for public transportation. The non-profit group ICLEI – Local Governments for Sustainability USA – was targeted by anti-Agenda 21 activists. In the same year, fears of Agenda 21 "went main stream" when the Republican National Committee adopted a platform resolution stated that "We strongly reject the U.N. Agenda 21 as an erosion of American sovereignty."

Several state and local governments have considered or passed motions and legislation opposing Agenda 21.Most such bills failed, "either dying in committee, getting defeated on the statehouse floor or – in the case of Missouri's 2013 bill – getting vetoed by the governor."Alabama was one state that did adopt an anti-Agenda 21 resolution, unanimously passing in 2012 a measure to block "any future effort to 'deliberately or inadvertently infringe or restrict private property rights without due process, as may be required by policy recommendations originating in, or traceable to 'Agenda 21.'"

12.6. The Kyoto protocol

The Kyoto Protocol was an international treaty which extended the 1992 United Nations Framework Convention on Climate Change (UNFCCC) It commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that (part one) global warming is occurring and (part two) that 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. There were 192 parties (Canada withdrew from the protocol, effective December 2012) to the Protocol in 2020.

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" (Article 2).

The Kyoto Protocol applied to the seven greenhouse gasses listed in Annex A: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3). Nitrogen trifluoride was added for the second compliance period during the Doha Round.

The Protocol 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. They placed the obligation to reduce current emissions on developed countries.

The Protocol's first commitment period started in 2008 and ended in 2012. All 36 countries fully participated in the first commitment period complied with the Protocol. However, nine countries had to resort to the flexibility mechanisms by funding emission reductions in other countries because their national emissions were slightly higher than their targets. The financial crisis of 2007-08 helped reduce emissions. The greatest emission reductions were seen in the former Eastern Bloc countries because the dissolution of the Soviet Union reduced their emissions in the early 1990s. Even the global emissions increased by 32% from 1990 to 2010 though the 36 developed countries reduced their emissions.

In the 2012, the second commitment period was agreed and extend the agreement up to 2020, known as the Doha Amendment to the Kyoto Protocol, in which 37 countries had binding targets: Australia, the European Union (and it's the 28 member states, now 27), Belarus, Iceland, Kazakhstan, Liechtenstein, Norway, Switzerland, and Ukraine. Belarus, Kazakhstan, and Ukraine stated that they may withdraw from the Kyoto Protocol or not put into legal force the Amendment with second round targets. Japan, New Zealand, and Russia had participated in Kyoto's first-round but did not take on new targets in the second commitment period. Other developed countries who were without second-round targets were Canada (which withdrew from the Kyoto Protocol in 2012) and the United States (which did not ratify). Canada's decision to withdraw was very disappointing to Environment minister, Peter Kent. The Canada did it to avoid a $14 billion fine. In October 2020, 147 states accepted the Doha Amendment. It entered into force on 31 December 2020, following its acceptance by at least 144 states, of the 37 parties with binding commitments, 34 had ratified. This resulted in the 2015 adoption of the Paris Agreement, which is a separate instrument under the UNFCCC other than an amendment of the Kyoto Protocol.

Background

The view that human activities are likely responsible for most of the observed increase in global mean temperature ("global warming") since the mid-20th century is an accurate reflection of current scientific thinking. Human-induced warming of the climate is expected to continue throughout the 21st century and beyond.

The Intergovernmental Panel on Climate Change (IPCC, 2007) has produced a range of projections of what the future increase in global mean temperature might be. The IPCC's projections are "baseline" projections, meaning that they assume no future efforts are made to reduce greenhouse gas emissions. The IPCC projections cover the time period from the beginning of the 21st century to the end of the 21st century. The "likely" range (as assessed to have a greater than 66% probability of being correct, based on the IPCC's expert judgment) is a projected increase in global mean temperature over the 21st century of between 1.1 and 6.4 °C.

The range in temperature projections partly reflects different projections of future greenhouse gas emissions 22-24. Different projections contain different assumptions of future social and economic development (economic growth, population level, energy policies), which in turn affects projections of future greenhouse gas (GHG) emissions 22-24. The range also reflects uncertainty in the response of the climate system to past and future GHG emissions (measured by the climate sensitivity) in year 22-24.

Chronology

1992 – The UN Conference on the Environment and Development was held in Rio de Janeiro. It results in the Framework Convention on Climate Change ("FCCC" or "UNFCCC") among other agreements.

1995 – Parties to the UNFCCC in Berlin (the 1st Conference of Parties (COP) of UNFCCC to outline specific targets on emissions.

1997 – In December the parties concluded the Kyoto Protocol in Kyoto, Japan, in which they agreed to broad outlines of emissions targets.

2004 – Russia and Canada ratify the Kyoto Protocol to the UNFCCC bringing the treaty into effect on 16 February 2005.

