CLIMATIC CHANGE

CONCEPT OF GLOBAL CLIMATE CHANGE: -

The earth's climate patterns create and sustain the natural environment on which humans and all other species depend. The planet's environmental zones – from equatorial forests to polar regions – and the wealth of species they contain result from the different climates that exist on the earth. As a result of increasing human population and impact of its activities on natural resources, the earth's environment has undergone significant changes, especially during latter half of the 20th century. The two lead culprits of global warming and climate change are carbon emissions and ozone – depleting substances.

The earth's climate patterns are governed largely by an average global temperature, which has been gradually rising for more than a century. This warming may be a natural temperature fluctuation, but greenhouse gases – released by industries over the past few years and increasing as a result of deforestation may have built up in the atmosphere to such an extent that they may be enhancing the warming effect induced by normal levels of naturally occurring atmospheric greenhouse gases. Enhanced warming of planet may not be evenly seen, and the time taken for the climate to respond to any warming will vary between different areas.

The importance of the CO_2 climate issue was beginning to be recognized and addressed by a larger community in the 1950s and John Von Neumann wrote about the possibility of "climate control". The first expression of concern about climate change which might be brought about by increasing greenhouse gases was in 1957 by two scientists at the Scripps Institute of Oceanography, Roger Revelle and Hans Suess, who also pointed out that newly added carbon dioxide would probably remain in the atmosphere for many centuries because of the slowness with which the oceans could absorb it. During the late 1980s scientists began to suggest that the earth's energy flux was no longer in balance. Earth's surface was getting warmer, affecting the elements of the climate system. By 1995, it became evident that the main culprit was carbon dioxide emissions from various anthropogenic activities. An increase in the carbon dioxide concentration in the atmosphere retains the heat energy of the sun rays and increases the earth's temperature. A slight increase in the temperature of the earth has been found during the last 50 years, which is evident from the following figures.

Year	Average temperature of the earth (In ÚC.)	CO_2 conc. (In PPM)
1950	13.84	—
1960	13.96	316.8
1970	14.02	325.5
1980	14.18	338.5
1990	14.4	354.0
2000	14.6	366.7

According to a recent study, global mean surface temperature could rise by 2 - 5°C over pre-industrial average by 2100. Temperature rise of 2°C by end of century will still be manageable. By 2015, already 1°C temperature increase has occurred. Climate change and global warming in future years to come may have serious effects on agriculture, food security, availability of forest products, fisheries, aquaculture, coastal areas flooding, melting of glaciers, etc.

'UNTOLD SUFFERING' MAY BE INEVITABLE

'Climate emergency', say 11,000 scientists

Signatories, including 69 from India, also provide mitigating actions

Declaring a global climate emergency, over 11,000 scientists from 153 countries have warned that "untold suffering" is inevitable without deep and lasting shifts in human activities that contribute to greenhouse gas emissions and other factors related to climate change. In a paper published on Tuesday in the peer-reviewed journal *BioScience*, 11,258 signatories, including 69 from India, presented trends in climate change and provided a set of effective mitigating actions.

The declaration of a climate emergency is based on scientific analysis of more than 40 years of publicly available data covering a broad range of measures, including energy use, surface temperature, population growth, land clearing, deforestation, polar ice mass, fertility rates, gross domestic product and carbon emissions.

"Despite 40 years of major global negotiations, we have continued to conduct business as usual and have failed to address this crisis," said William J Ripple, a professor of ecology in the Oregon State University (OSU) College of Forestry in the US, adding, "Climate change has arrived and is accelerating faster than many scientists expected."

The global coalition of scientists led by Ripple and Christopher Wolf from OSU point to six areas in which humanity should take immediate steps to slow the planet's warming — energy, short-lived pollutants, nature, food, economy, and population.

Referring to the India context, Gyan Prakash Sharma, assistant professor at the University of Delhi and one of the signatories, said many things, including the monsoon, have changed in environmental pattern. "There is a tremendous change in the monsoon pattern across the country, which has triggered the changes in agricultural practices," he said.

According to the paper, mitigating and adapting to climate change while honouring the diversity of humans entails major transformations in the ways global society functions and interacts with natural ecosystems. The signatories said they are encouraged by the recent surge of concern. "Governmental bodies are making climate emergency declarations. Schoolchildren are striking, according to the declaration... Ecocide lawsuits are proceeding in courts. Grassroots citizen movements are demanding change, and many countries, states and provinces, cities, and businesses are responding... As an Alliance of World Scientists, we stand ready to assist decision makers in a just transition to a sustainable and equitable future," they said.

