

Concept of Climate Change

- The balance between incoming energy from the sun and outgoing energy from Earth ultimately drives our climate.
- This energy balance is governed by the first law of thermodynamics, also known as the law of conservation of energy.
- This law states that energy can be transferred from one system to another in many forms, but it cannot be created or destroyed.
- Therefore, any energy “lost” during one process will equal the same amount of energy “gained” during another.

Climate change

- Climate change is a change in the usual weather found in a place.
- It could be a change in any of the following factors
 - Temperature
 - Pressure
 - Humidity
 - Rainfall
 - Wind

- The Earth's climate has changed throughout history.
- Just in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7,000 years ago.
- It marked the beginning of the modern climate era— and of human civilization.
- Most of these climate changes are attributed to very small variations in Earth's orbit that change the amount of solar energy our planet receives.

Causes of climate change

- There is an energy balance in the atmosphere which maintains the climate on Earth.
- When averaged over the course of a year, the amount of incoming solar radiation received from the sun has balanced the amount of outgoing energy emitted from Earth. This equilibrium is called Earth's energy or radiation balance.
- When this energy balance is disrupted, it causes a change in the climate.

- Any factor that causes a change to Earth's energy balance is known as a radiative forcing or a forcing.
- A positive forcing, such as that produced by increasing concentrations of greenhouse gases, tends to warm the Earth's surface.
- A negative forcing, such as that produced by airborne particulates that reflect solar energy, tends to cool the Earth's surface.

- Forcings may also be either
 - natural- or
 - human-caused (also known as anthropogenic)

Natural Causes of climate change

The natural causes of climate change are

- Continental drift and plate tectonics
- Sunspot and solar cycle
- Volcanoes
- Forest fires
- Earth's tilt
- Comets and Meteorites

Continental drift and plate tectonics

- The continents had a different arrangement hundreds of million years ago.
- Landmass or more specifically plates have been in continuous movement and have been gradually drifting apart due to plate tectonics.
- This drift also had an impact on the climate.
- Drift changed the position and physical features of the landmass, the position of water bodies, the flow of ocean currents and winds, which in turn affected the global climate.
- The drift process is still continued today as seen in the Himalayas rising by about 1 cm every year.

➤ **Sunspot and solar cycle**

- Sunspots are storms on the sun's surface that cause intense magnetic activity, solar flares and hot gassy ejections from the sun's corona.
- It affects atmospheric phenomena on Earth, such as cloud cover.
- But these changes in the solar energy output are considered very small to explain major changes in our climate in a short duration of recent decades.

Volcanoes

- Volcanic eruption causes outburst of gases and dust particles which block the incoming rays of the Sun.
- The blockage of insolation causes cooling of the weather.
- The optical properties of SO_2 and sulfate aerosols, which strongly absorb or scatter solar radiation, create a global layer of sulfuric acid haze.
- The eruption of Mount Pinatubo (Philippines) in 1991 decreased global temperatures decreased by about 0.5°C for up to three years
- Although the volcanic activity may last only a few days yet the large volumes of gases and ash can influence the climatic pattern over the several years.

Forest fires

- Wildfires, which are intensified by global warming, also exacerbate global warming.
- Forest fires produce a lot of smoke which carries soot particles that increase the greenhouse effect in the atmosphere.
- Black carbon, a component of soot, absorbs heat in the atmosphere and hastens snowmelt when it lands on snow.
- While forests and healthy soil normally absorb carbon dioxide, fires cause the release of carbon dioxide from vegetation and soil into the atmosphere, trapping ever more heat.

Comets and meteorites

- Meteorites striking Earth also affect sea level, rainfall, temperature, ocean currents, and atmospheric circulation.
- An impact from a body of the size of meteorites would have released huge quantities of vaporised material into the atmosphere, blocking out the Sun and causing an initial "impact winter".
- In addition, chemical reactions taking place in the atmosphere between pollutants would result in the formation of globally distributed acid rains.
- Luckily such impacts only occur rarely, perhaps every few million or tens of millions of years.

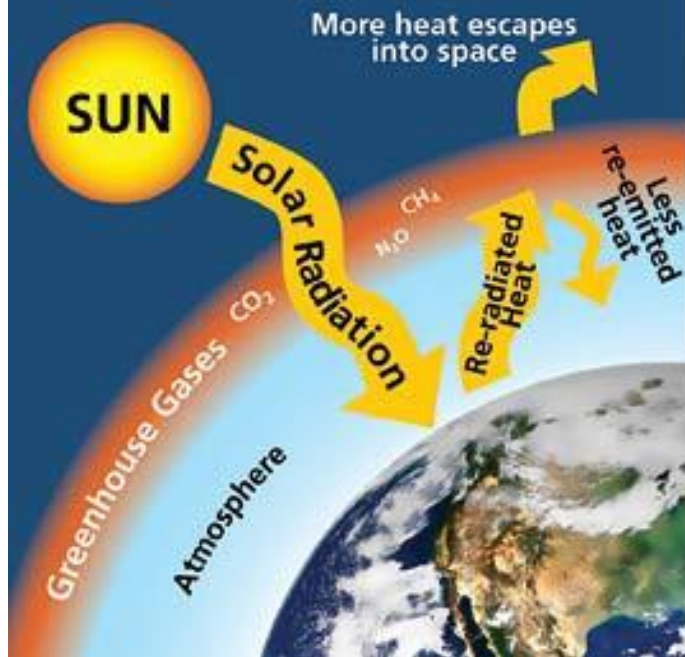
Anthropogenic causes

- The most important anthropogenic cause for climate change is attributed to global warming trend observed since the mid-20th century.
- According to most climate scientists the chief cause of the current global warming trend is the increase in the "greenhouse effect".