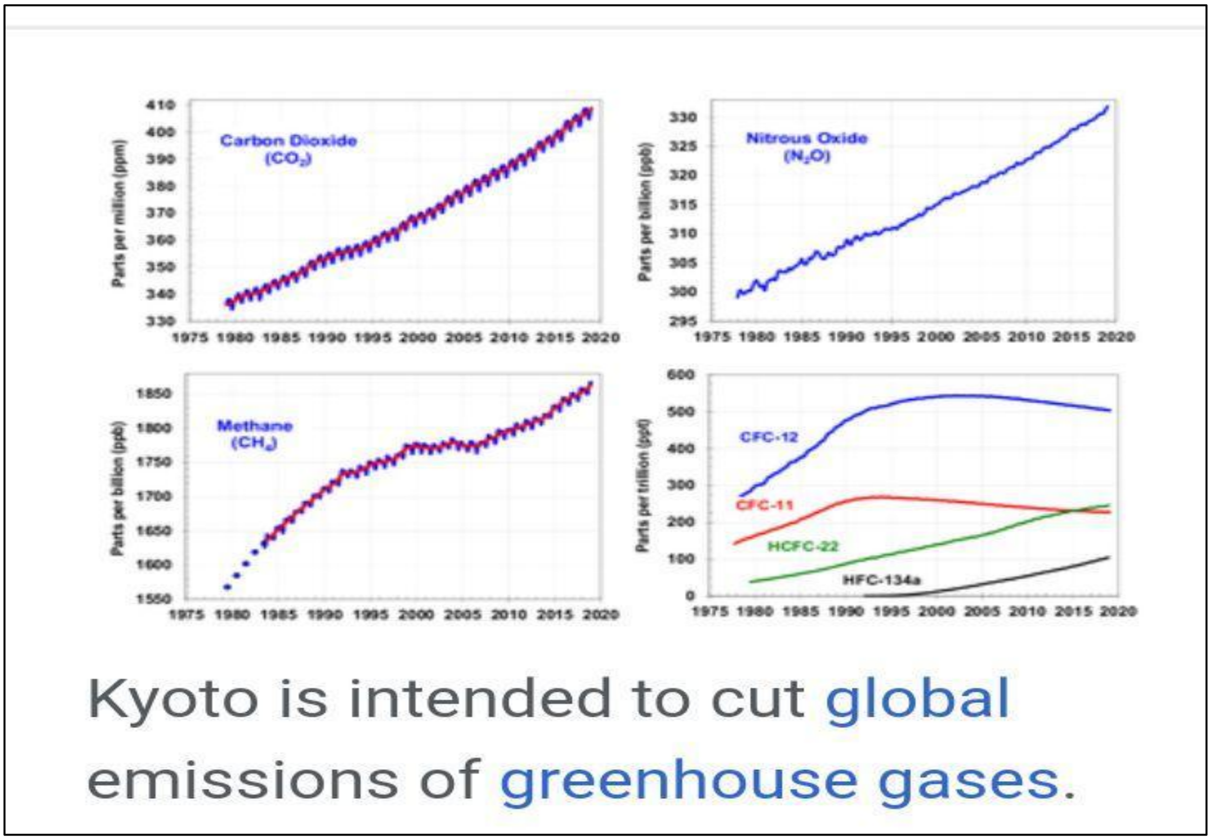
2011 – Canada became the first signatory to announce its withdrawal from the Kyoto Protocol.

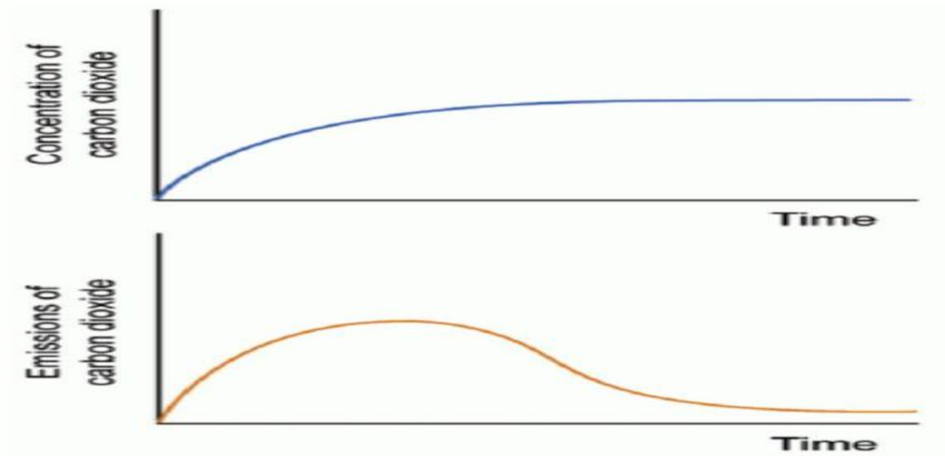
2012 – On 31 December 2012, the first commitment period under the Protocol expired.

12.7. Article 2 of the UNFCCC

Most countries are Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Article 2 of the Convention states its ultimate objective, which is to stabilize the concentration of greenhouse gasses in the atmosphere "at a level that would prevent dangerous anthropogenic (human) interference with the climate system."The natural, technical and social sciences can provide information on decisions relating to this objective including the possible magnitude and rate of future climate changes. However, the IPCC has also concluded that the decision of what constitutes "dangerous" interference requires value judgments, which will vary between different regions of the world. Factors that might affect this decision include the local consequences of climate change impacts and the ability of a particular region to adapt to climate change (adaptive capacity), and the ability of a region to reduce its GHG emissions (mitigative capacity).

Objectives of the Kyoto protocol





In order to stabilize the atmospheric concentration of CO_2, emissions worldwide would need to be dramatically reduced from their present level.[25]

The main goal of the Kyoto Protocol was to control emissions of the main anthropogenic (human-emitted) greenhouse gasses (GHGs) in ways that reflect underlying national differences in GHG emissions, wealth, and capacity to make the reductions. The treaty follows the main principles agreed in the original 1992 UN Framework Convention. According to the treaty, in 2012, Annex I Parties who have ratified the treaty must have fulfilled their obligations of greenhouse gas emissions limitations established atthe Kyoto Protocol's first commitment period (2008–2012). These emissions limitation commitments are listed in Annex B of the Protocol.

The Kyoto Protocol's first round commitments were the first detailed step taken within the UN Framework Convention on Climate Change. The Protocol establishes a structure of rolling emission reduction commitment periods. It sets a timetable, starting in 2006 for negotiations to establish emission reduction commitments for a second commitment period. The first period emission reduction commitments expired on 31 December 2012.

The ultimate objective of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would stop dangerous anthropogenic interference with the climate system." Even if Annex I Parties succeed in meeting their first-round commitments, much greater emission reductions will be required in future to stabilize atmospheric GHG concentrations.

For each of the different anthropogenic GHGs, different levels of emission reductions would be required to meet the objective of stabilizing atmospheric concentrations Carbon dioxide (CO2) is the most important anthropogenic GHG. Stabilizing the concentration of CO2 in the atmosphere would ultimately require the effective elimination of anthropogenic CO2 emissions.

Principal concepts of the Kyoto Protocol:

The main feature of the Protocol is that it established legally binding commitments to reduce emissions of greenhouse gasses for Annex I Parties. The commitments were based on the Berlin Mandate, which was a part of UNFCCC negotiations leading up to the Protocol.