According to Thomas Newsome at the University of Sydney, scientists have a moral obligation to warn humanity of any great threat. "From the data we have, it is clear we are facing a climate emergency," Newsome said in a statement.

Graphics in the paper illustrate several key climate-change indicators and factors over the 40 years since scientists from 50 nations met at the First World Climate Conference in Geneva in 1979. The scientists noted that multiple global assemblies in recent decades have agreed that urgent action is essential, but greenhouse gas emissions are still rapidly rising.

Other ominous signs from human activities include sustained increases in per-capita meat production, global tree cover loss and number of airline passengers, they explained.

There are some encouraging signs — such as decreases in global birth rates, decelerated forest loss in the Brazilian Amazon and increases in wind and solar power — but even these are tinged with worry, the scientists noted. The decline in birth rates has slowed over the last 20 years, for example, and the pace of Amazon forest loss appears to be starting to increase again, they wrote.

Ripple said, "Global surface temperature, ocean heat content, extreme weather and its costs, sea level, ocean acidity, and area burned in the United States are all rising. Globally, ice is rapidly disappearing as demonstrated by decreases in minimum summer Arctic sea ice, Greenland and Antarctic ice sheets, and glacier thickness. All of these rapid changes highlight the urgent need for action." PTI

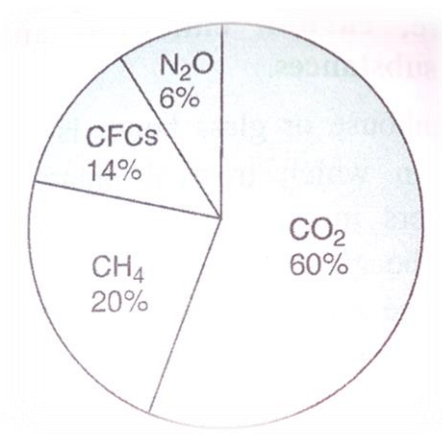
-Mumbai Mirror dated November 8, 2019 [Include key points from this article in the answer]

GREENHOUSE EFFECT: -

A greenhouse or a glasshouse is an enclosure of glasses in which tropical plants are grown during winters in areas of colder climate. Heat trapped by the glass keeps the temperature inside the greenhouse much higher than the surrounding atmosphere. A similar heating phenomenon occurs in the atmosphere also under normal conditions i.e. with normal concentrations of carbon dioxide and other greenhouse gases and hence the name greenhouse effect. Since CO_2 is confined exclusively to the troposphere, its higher concentration may act as a serious pollutant. Under normal conditions the temperature of the earth is maintained by the energy balance of the sun rays that strike the planet and heat that is radiated back into space. The layer of the gas prevents the heat from being re-radiated out. This CO_2 layer thus functions like the glass panels of a greenhouse allowing the sunlight to filter through but preventing the heat from being re-radiated in outer space. This is called the so-called "natural greenhouse effect". This natural greenhouse effect is essential to maintain the temperature of the earth at a normal habitable level. In fact, without greenhouse effect the average temperature at earth's surface would have been chilly, -18°C rather than the present average of 15°C. However, when there is an increase in CO2 concentration as a pollutant in the atmosphere most heat is absorbed by the CO_2 layer and water vapour in the atmosphere, which adds to the heat that is already present. The net result is the heating up of the earth's atmosphere. This is called "enhanced greenhouse effect". Thus, increasing CO_2 levels tend to warm the air in the lower layers of atmosphere on a global scale. The warming effect of greenhouse gases in the atmosphere was first recognized in 1827 by the French scientist Jean – Baptiste Fourier, best known for his contributions in mathematics.

GREENHOUSE GASES: -

During the course of the 19th century, experiments and observations were undertaken to calculate the effect of the gases involved, and carbon dioxide and water vapour became recognized as the most important gases involved in the greenhouse effect. Other important gases taking part in this phenomenon are methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) which also absorb solar radiation. These five gases act like a blanket spread over the earth's surface helping it to keep warm. These gases occur in minute quantities in the atmosphere but play a critical role in maintaining even temperatures on earth. Carbon dioxide constitutes about 60% of total warming, whereas methane, CFCs and N_2O contribute 20%, 14% and 6% respectively.