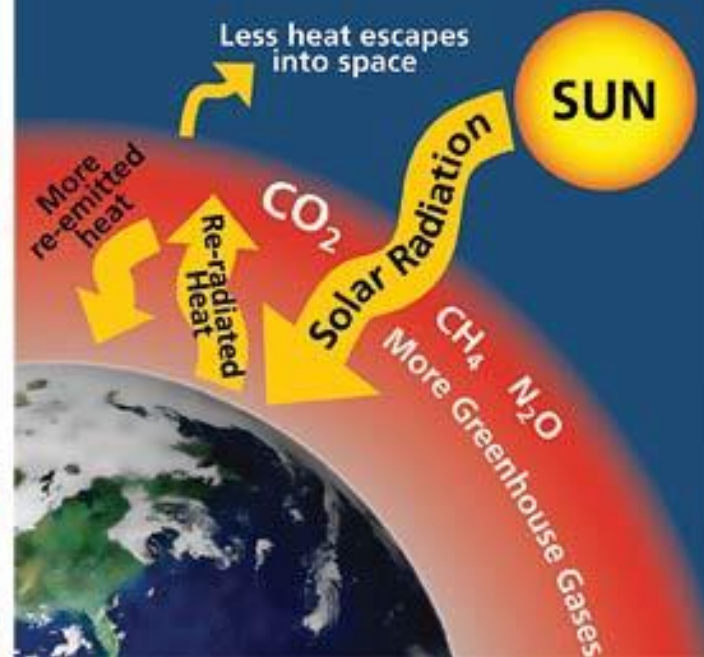
Greenhouse effect

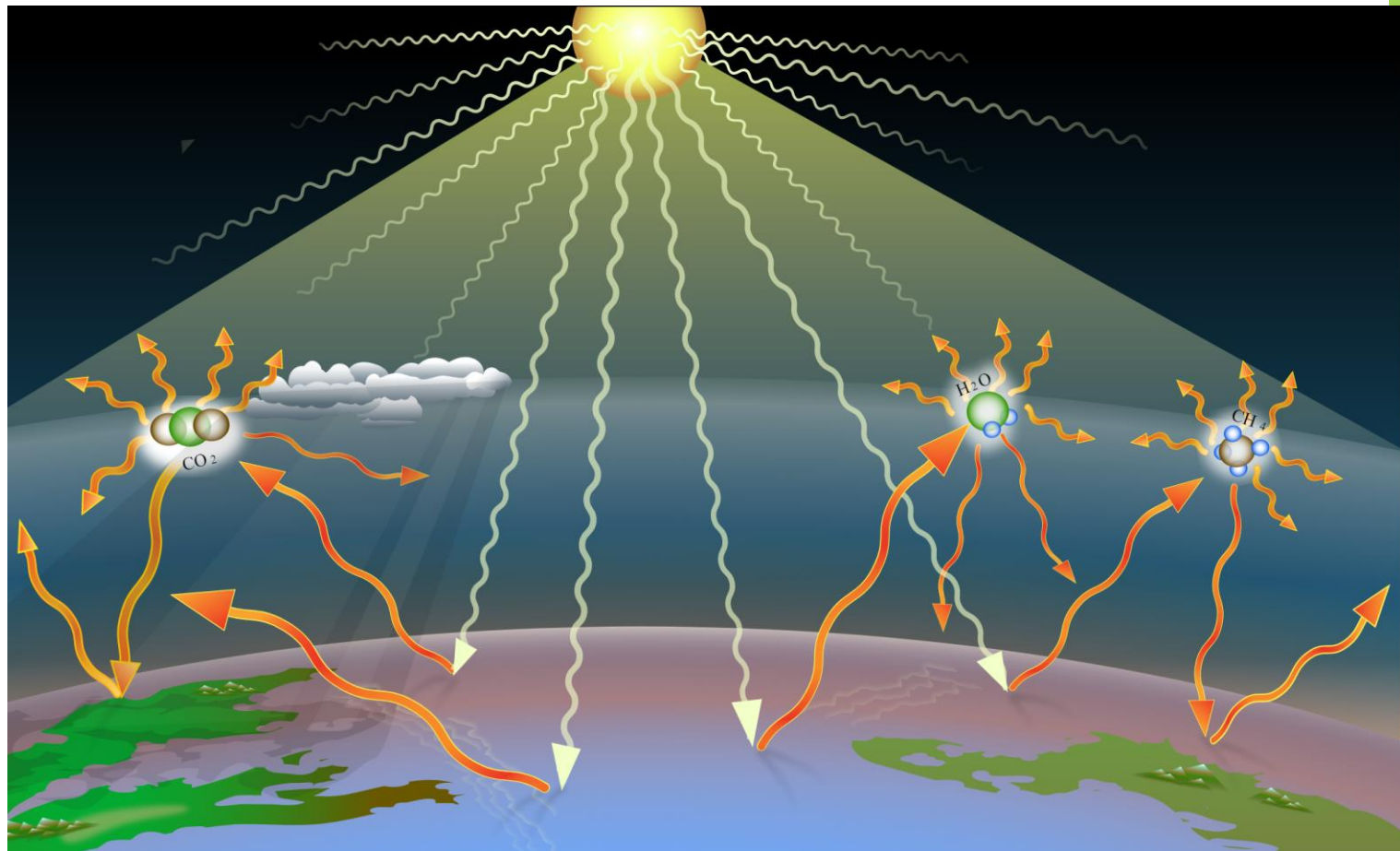
- Earth is sometimes called the “Goldilocks” planet – it’s not too hot, not too cold, and the conditions are just right to allow life, including us, to flourish.
- Part of what makes Earth so amenable is the naturally-arising greenhouse effect, which keeps the planet at a friendly 15 °C (59 °F) on average.
- A greenhouse effect is the effect produced by a greenhouse.

Natural Greenhouse Effect



Human Enhanced Greenhouse Effect





- A greenhouse is a building with glass walls and a glass roof.
- Greenhouses are used to grow plants, such as tomatoes and tropical flowers in cold areas.
- A greenhouse stays warm inside, even during the winter.
- In the daytime, sunlight shines into the greenhouse and warms the plants and air inside.
- At nighttime, it's colder outside, but the greenhouse stays pretty warm inside. That's because the glass walls of the greenhouse trap the Sun's heat.

- The greenhouse effect is produced the same way on Earth as a whole.
- Earth acts like the building and the gases in the atmosphere acts like the glass in the greenhouse.
- The gases in the atmosphere trap the heat of the Sun's rays within them to keep the Earth warm.
- These heat trapping gases in the atmosphere are called greenhouse gases.