In order to meet the objectives of the Protocol, Annex I Parties are required to prepare policies and measures for the reduction of greenhouse gasses in their respective countries. In addition, they are required to increase the absorption of these gasses. they are to utilize all mechanisms available, such as joint implementation, the clean development mechanism and emissions trading, in order to be rewarded with credits that would allow more greenhouse gas emissions at home. Minimizing impacts on developing countries, it by establishing an adaptation fund for climate change. Reporting and Review in order to ensure the integrity of the Protocol. Establishing a compliance committee to enforce compliance with the commitments under the protocol.

First commitment period: 2008–2012

Under the Kyoto Protocol, 37 industrialized countries and the European Community (the European Union-15, made up of 15 states at the time of the Kyoto negotiations) commit themselves to binding targets for GHG emissions. The targets apply to the four greenhouse gasses viz. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), and two groups of gasses, hydro fluorocarbons (HFCs) and per fluorocarbons (PFCs).The six GHG are translated into CO_2 equivalents in determining reductions in emissions. These reduction targets are in addition to the industrial gasses, chlorofluorocarbons, or CFCs, which are dealt with under the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer.

Under the Protocol, only the Annex I Parties have committed themselves to national or joint reduction targets formally called "quantified emission limitation and reduction objectives" (QELRO) – Article 4.1).Parties to the Kyoto Protocol not listed in Annex I of the convention (the non-Annex I Parties) are mostly low-income developing countries,:4 and may participate in the Kyoto Protocol through the Clean Development Mechanism (explained below).

The emissions limitations of Annex I Parties vary between different Parties. Some Parties have emissions limitations reduced below the base year level, some have limitations at the base year level (no permitted increase above the base year level), while others have limitations above the base year level.

Emission limits do not include emissions by international aviation and shipping. Although Belarus and Turkey are listed in the convention's Annex I, they do not have emissions targets as they were not Annex I Parties when the Protocol was adopted. Kazakhstan does not have a target, but has declared that it wishes to become an Annex I Party to the convention.

For most state parties, 1990 is the base year for the national GHG inventory and the calculation of the assigned amount. However, five state parties have an alternative base year:

Bulgaria: 1988;

Hungary: the average of the years 1985–1987;

Poland: 1988;

Romania: 1989;

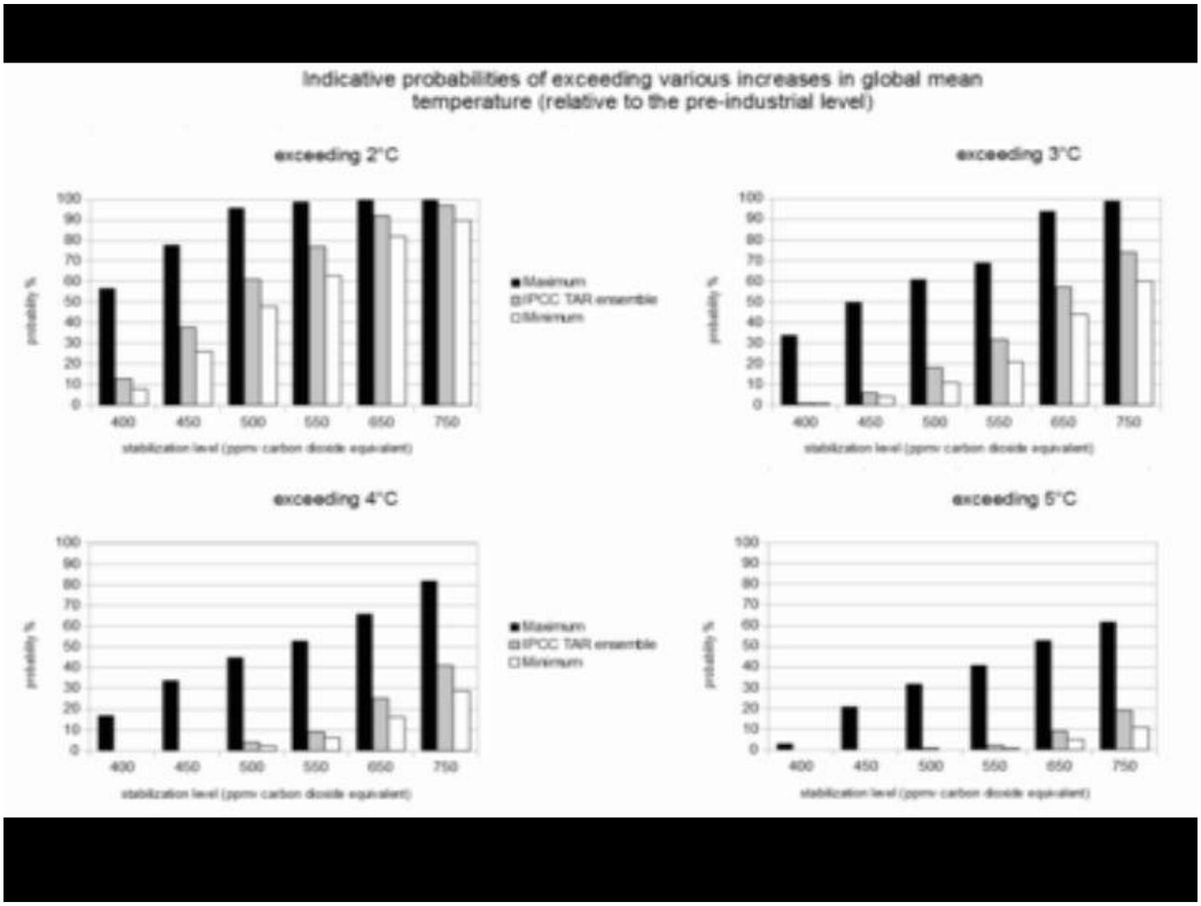
Slovenia: 1986.

Annex I Parties can use a range of sophisticated "flexibility" mechanisms (see below) to meet their targets. Annex I Parties can achieve their targets by allocating reduced annual allowances to major operators within their borders, or by allowing these operators to exceed their allocations by offsetting any excess through a mechanism that is agreed by all the parties to the UNFCCC, such as by buying emission allowances from other operators which have excess emissions credits.

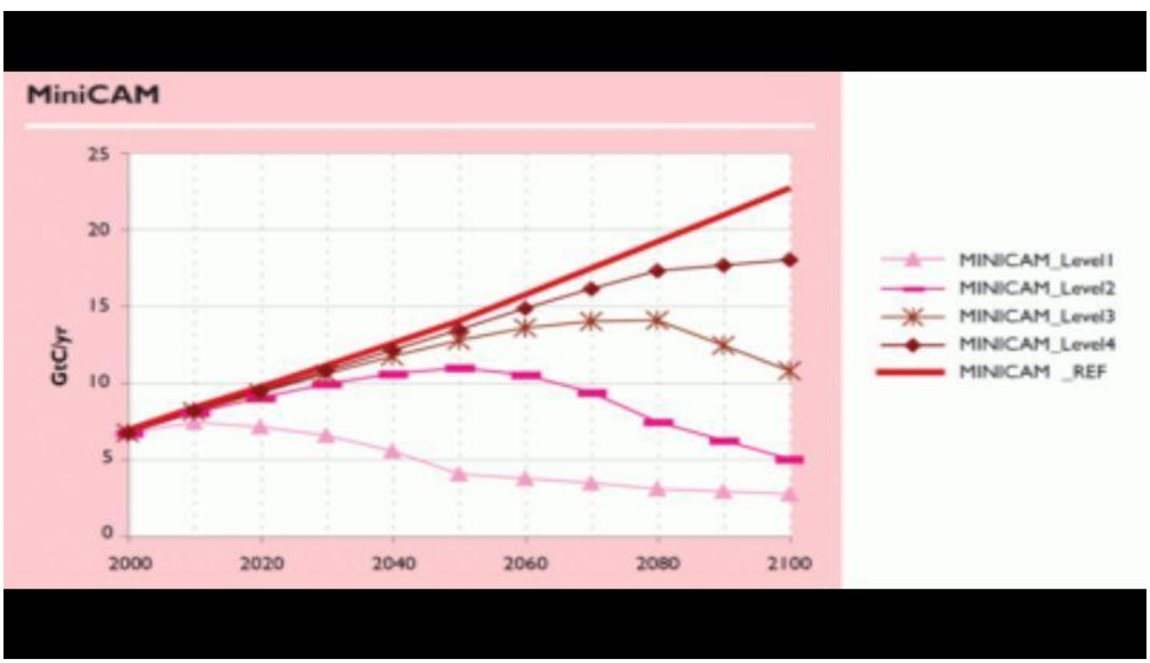
Stabilization of GHG concentrations

As noted earlier on, the first-round Kyoto emissions limitation commitments are not sufficient to stabilize the atmospheric concentration of GHGs. Stabilization of atmospheric GHG concentrations will require further emissions reductions after the end of the first-round Kyoto commitment period in 2012.

Background



Indicative probabilities of exceeding various increases in global mean temperature for different stabilization levels of atmospheric GHG concentrations.



Different targets for stabilization require different levels of cuts in emissions over the time. Lower stabilization targets require global emissions to be reduced more sharply in the near-term.

Analysts have developed scenarios of future changes in GHG emissions that lead to a stabilization in the atmospheric concentrations of GHGs. Climate models suggest that lower stabilization levels are associated with lower magnitudes of future global warming, while higher stabilization levels are associated with higher magnitudes of future global warming.

To achieve stabilization, global GHG emissions must peak, then decline.The lower the desired stabilization level, the sooner this peak and decline must occur (see figure opposite). For a given stabilization level, larger emissions reductions in the near term allow for less stringent emissions reductions later. On the other hand, less stringent near term emissions reductions would, for a given stabilization level, require more stringent emissions reductions later on.

The first period Kyoto emissions limitations can be viewed as a first-step towards achieving atmospheric stabilization of GHGs. In this sense, the first period Kyoto commitments may affect the future atmospheric stabilization level that can be achieved.

Relation to temperature targets

At the 16th Conference (2010) parties to the UNFCCC, agreed that future global warming should be limited below 2°C relative to the pre-industrial temperature level. One of the stabilization levels discussed in relation to this temperature target is to hold atmospheric concentrations of GHGs at 450 parts per million (ppm). CO_2- eq. Stabilization at 450 ppm could be associated with a 26 to 78% risk of exceeding the 2 °C target.

Annex I emissions would need to be 25% to 40% below 1990 levels by 2020, and 80% to 95% below 1990 levels by 2050. The only Annex I Parties have to made voluntary pledges in line Japan (25% below 1990 levels by 2020) and Norway (30–40% below 1990 levels by (2020) 450 ppm scenarios projected for non-Annex I Parties targets. Projections indicated that by 2020, non-Annex I emissions in several regions (Latin America, the Middle East, East Asia, and centrally planned Asia) would need to be substantially reduced below Business-as-usual" are projected non-Annex I emissions in the absence of any new policies to control emissions. Projections indicated that by 2050, emissions in all non-Annex I regions would need to be substantially reduced below business-as-usual.

Conference of the Parties

DF3 Session Kyoto Protocol Panelists

The official meeting of all states party to the Kyoto Protocol. It serves as the formal meeting of UNFCCC. Parties to the Convention may participate in Protocol-related meetings either as parties to the Protocol or as observers.

The first conference was held in 1995 in Berlin. The first Meeting of Parties of the Kyoto Protocol (CMP) was held in 2005 in conjunction with COP 11. The 2013 conference was held in Warsaw. Later COPs were held in Lima, Peru, in 2014 and in Paris, France, in 2015. The 2015 event, COP 21, aimed to hold the global average rise in temperature below 2° degrees Celsius. COP 22 was planned for Marrakesh, Morocco and COP 23 for Bonn, Germany.

Amendment and successor

In the non-binding "Washington Declaration" agreed on 16 February 2007, heads of governments from Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, the United States, Brazil, China, India, Mexico and South Africa agreed in principle on the outline of a successor to the Kyoto Protocol. They envisaged a global cap-and-trade system that would apply to both industrialized nations and developing countries, and initially hoped that it would be in place by 2009.

The United Nations Climate Change Conference in Copenhagen in December 2009 was one of the annual series of UN meetings that followed the 1992 Earth Summit in Rio. In 1997 the talks led to the Kyoto Protocol, and the conference in Copenhagen was considered to be the opportunity to agree on a successor to Kyoto that would bring about meaningful carbon cuts.