How greenhouse effect works?

- The sun's high temperature causes it to emit solar radiation of mostly shorter wavelengths.
- Therefore, incoming solar energy from the sun primarily consist of shorter wavelengths of energy, mostly in the visible part of the electromagnetic spectrum.
- The sun's visible wavelengths of radiation pass easily through the atmosphere and reach Earth.
- Approximately 51% of this sunlight is absorbed at Earth's surface by the land, water, and vegetation.

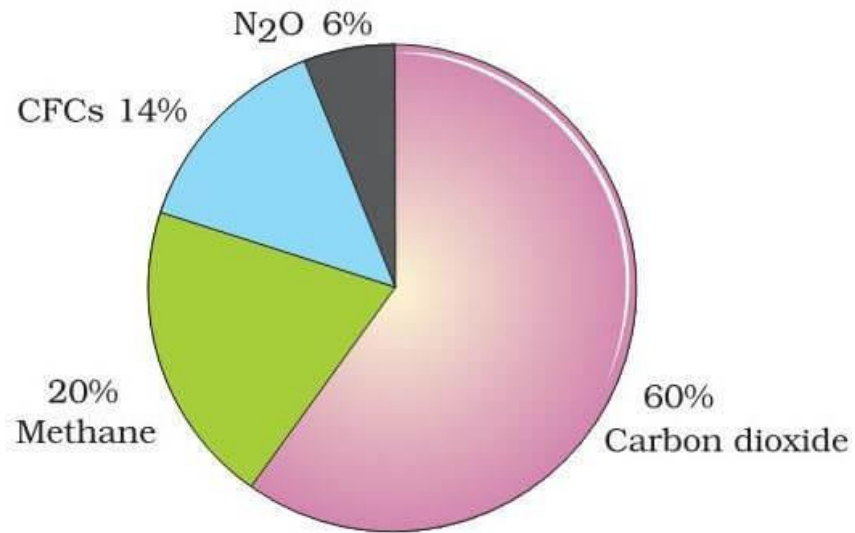
- Some of this energy is emitted back from the Earth's surface in the form of infrared radiation.
- Because Earth is colder than the sun, it emits radiation at much longer wavelengths (in the infrared part of the spectrum).
- Water vapor, carbon dioxide, methane, and other trace gases in Earth's atmosphere absorb the longer wavelengths of outgoing infrared radiation from Earth's surface.

- These gases then emit the infrared radiation in all directions, both outward toward space and downward toward Earth.
- This process creates a second source of radiation to warm to surface— visible radiation from the sun and infrared radiation from the atmosphere – which causes Earth to be warmer than it otherwise would be.
- This process is known as the natural greenhouse effect and keeps Earth's average global temperature at approximately 15°C (59°F).
- Without the greenhouse effect, Earth's average surface temperature would be only about -18 °C and the earth would have been a frozen, barren planet.

Why do greenhouse gases absorb heat?

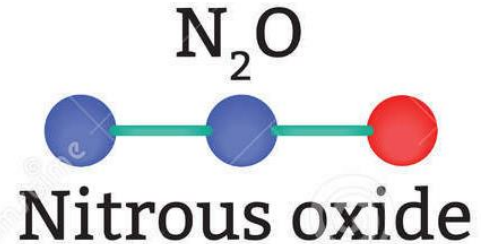
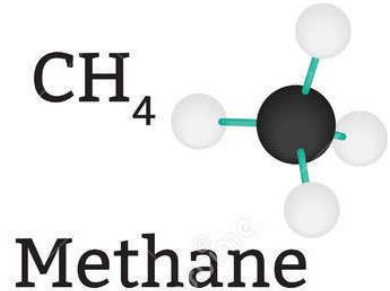
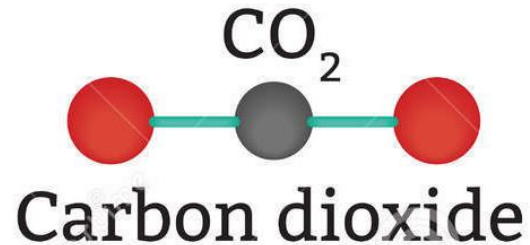
- Greenhouse gases are more complex than other gas molecules in the atmosphere.
- They have a structure which enables them to trap heat.
- There are several different types of greenhouse gases.
- The major ones are carbon dioxide, water vapor, methane, and nitrous oxide. These gas molecules all are made of three or more atoms.
- **The atoms are held together loosely enough that they vibrate when they absorb heat.**