The 2010 Cancún agreements include voluntary pledges made by 76 developed and developing countries to control their emissions of greenhouse gases. [155] In 2010, these 76 countries were collectively responsible for 85% of annual global emissions.

By May 2012, the US, Japan, Russia, and Canada had indicated they would not sign up to a second Kyoto commitment period. In November 2012, Australia confirmed it would participate in a second commitment period under the Kyoto Protocol and New Zealand confirmed that it would not.

New Zealand's climate minister Tim Groser said the 15-year-old Kyoto Protocol was outdated, and that New Zealand was "ahead of the curve" in looking for a replacement that would include developing nations.[159] Non-profit environmental organizations such as the World Wildlife Fund criticized New Zealand's decision to pull out.

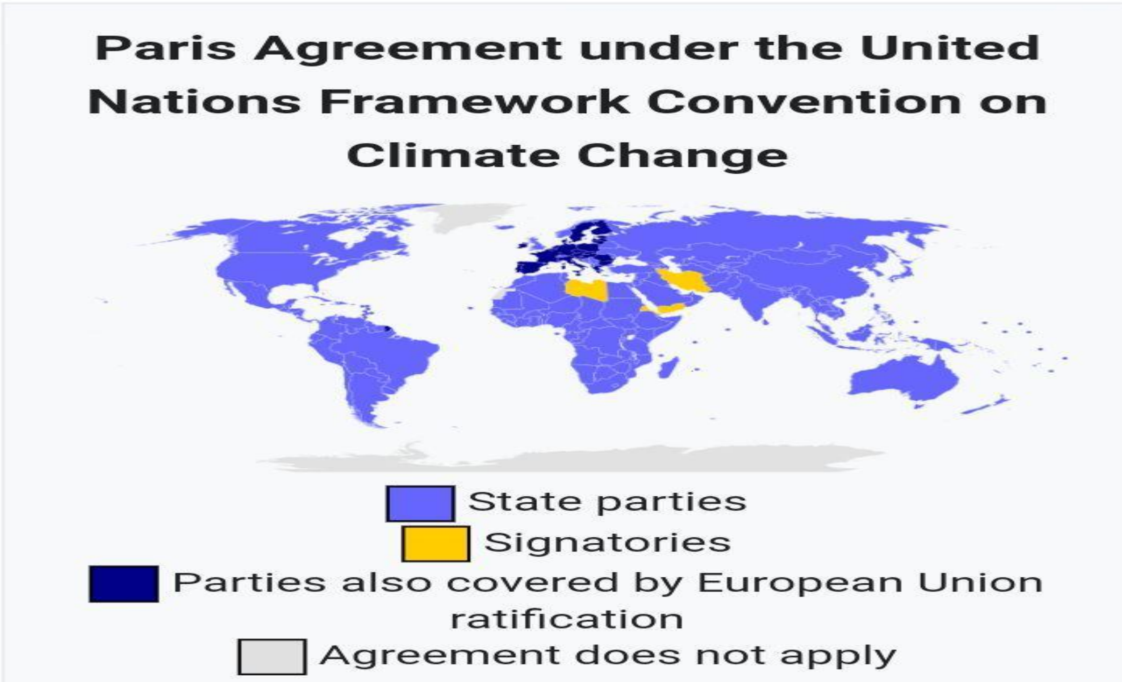
On 8 December 2012, at the end of the 2012 United Nations Climate Change Conference, an agreement was reached to extend the Protocol to 2020 and to set a date of 2015 for the development of a successor document, to be implemented from 2020 (see lede for more information).The outcome of the Doha talks has received a mixed response, with small island states critical of the overall package. The Kyoto second commitment period applies to about 11% of annual global emissions of greenhouse gasses. Other results of the conference include a timetable for a global agreement to be adopted by 2015 which includes all countries. At the Doha meeting of the parties to the UNFCCC on 8 December 2012, the European Union chief climate negotiator, ArturRunge-Metzger, pledged to extend the treaty, binding on the 27 European Member States, up to the year 2020 pending an internal ratification procedure.

Ban Ki Moon, Secretary General of the United Nations, called on world leaders to come to an agreement on halting global warming during the 69th Session of the UN General Assembly on 23 September 2014 in New York. The next climate summit was held in Paris in 2015, out of which emerged the Paris Agreement, the successor to the Kyoto Protocol.

12.8. Paris agreement

The Paris Agreement (French: Accord de Paris), often referred to as the Paris Accords or the Paris Climate Accords, is an international treaty on climate change. Adopted in 2015, the agreement covers climate change mitigation, adaptation, and finance. The Paris Agreement was negotiated by 196 parties at the 2015 United Nations Climate Change Conference in Paris, France. In February 2023, the 195 members of the United Nations Framework Convention on

Climate Change (UNFCCC) are parties to the agreement. Of the four UNFCCC member states only major emitter Iran have not ratified the agreement. The United States withdrew from the agreement in 2020, but rejoined in 2021.



The Paris Agreement was opened for signature on 22 April 2016 (Earth Day) at a ceremony in New York. After the European Union ratified the agreement, sufficient countries had ratified the agreement responsible for enough of the world's greenhouse gasses for the agreement to enter into force on 4 November 2016.

The Paris Agreement's long-term temperature goal is to keep the rise in mean global temperature to well below 2 °C (3.6 °F) above pre-industrial levels, and preferably limit the increase to 1.5 °C (2.7 °F), recognizing that this would substantially reduce the effects of climate change. Emissions should be reduced as soon as possible and reach net-zero by the middle of the 21st century.[3] To stay below 1.5 °C of global warming, emissions need to be cut by roughly 50% by 2030. This is an aggregate of each country's nationally determined contributions.

It aims to help countries adapt to climate change effects, and mobilize enough finance. Under the agreement, each country must determine, plan, and regularly report on its contributions. No mechanism forces a country to set specific emissions targets, but each target should go beyond previous targets. In contrast to the 1997 Kyoto Protocol, the distinction between developed and developing countries is blurred, so that the latter also have to submit plans for emission reductions. The agreement was lauded by world leaders, but criticized as insufficiently binding by some environmentalists and analysts. There is debate about the effectiveness of the agreement. While current pledges under the Paris Agreement are insufficient for reaching the set temperature goals, there is a mechanism of increased ambition. The Paris Agreement has been successfully used in climate litigation forcing countries and an oil company to strengthen climate action. On 4 July 2022, the Supreme Federal Court of Brazil recognized the Paris agreement as a human rights treaty.

Development

Heads of delegations at the 2015 United Nations Climate Change Conference in Paris

Lead-up

The UN Framework Convention on Climate Change (UNFCCC), adopted at the 1992 Earth Summit is one of the first international treaties on the topic. It stipulates that parties should meet regularly to address climate change. It forms the foundation to future climate agreements.

The Kyoto Protocol, regulated greenhouse gas reductions for a limited set of countries from 2008 to 2012. The protocol was extended until 2020 with the Doha Amendment in 2012. The United States decided not to ratify the Protocol, mainly because of its legally-binding nature. This, and distributional conflict, led to failures of subsequent international climate negotiations. The 2009 negotiations were intended to produce a successor treaty of Kyoto, but the negotiations collapsed and the resulting Copenhagen Accord was not legally binding and did not get adopted universally.

The Accord did lay the framework for the bottom-up approach of the Paris Agreement. Under the leadership of UNFCCC executive secretary Christiana Figure. The negotiations regained momentum after Copenhagen's failure. During the 2011, United Nations Climate Change Conference, the Durban Platform was established to negotiate a legal instrument governing climate change mitigation measures from 2020. The platform had a mandate to be informed by the Fifth Assessment Report of the IPCC and the work of the subsidiary bodies of the UNFCCC. The resulting agreement was to be adopted in 2015.

Negotiations and adoption

Negotiations in Paris took place over a two-week span, and continued throughout the three final nights. Various drafts and proposals had been debated and streamlined in the preceding year. According to one commentator, two ways, firstly to ensure that INDCs were completed before the start of the negotiations, and secondly to invite leaders just for the beginning of the conference.

The negotiations almost failed. But the French solved the problem by changing the “typographical error". At the conclusion of COP21 (the 21st meeting of the Conference of the Parties), on 12 December 2015, the final wording of the Paris Agreement was adopted by consensus by the 195 UNFCCC participating member states and the European Union. Nicaragua indicated they had wanted to object to the adoption as they denounced the weakness of the agreement, but were not given a chance. In the agreement the members promised to reduce their carbon output "as soon as possible" and to do their best to keep global warming "to well below 2° degrees C" (3.6 °F).

Signing and entry into force

The Paris Agreement was open for signature by states and regional economic integration organizations that are parties to the UNFCCC (the convention) from 22 April 2016 to 21 April 2017 at the UN Headquarters in New York. Signing of the agreement is the first step towards ratification, but it is possible to accede to the agreement without signing. It binds parties not to act in contravention of the goal of the treaty. On 1 April 2016, the United States and China, which represent almost 40% of global emissions, confirmed they would sign the Paris Climate Agreement. The agreement was signed by 175 parties (174 states and the European Union) on the first day when it was opened for signature. As on March 2021, 194 states and the European Union have signed the agreement.

Signing by John Kerry in United Nations General Assembly Hall for the United States

The agreement would enter into force (and thus become fully effective) if 55 countries that produce at least 55% of the world's greenhouse gas emissions (according to a list produced in 2015) ratify or otherwise join the treaty. Alternative ways to join the treaty are acceptance, approval or accession. The first two are typically used when a head of state is not necessary to bind a country to a treaty, whereas the later.

Typically happens when a country joins a treaty already in force. After ratification by the European Union, the agreement obtained enough parties to enter into effect on 4 November 2016.

Both the EU and its member states are individually responsible for ratifying the Paris Agreement. A strong preference was reported that the EU and its 28 member states ratify at the same time to ensure that they do not engage themselves to fulfilling obligations that strictly belong to the other. There were fears by observers that disagreement over each member state's share of the EU-wide reduction target, as well as Britain's vote to leave the EU might delay the

Paris pact. However, the EU deposited its instruments of ratification on 5 October 2016, along with seven EU member states.

Parties

The EU and 194 states, totaling over 98% of anthropogenic emissions, have ratified or acceded to the agreement. The only countries which have not ratified are some greenhouse gas emitters in the Middle East: Iran with 2% of the world total being the largest. Libya and Yemen have also not ratified the agreement. Eritrea is the latest country to ratify the agreement, on 7 February 2023.

Article 28 enables parties to withdraw from the agreement after sending a withdrawal notification to the depositary. Notice can be given no earlier than three years after the agreement goes into force for the country. Withdrawal is effective one year after the depositary is notified.

United States withdrawal and remittance

On 4 August 2017, the Trump administration delivered an official notice to the United Nations that the United States, the second largest emitter of greenhouse gasses after China, intended to withdraw from the Paris Agreement as soon as it was eligible to do so. The notice of withdrawal could not be submitted until the agreement was in force for three years for the US, on 4 November 2019. The U.S. government deposited the notification with the Secretary General of the United Nations and officially withdrew one year later on 4 November 2020.President Joe Biden signed an executive order on his first day in office, 20 January 2021, to re-admit the United States into the Paris Agreement. Following the 30-day period set by Article 21.3, the U.S. was readmitted to the agreement.United States Climate Envoy, John Kerry took part in virtual events, saying that the US would "earn its way back" into legitimacy in the Paris process. United Nations Secretary-General António Guterres welcomed the return of the United States as restoring the “missing link that weakened the whole".

Content

The Paris Agreement is a short agreement with 16 introductory paragraphs and 29 articles. It contains procedural (e.g. the criteria for entry into force) and operational articles (mitigation, adaptation and finance). It is a binding agreement, but many of its articles do not imply obligations or facilitate international collaboration. It covers most greenhouse gas emissions, but does not apply to international aviation and shipping, which fall under the responsibility of the

International Civil Aviation Organization and the International Maritime Organization, respectively.

Aims:

The aim of the agreement, as described in Article 2, is to have a stronger response to the danger of climate change; it seeks to enhance the implementation of the United Nations Framework Convention on Climate Change through:

a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;

c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

Countries furthermore aim to reach "global peaking of greenhouse gas emissions as soon as possible.