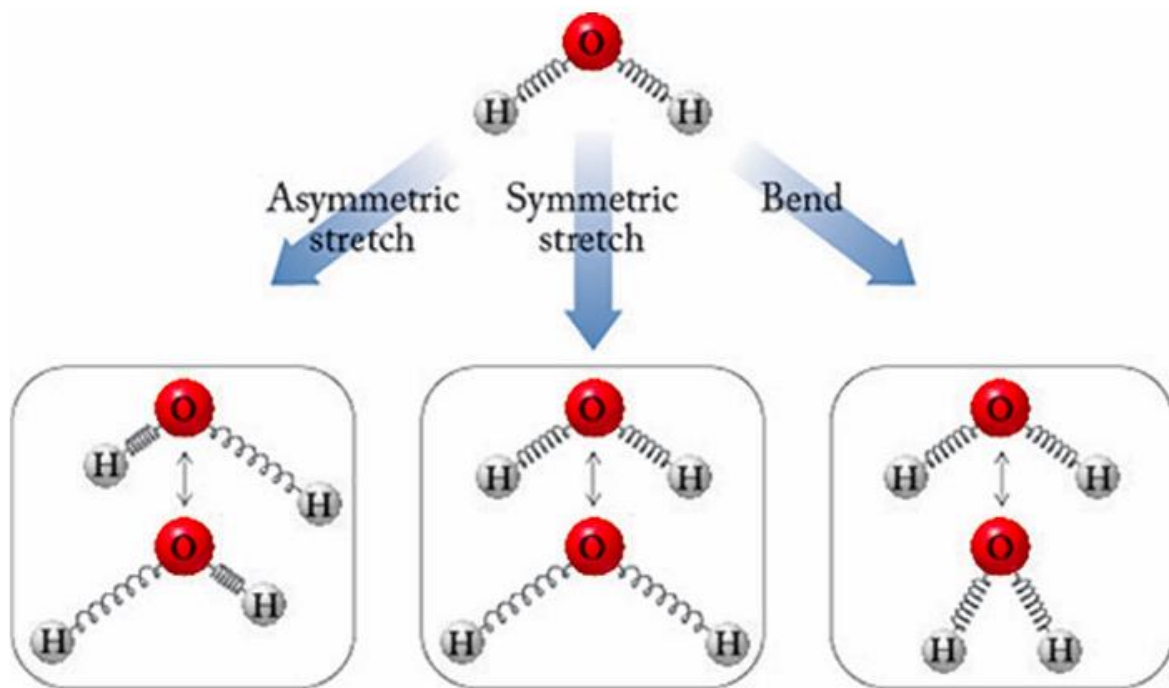
- Eventually, the vibrating molecules release the radiation, which will likely be absorbed by another greenhouse gas molecule.
 - This process keeps heat near the Earth's surface.
 - Most of the gas in the atmosphere is nitrogen and oxygen – both of which are molecules made of two atoms.
 - The atoms in these molecules are bound together tightly and unable to vibrate, so they cannot absorb heat and contribute to the greenhouse effect.
- If greenhouse gases are not checked, by the turn of the century the temperature may rise by 5°C.



Relative contribution of various greenhouse gases to total global warming

Greenhouse effect molecules





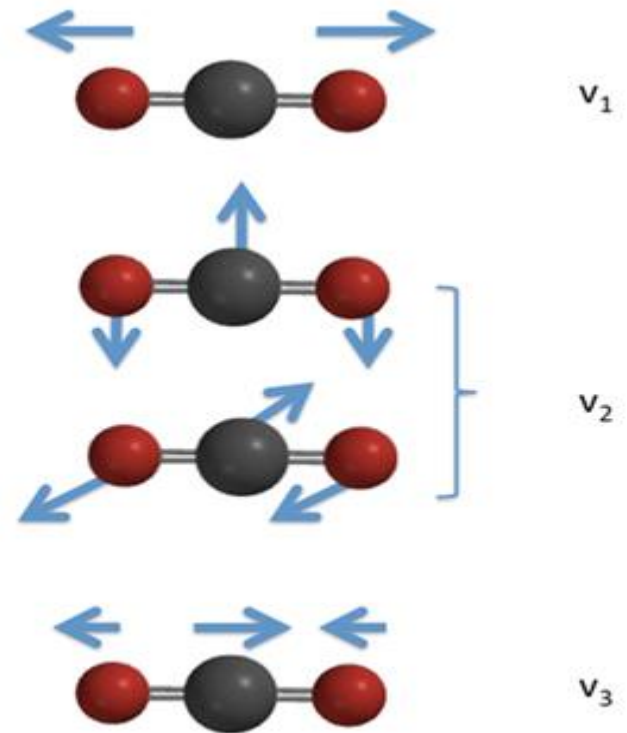


Fig. 1 Vibrational modes

Carbon dioxide

- Primary GHG.
- It is released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels.
- It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface. It is **largely responsible for the greenhouse effect**
- Humans have increased atmospheric CO₂ concentration by more than a third since the Industrial Revolution began.
- It is still increasing gradually due to industrialisation and urbanisation.
- This is the most important long-lived "forcing" of climate change.

- **Ozone**

- Ozone is another important greenhouse gas. But it is in **very small proportions at the surface**.
- Most of it is confined to the **stratosphere** where it **absorbs the harmful UV radiation**.
- At ground level, pollutants like **NO₂ react with volatile organic compounds** in the **presence of sunlight** to **produce ozone (tropospheric ozone)**.

- **Water vapour**

- Water vapour is also a variable gas in the atmosphere, which decreases with altitude.
- Water vapour also decreases from the equator towards the poles.
- In the warm and wet tropics, it may account for **four per cent** of the air by volume, while in the dry and cold areas of desert and polar regions, it may be less than one per cent of the air.
- One unique feature about this greenhouse gas is that it **absorbs both incoming (a part of incoming) and outgoing solar radiation**.

- **Methane**

- Methane is the **most important greenhouse gas after carbon dioxide**.
- It is produced from **decomposition of animal wastes and biological matter**.
- The emission of this gas can be restricted by using animal wastes and biological matter to produce **gobar gas (methane)**.

- A hydrocarbon gas produced both through natural sources and human activities.
- Natural sources include wetlands, digestion of livestock, oceans, volcanoes and wildfires.
- Human activities include decomposition of wastes in landfills, agriculture, and especially rice cultivation, manure management associated with domestic livestock, natural gas industry, etc.
- It is 20 times more potent as a GHG than CO₂ but has a short lifespan.

- **Nitrous Oxide (N₂O)**

- **N₂O or Nitrous Oxide is a greenhouse gas.**
- **NO and NO₂** (nitric oxide or nitrogen oxide and nitrogen dioxide) emissions cause **global cooling.**

- Source: Nitrogen fixation, fertilizers in agriculture, fossil fuel combustion, wastewater management, and industrial processes.
- It is even more potent than methane as a GHG (300 times than CO₂).

- **Carbon Monoxide**

- Carbon monoxide is a **short-lived greenhouse gas (it is less dense than air)**.
- Through natural processes in the atmosphere, it is eventually **oxidized to carbon dioxide**.

Fluorinated gases:

- Source: Industrial processes such as aluminum and semiconductor manufacturing, substitute for ODS (Ozone Depleting Substances) in products like refrigerators, air-conditioners, foams and aerosol cans.
- Four types: Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆) and nitrogen trifluoride (NF₃).
- They have very high GWP (Global Warming Potential).