Loss and damage

It is not possible to adapt to all effects of climate change: even in the case of optimal adaptation, severe damage may still occur. The Paris Agreement recognizes loss and damage of this kind. Loss and damage can stem from extreme weather events, or from slow-onset events such as the loss of land to sea level rise for low-lying islands. Previous climate agreements classified loss and damage as a subset of adaptation.

The push to address loss and damage as a distinct issue in the Paris Agreement came from the Alliance of Small Island States and the Least Developed Countries, whose economies and livelihoods are most vulnerable to the negative effects of climate change.The Warsaw Mechanism, established two years earlier during COP19 and set to expire in 2016, categorizes loss and damage as a subset of adaptation, which was unpopular with many countries. It is recognized as a separate pillar of the Paris Agreement.The United States argued against this, possibly worried that classifying the issue as separate from adaptation would create yet another climate finance provision.In the end, the agreement calls for "averting, minimizing, and addressing loss and damage" but specifies that it cannot be used as the basis for liability. The agreement adopts the Warsaw Mechanism, an institution that will attempt to address questions about, how to classify, address, and share responsibility for loss.

Transparency

The parties are legally bound to have their progress tracked by technical expert review to assess achievement toward the NDC and to determine ways to strengthen ambition.Article 13 of the Paris Agreement articulates an "enhanced transparency framework for action and support" that establishes harmonized monitoring, reporting, and verification (MRV) requirements. Both developed and developing nations must report every two years on their mitigation efforts, and all parties will be subject to technical and peer review.

While the enhanced transparency framework is universal, the framework is meant to provide "built-in flexibility" to distinguish between developed and developing countries' capacities. The Paris Agreement has provisions for an enhanced framework for capacity building. It recognizes the varying circumstances of countries, and notes that the technical expert review for each country considers that country's specific capacity for reporting. Parties in agreement, send their first Biennial Transparency Report (BTR), and greenhouse gas inventory figures to the UNFCCC by 2024, after, every two years of that. Developed countries submit their first BTR in 2022 and inventories annually from that year. The agreement also develops a Capacity-Building Initiative for Transparency to assist developing countries in building the necessary institutions and processes for compliance.

Flexibility can be incorporated into the enhanced transparency framework via the scope, level of detail, or frequency of reporting, tiered based on a country's capacity. The requirement for in-country technical reviews could be lifted for some less developed or small island developing countries. Ways to assess capacity include financial and human resources in a country necessary for NDC review.

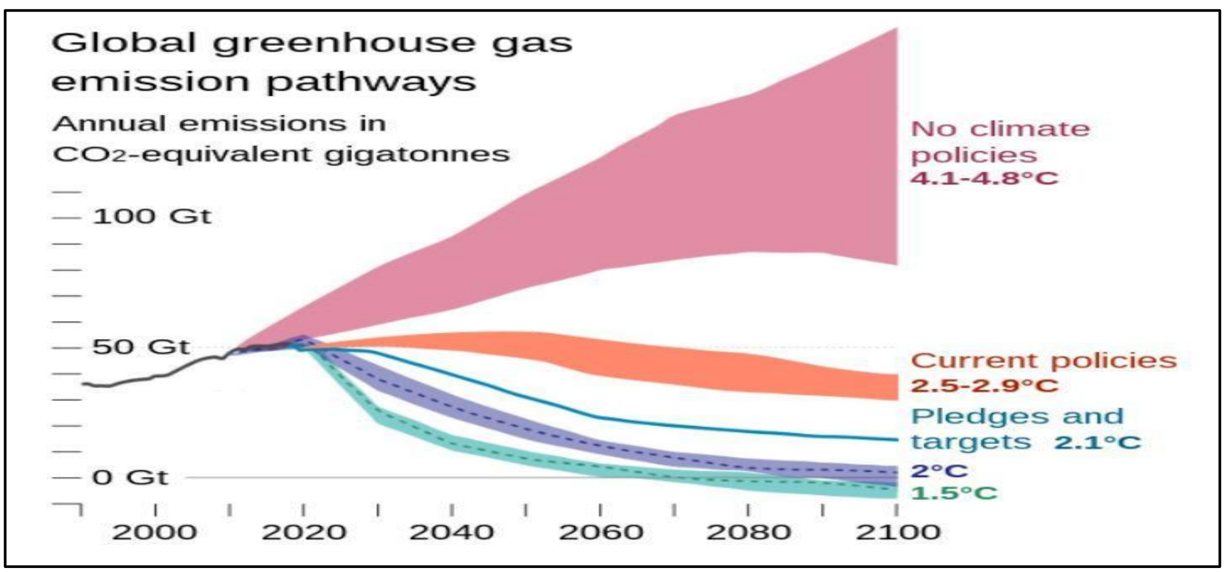
Implementation and effectiveness

The Paris Agreement is implemented via national policy. It would involve improvements to energy efficiency to decrease the energy intensity of the global economy. Implementation also requires fossil fuel burning to be cut back and the share of sustainable energy to grow rapidly. Emissions are being reduced rapidly in the electricity sector, but not in the building, transport and heating sector. Some industries are difficult to decarbonize, and for those carbon dioxide removal may be necessary to achieve net-zero emissions.

To stay below 1.5 °C of global warming, emissions need to be cut by roughly 50% by 2030. This is an aggregate of each country's nationally determined contributions. By mid-century, CO2 emissions would need to be cut to zero, and total greenhouse gasses would be net-zero just after mid-century.

There are barriers to implementing the agreement. Some countries struggle to attract the finance necessary for investments in decarbonization. Climate finance is fragmented, further complicating investments. Another issue is the lack of capabilities in government and other institutions to implement policy. Clean technology and knowledge is often not transferred to countries or places that need it. In December 2020, the former chair of the COP 21, Laurent Fabius, argued that the implementation of the Paris Agreement could be bolstered by the adoption of a Global Pact for the Environment. The latter would define the environmental rights and duties of states, individuals and businesses.

Effectiveness of mitigation



Scenarios of global greenhouse gas emissions.