- **Fluorinated gases**
 - **Chlorofluorocarbons (CFCs)**
 - This anthropogenic compound is also a greenhouse gas, with a much **higher potential to enhance the greenhouse effect** than CO₂.

- **Hydrofluorocarbons**

- Hydrofluorocarbons are used as **refrigerants, aerosol propellants, solvents, and fire retardants**.
- These chemicals were developed as a **replacement for chlorofluorocarbons (CFCs)**.
- Unfortunately, HFCs are potent greenhouse gases with **long atmospheric lifetimes**.

- Perfluorocarbons produced in aluminum and semiconductor industries have even longer atmospheric lifetimes and high GWPs.
- Sulfur hexafluoride has a GWP of 22,800, making it the most potent greenhouse gas designated by the Intergovernmental Panel on Climate Change.

- **Perfluorocarbons**

- Perfluorocarbons are compounds produced as a **by-product in aluminium production** and the **manufacturing of semiconductors**.
- Like HFCs, PFCs generally have **long atmospheric lifetimes** and **high global warming potential**.

- **Sulphur hexafluoride**

- Sulphur hexafluoride is also a greenhouse gas.
- Sulphur hexafluoride is used in **magnesium processing and semiconductor manufacturing**, as well as a **tracer gas for leak detection**.
- Sulphur hexafluoride is used in electrical transmission equipment, including circuit breakers.

- **Black Carbon or Soot**

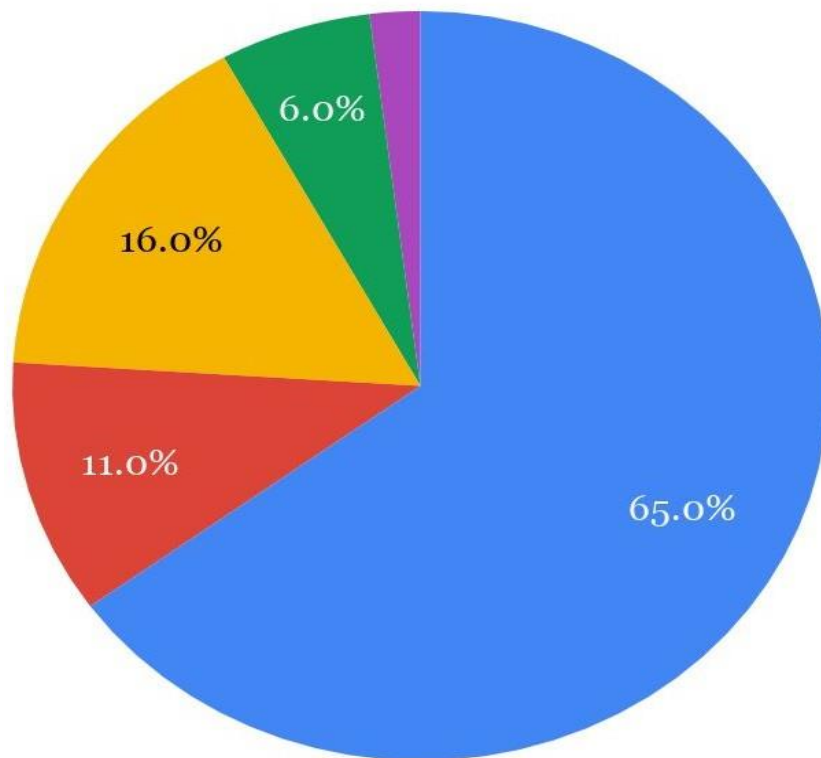
- Black carbon (BC) is a solid particle or aerosol (though not a gas) that contributes to warming of the atmosphere. Black carbon, commonly known as soot.
- Soot is a form of **particulate air pollutant**, produced from **incomplete combustion**.
- Black carbon warms the earth by absorbing heat in the atmosphere and by **reducing albedo** (the ability to reflect sunlight) when deposited on snow and ice.
- BC is the **strongest absorber of sunlight and heats the air directly**.
- In addition, it darkens snow packs and glaciers through deposition and leads to melting of ice and snow.
- Regionally, **BC disrupts cloudiness and monsoon rainfall**.
- Black carbon stays in the atmosphere for **only several days to weeks**.
- Thus, the effects of BC on the atmospheric warming and glacier retreat disappear within months of reducing emissions.

- **Brown Carbon**

- Brown carbon is a ubiquitous and unidentified component of organic aerosol.
- Biomass burning (possibly domestic wood burning) is shown to be a major source of brown carbon
- Brown carbon is generally referred for greenhouse gases and black carbon for particles resulting from impure combustion, such as soot and dust.

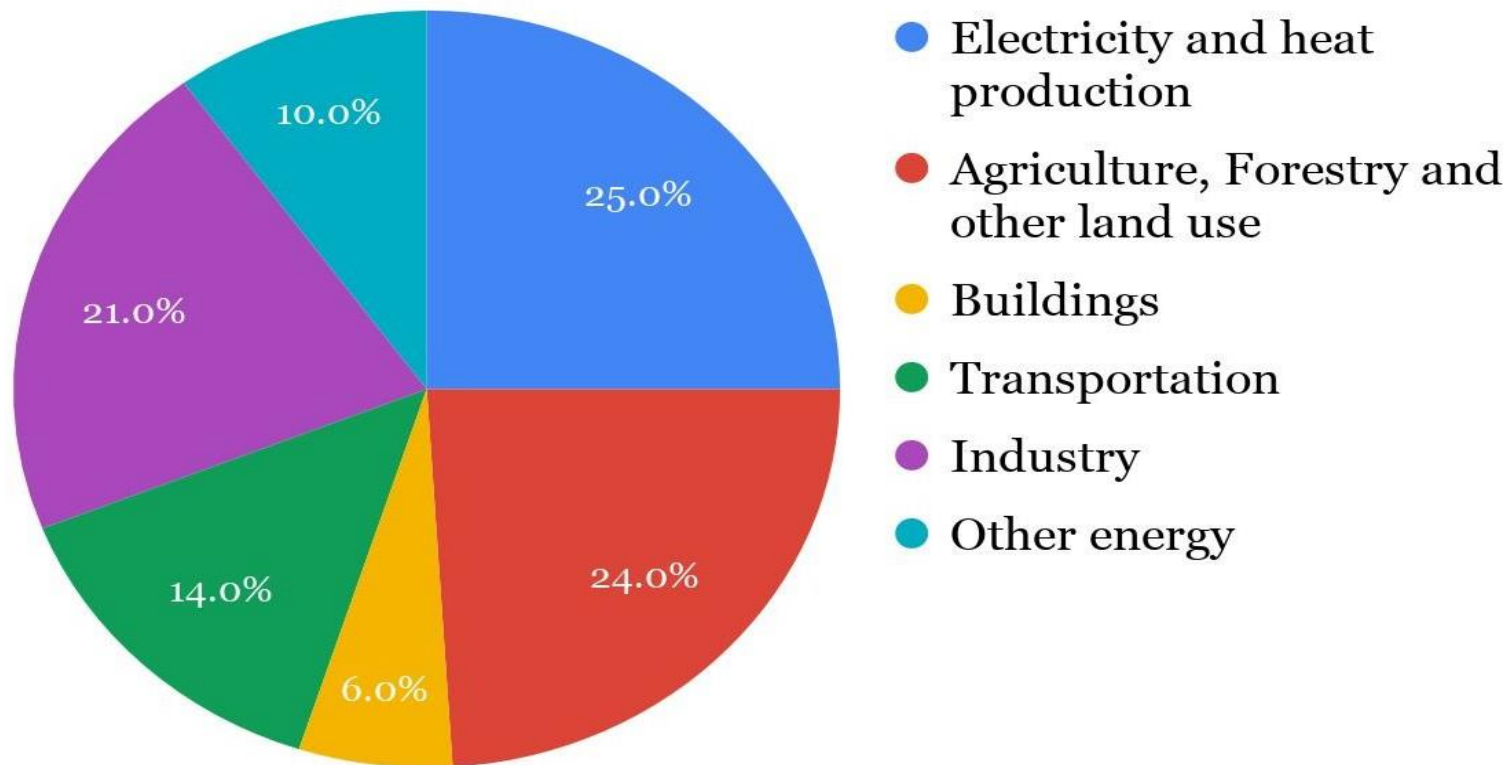
- If the concentration of greenhouse gases increases, then more infrared radiation will be absorbed and emitted back toward Earth's surface, creating an enhanced or amplified greenhouse effect.
- Balance to the energy budget is thus restored when Earth's average global temperature increases.

Global Greenhouse gas emissions

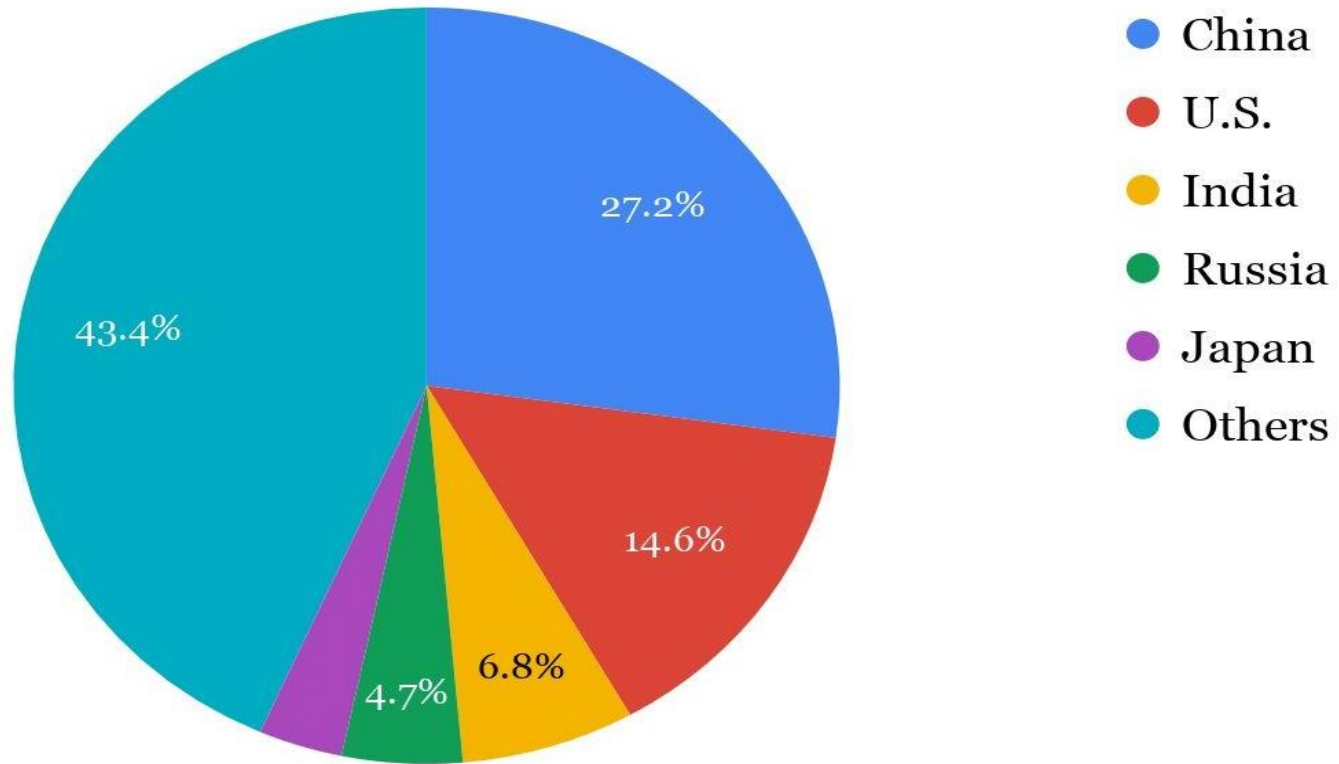


- Carbon dioxide (fossil fuel and industrial processes)
- Carbon dioxide (forestry and other land use)
- Methane
- Nitrous oxide
- F-gases

Global greenhouse gas emissions by sector



Carbon dioxide emissions by country, 2019



- There are huge disparities between the world's top 15 CO₂ emissions-generating countries.
- China creates almost double the emissions of second-placed US, which is in turn responsible for more than twice the level of third-placed India.
- Collectively, the top 15 generate 72% of CO₂ emissions.
- The rest of the world's 180 countries produce nearly 28% of the global total— close to the amount China produces on its own.