If all countries achieve their current Paris Agreement pledges, average warming by 2100 would still exceed the maximum 2°C target set by the agreement. The effectiveness of the Paris

Agreement to reach its climate goals is under debate, with most experts saying it is insufficient for its more ambitious goal of keeping global temperature rise under 1.5 °C. Many of the exact provisions of the Paris Agreement have yet to be straightened out, so that it may be too early to judge effectiveness. According to the 2020 United Nations Environment Programme (UNEP), with the current climate commitments of the Paris Agreement, global mean temperatures will likely rise by more than 3 °C by the end of the 21st century. Newer net-zero commitments were not included in the NDCs, and may bring down temperatures a further 0.5 °C.

The initial pledges by countries are inadequate, faster and more expensive future mitigation needed to reach the targets. Furthermore, there is a gap between pledges by countries in their NDCs and implementation and one third of the emission gap between the lowest-costs and actual reductions in emissions would be closed by implementing existing pledges. Studies about Nature found that in 2017, none of the major industrialized nations were implementing the policies they had pledged, and none met their pledged emission reduction targets, and even if they had, the sum of all member pledges (as of 2016) would not keep global temperature rise "well below 2 °C.

In 2021, a study using a probabilistic model concluded that the rates of emissions reductions would have to increase by 80% beyond NDCs and likely to meet the 2 °C upper target of the Paris Agreement. The probabilities of major emitters meeting their NDCs without such an increase is very low. It estimated that with current trends the probability of staying below 2 °C of warming is 5% and 26%, if NDCs were met and continued post-2030 by all signatories.

Effectiveness of capacity building and adaptation

In 2020, there is little scientific literature on the topics of the effectiveness of the Paris Agreement on capacity building and adaptation, even though they feature prominently in the Paris Agreement. The literature available is mostly mixed in its conclusions about loss and damage, and adaptation.

International response

The agreement was lauded by French President François Hollande, UN Secretary General Ban Ki-moon and Christiana Figueres, Executive Secretary of the UNFCCC.The president of Brazil, Dilma Rousseff, called the agreement "balanced and long-lasting", and India's prime minister Narendra Modi commended the agreement's climate justice.When the agreement achieved the required signatures in October 2016, US President Barack Obama said that "Even if we meet every target, we will only get to part of where we need to go."Healso stated "this agreement will help delay or avoid some of the worst consequences of climate change [and] will help other nations ratchet down their emissions over time."

Some environmentalists and analysts reacted cautiously, acknowledging the "spirit of Paris" in bringing together countries, but expressing less optimism about the pace of climate mitigation and how much the agreement could do for poorer countries. James Hansen, a former NASA scientist and leading climate change expert, voiced anger that most of the agreement consists of "promises" or aims and not firm commitments and called the Paris talks a fraud with "no action, just promises".Criticism of the agreement from those arguing against climate action has been diffuse, which may be due to the weakness of the agreement. This type of criticism typically focuses on national sovereignty and ineffectiveness of international action.

LitigationThe Paris Agreement has become a focal point of climate change litigation. One of the first major cases in this area was State of the Netherlands v. Urgenda Foundation, which was raised against the Netherlands' government after it had reduced its planned emissions reductions goal for 2030 prior to the Paris Agreement. After an initial ruling against the government in 2015 that required it to maintain its planned reduction, the decision was upheld on appeals through the Supreme Court of the Netherlands in 2019, ruling that the Dutch government failed to uphold human rights under Dutch law and the European Convention on Human Rights by lowering its emission targets. The 2 °C temperature target of the Paris Agreement provided part of the judgment's legal basis. The agreement, whose goals are enshrined in German law, also formed part of the argumentation in Neubauer et al. v. Germany, where the court ordered Germany to reconsider its climate targets.

In May 2021, the district court of The Hague ruled against oil company Royal Dutch Shell in Milieudefensie et. al. V Royal Dutch Shell. The court ruled that it must cut its global emissions by 45% from 2019 levels by 2030, as it was in violation of human rights. This lawsuit was considered the first major application of the Paris Agreement towards a corporation.

Paris agreement as a human rights issue

On 4 July 2022, the Supreme Federal Court of Brazil recognized the Paris agreement as a "human's right treaty". According to the ruling of the court in Brazil it should "supersede national law". In the same month the United Nations Human Rights Council in a resolution "(A/HRC/50/L.10/Rev.1) on Human rights and climate change, adopted without a vote" called to ratify and implement the agreement and emphasized the link between stopping climate change and the right to food. The Office of the United Nations High Commissioner for Human Rights officially recognized that "Climate change threatens the effective enjoyment of a range of human rights including those to life, water and sanitation, food, health, housing, self-determination, culture and development.

12.9. Summary

The IPCC prepares comprehensive Assessment Reports about the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place. It also produces Special Reports on topics agreed to by its member governments, as well as Methodology Reports that provide guidelines for the preparation of greenhouse gas inventories. According to India, A “mere decision of the Council” to take over enforcement of climate change action would disrupt the Paris Agreement and multilateral efforts to find solutions. Climate change is a global threat to security in the 21st century. We must act now to limit future risks to the planet we share and the peace we seek. With global **warming of 1.1°C,** some impacts of climate change are already locked in, causing disruptions in the lives of billions of people. India, which has almost all the world’s agro-ecological zones, is not spared.

12.10. Terminal questions

Q.1. What is Indian plannel of climate change and how it work.

Answer:--

Q.2. What is Climate Change; discuss the role of Indian pannel of climate change to reduce climate change.

Answer:--

Q.3. Discuss about sustainable development submit.

Answer: --

Q.4. Discuss the policies and program of Kyoto protocol.

Answer: --

Q.5. Discuss about national action plan on climate change.

Answer: --

12.11. Further suggested readings

1. Environmental Science, Subhas Chandra Santra, new central book agency, 3rd Edition, 2011
2. Non-conventional Energy Resources, D.S. Chauhan, New Age International.
3. Renewal Energy Technologies: A Practical Guide for Beginners, C.S. Solanki, PHI Learning.
4. Advances in Energy System and Technology, Peter Auer, Vol. 1 & II Edited by Academic Press.
5. Godfrey, Renewable Energy Power fora Sustainable Future, Boyle, Oxford University Press.