- **GHG Protocol**

- GHG Protocol is developing standards, tools and online training that helps countries, cities and companies track progress towards their climate goals.
- GHG Protocol establishes frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions.
- GHG Protocol arose when World Resources Institute (WRI) (NGO US BASED) and World Business Council for Sustainable Development (WBCSD) GENEVA recognized the need for an international standard for **corporate GHG accounting** and reporting in the late 1990s.

Global Warming Potential (GWP)

- GWP is a parameter to measure the amount of heat a GHG traps in the atmosphere.
- In other words, it is a tool to compare the global warming effects of different GHGs.
- Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO₂).

- The time period usually used for GWPs is 100 years.
- GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory).
- It allows policymakers to compare emissions reduction opportunities across sectors and gases.
- The larger the GWP, the more a given GHG warms the Earth compared to CO₂ over that time period (usually 100 years).

Gas	GWP (100-year)	Lifetime (years)
Carbon di oxide	1	50-200
Methane	21	12
Nitrous oxide	310	120
Hydrofluorocarbons (HFCs)	140 -11,700	1-270
Perfluorocarbons (PFCs)	6,500-9,200	800-50,000
Sulphur hexafluoride (SF ₆)	23,900	3,200

The larger the GWP ,the more warming the gas causes.
For ex- methane's 100 year GWP-is 21 which means that methane will cause 21 times as much as an equivalent mass of carbon dioxide over a 100 year time period.

- The effects of climate change can be studied under the following heads
 - Rise in Temperature
 - Melting ice
 - Rise in sea levels
 - Extreme climates
 - Ocean acidification
 - Extreme drought and wildfires
 - Agriculture
 - Ecosystems and societies

Rise in Temperature

- Since the Industrial Revolution, the surface temperature over land has increased more rapidly than that of the oceans.
- This is due to the higher heat capacity of oceans as compared to the land.
- The polar regions have warmed more than the tropical regions. This is happening because, as the brighter ice (with higher albedo and reflectivity) melts, the darker water (with a lower albedo) can absorb more heat and intensify the warming.

Temperature of the Lower Atmosphere

- Measurements from satellites and weather balloons show that the lowest layer of the atmosphere—the layer where we live, airplanes fly, and weather occurs—is warming.
- Greenhouse gases are building up in this layer, trapping heat radiated from Earth's surface and raising the planet's temperature.

Air Temperature over Ocean

- Thermometers on ships and floating buoys show that air near the ocean's surface is getting warmer, increasing its ability to evaporate water.
- In turn, we see an increase in heavy precipitation events and flooding on land.

Air Temperature over Land

- Satellites and weather stations on land show that average air temperature at the surface is going up.
- Consequently, we see an increase in the number of heat wave events and the area affected by drought.

Sea Surface Temperature

- Satellite sensors and thermometers on ships and buoys show that the temperature of water at the ocean's surface is rising.
- Warm surface waters can damage coral reefs, reducing opportunities for fishing and tourism, and leave coasts vulnerable to storm surges and erosion.

- Scientists project global mean temperature to increase by approximately 1°C for the lowest emissions scenario and 4°C for the highest emissions scenario by 2100.
- This projected global mean temperature change for the 21st century will depend on which scenario actually occurs.
- The low emissions scenario assumes that humans will aggressively reduce emissions so that the increase by 2100 is only 2°C higher than pre-industrial levels.
- This 2°C seems to be a critical number for many scientists, including the IPCC.

According to the Intergovernmental Panel on Climate Change (IPCC)

- Warming by 1.5-2 degree celsius would not be the same everywhere on the planet.
- The strongest warming is happening in the Arctic during its cool seasons, and in Earth's mid-latitude regions during the warm season.
- .

- Most land regions will see more hot days, especially in the tropics.
- At 1.5 degrees Celsius warming, about 14 percent of Earth's population will be exposed to severe heat waves at least once every five years, while at 2 degrees warming that number jumps to 37 percent.
- Extreme heat waves will become widespread at 1.5 degrees Celsius warming.
- At Earth's mid-latitudes, the hottest days will be up to 3 degrees Celsius hotter at 1.5 degrees Celsius warming and up to 4 degrees Celsius warmer at 2 degrees Celsius warming.
- At 2 degrees Celsius warming, the deadly heat waves India and Pakistan saw in 2015 may occur annually.

- Arctic land regions will see cold extremes warm by as much as 5.5 degrees Celsius at 1.5 degrees Celsius warming or less, while at warming of 1.5 to 2 degrees Celsius, cold extremes will be up to 8 degrees Celsius warmer.
- Cold spells will also be shorter.

- In the absence of policies, global warming is expected to reach 4.1°C – 4.8°C above pre-industrial by the end of the century.
- Limiting warming to 1.5°C above pre-industrial levels by 2100 means that the emissions of greenhouse gases need to be reduced rapidly in the coming years and decades, and brought to zero around mid-century.

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Melting ice

- Ice and snow still cover 10% of Earth's landmasses and 7% of the oceans.
- Places on Earth where it is so cold that water is in its solid form as snow or ice are known as the cryosphere.
- The cryosphere includes ice and snow (precipitation made of ice crystals) in the form of frozen ground, such as
 - Permafrost
 - Ice sheets, glaciers
 - Sea ice

- In the last 26 years, Greenland's melting ice has added 0.4 inches (11 millimeters) to sea level rise.

- The Antarctic ice sheet contains 90% of the freshwater on Earth.
- If all of this ice on Antarctica melted, global sea level would rise at least 61 meters (200 feet).

Extreme climates

Heat waves

- A heat wave is generally a period of several days to weeks of abnormally hot weather that may or may not be accompanied by high humidity.
- The World Meteorological Organization defines a heat wave as five or more consecutive days of temperatures 5°C (9°F) above the average maximum temperature.
- With an increasing number of hotter days, there have been a greater number of heat waves.

Storm events

- Cyclonic storm events can be some of the most powerful storm events on the planet.
- Scientists say that there will be more tropical cyclones and temperate cyclones with increasing global warming trends.

Water cycle changes - Precipitation and drought

- Earth's water cycle changes in response to natural variability, but scientists are becoming more certain that the human impact of increasing greenhouse gas emissions will cause more changes to the water cycle.
- Evaporation rates will increase with a warmer climate, causing an increase in the amount of moisture in the lower atmosphere.
- With higher water vapor concentrations, there is an increased frequency of intense precipitation events, primarily over land areas.
- In addition, there will be greater chances of the precipitation falling as rain than snow due to the warmer temperatures.

Flooding

- Flooding is defined as an overflow of water onto normally dry land.
- As extreme rain events increase, flooding events are also expected to increase. A flooding event can be caused by human-related factors.
- However, the majority of floods are related to weather events. There are four main types of these weather-related flooding events:
 - Flash floods,
 - Urban flooding
 - River flooding, and
 - Coastal flooding

- A flash flood is a short-term event, happening within just a few hours, caused by heavy precipitation as well as rapid snowmelt, or the failure of dams or levees.
- Urban flooding, caused by short-term heavy precipitation, occurs as a result of the large areas of impervious surfaces (such as roads, pavement, parking lots, and buildings).
- River flooding occurs when a river fills with water (drained from the surrounding watershed) and exceeds the channel capacity and overflows the banks to inundate adjacent low lying areas.
- Finally, storm surges that accompany hurricanes and other coastal storms push large seawater domes toward the shore causing coastal flooding.

Ocean acidification

- Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30 percent.
- This increase is the result of humans emitting more carbon dioxide into the atmosphere and hence more being absorbed into the oceans.
- The amount of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.

Coral reefs

- Climate change is the greatest global threat to coral reef ecosystems.
- As temperatures rise, mass coral bleaching events and infectious disease outbreaks are becoming more frequent.

The Biological Impacts

- Ocean acidification is expected to impact ocean species to varying degrees.
- Photosynthetic algae and seagrasses may benefit from higher CO₂ conditions in the ocean, as they require CO₂ to live just like plants on land.
- It may impact food security as more than a billion people worldwide rely on food from the ocean as their primary source of protein.

Extreme Drought and Wildfires

- Drought is defined as a prolonged period of time with abnormally low precipitation.
- Due to global warming, not all areas on the planet will have increases in precipitation.
- As warmer temperatures and drought conditions increase, there is also greater likelihood for more wildfires.

- Droughts are complex events that can be associated with significantly reduced precipitation, dry soils that fail to sustain crops, and reduced levels in reservoirs and other bodies of water that imperil drinking supplies.
- Global warming is said to increase the drought conditions on many areas of land.

2019 Amazon rainforest fires

- Forest fires do happen in the Amazon during the dry season between July and October.
- They can be caused by naturally occurring events, like lightning strikes, but this year most are thought to have been started by farmers and loggers clearing land for crops or grazing.
- This matters because the Amazon is the largest rainforest in the world and a vital carbon store that slows down the pace of global warming.
- Deforestation releases this trapped carbon into the atmosphere. It can also trigger change in rainfall patterns leading to drought conditions.

Agriculture

Impact on Crops

- At least three main channels through which climate change would impact farm incomes – an increase in average temperatures, a decline in average rainfall and an increase in the number of dry-days.
- Higher temperature- > Increased moisture stress and drought -> crop damage and lesser production
- Longer growing season + high temp -> more demand for water-> more drought
- More GHG emission-> more CO₂ in the atmosphere-> better plant water-use efficiency and rates of photosynthesis=> better crop yield but weeds grow faster.

- Sea-level rise + coastal flooding due to cyclones=> coastal land erosion + sea water intrusion=> salinisation + contamination of fresh water for drinking and irrigation.
- More floods, droughts and heat waves => crop failure + famine + water crisis.
- IPCC AR3 predicted that the poorest countries in tropical regions would be hit the hardest with threat to their food security.
- Malnutrition and diseases would be the biggest killer in these regions.

Ecosystem and Societies

- Climate change => high temperature and extreme conditions=> species unable to migrate to better climates would perish.
- Lesser crop productivity + increasing population => demand for food => demand for more cultivable land => deforestation => loss of biodiversity.
- Ocean acidification + ocean warming + sea level rise + changes in thermohaline circulation=> loss of planktons, shell-forming species like corals, fishes etc => marine ecosystem disturbed.

- Rise in temperature + anthropogenic activities like deforestation, tourism, degradation of mountain slopes=> degradation of mountain biodiversity.
- Melting of Himalayan glaciers + change in the cycle of freezing and thawing of snow => change in river water volume and flow + glacial lake outbursts => flooding like Kedarnath.

- Flooding and submergence in downstream areas => loss of vegetation and wild animals + water-borne diseases.
- Climate change=> desertification=> expansion of desert area + change in climatic characteristics of deserts.
- Ocean acidification=> threat to coral reefs in coastal areas and Indian islands
- Sea level rise + ocean warming=> reduction in delta and coastal land=> threat to mangroves and threatened species like sea turtles along Odisha beach.

Impact on Humans

- Humans are an integral part of Biosphere.
- Any disturbance in biodiversity and climate will affect human activities and requirements directly (All discussed changes so far would directly affect Human)
- Global warming can lead to aggravated pollution which will in turn lead to more diseases and epidemics.
- Flooding and waterlogging will increase water borne diseases.
- Drought and desertification implies reduced water availability and land resources.

- Decline in crop production due to climate change => population-food mismatch => hunger and malnutrition=> death of mainly poor people in tropical countries.
- Heat waves + flooding and droughts=> loss of life and property.
- GHG emission=> ozone layer depletion=> UV rays exposure=> weaker immune system, skin cancer etc.
- **Note-** Climate change is discriminatory in nature i.e. its impacts is more forcefully felt up on poor and deprived sections than rich and those having and controlling resources. It can be linked to right based issue as well.