Besides these major greenhouse gases, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), halons, carbon tetrachloride (CCl_4) and ozone also cause greenhouse effect.

Unfortunately, human activities have been making the blanket of greenhouse gases thicker, resulting in enhanced greenhouse effect. From about 1600 million tons of CO_2 in 1950 its level increased to about 6000 tons in the year 2000. The thicker blanket due to increasing concentration of greenhouse gases has disturbed the global climate system. There is global warming due to enhancement of greenhouse effect all over the world.

GHG	**Global Warming Potential (in tons of CO_2 equivalent)**
CO_2	1
CH_4	23
NO	269
HFC	1,700
PFC	6,500
SF_6	23,900

Sources of greenhouse gases:

The relative contribution of different sources to GHGs is enlisted as follows:

- Burning of fossil fuels - 49%
- Agriculture - 13%
- Deforestation - 14%
- Industrial processes - 24%

1. **Carbon dioxide –** Burning of fossil fuels is the main source of emission of carbon dioxide. Coal, gas and oil are burnt excessively in factories, power stations as well as in vehicles. When coal, firewood and natural gas are burnt, huge amounts of carbon dioxide are released into the atmosphere. It was during International Geophysical Year (IGY) Charles David Keeling, started monitoring of carbon dioxide at the Mauna Kea Observatory in Hawaii and at the South Pole. These two stations have given best picture available of the rise of carbon dioxide from 1958 onwards. Before the Industrial Revolution and the widespread burning of fossil fuels, and before we had embarked on large scale clearing of forests for agriculture in the nineteenth century, it is estimated that there was an increase of concentration of carbon dioxide by 20 – 30% in less than 200 years. Throughout the world, carbon emissions from fossil fuels burning have been increasing unusually during latter half of the 20th century. From about 1600 million tons of CO_2 in 1950, its level has increased to about 6000 tons in 2000. From fossil fuels alone, more than 18 x 10^{12} tons of CO_2 is being released into atmosphere every year. In our country, on an average, thermal power plants are likely to release around 50 million tons of CO_2 each year into the atmosphere. CO2 is also emitted during volcanic eruptions, respiration by living organisms. On a global time scale, the known amounts of CO_2 in limestone and fossil sediments suggest that normal persistence period of CO_2 in the atmosphere is around 1,00,000 years. It

is almost certain by the above figures that atmospheric levels of carbon dioxide will triple by the year 2100 at the current rate.

Why Paris climate goals may be out of reach

New climate models show scientists have consistently underestimated warming potential of CO2

#PARIS

New climate models show carbon dioxide is a more potent greenhouse gas than previously understood, a finding that could push the Paris treaty goals for capping global warming out of reach, scientists have told AFP.

Developed in parallel by separate teams in half-a-dozen countries, the models – which will underpin revised UN temperature projections next year – suggest scientists have for decades consistently underestimated the warming potential of CO2.

Vastly more data and computing power has become available since the current Intergovernmental Panel on Climate Change (IPCC) projections were finalised in 2013. "We have better models now," Olivier Boucher, head of the Institut Pierre Simon Laplace Climate Modelling Centre in Paris, said, adding that they "represent current climate trends more accurately". The most influential projections from government-backed teams in the US, Britain, France and Canada point to a future in which CO2 concentrations that have long been equated with a 3 degrees Celsius world would more likely heat the planet's surface by four or five degrees.

"If you think the new models give a more realistic picture, then it will, of course, be harder to achieve the Paris targets, whether it is 1.5 or two degrees Celsius," scientist Mark Zelinka said.

Zelinka, from the Lawrence Livermore National Laboratory in California, is the lead author of the first peer-reviewed assessment of the new generation of models, published earlier this month in Geophysical Research Letters. For more than a century, scientists have puzzled over a deceptively simple question: if the amount of CO2 in the atmosphere doubles, how much will Earth's surface warm over time? The resulting temperature increase is known as Earth's "climate sensitivity". AFP

- Mumbai Mirror dated 15th January, 2020 [Include the warming potential of CO_2 from this article]

Restore soil to absorb billions of tonnes of carbon: Study

About 40 per cent of carbon absorption potential can be achieved if existing soil is left alone without increasing agriculture

Restoring and protecting the world's soil could absorb more than five billion tonnes of carbon dioxide each year – roughly what the US emits annually – new research showed Monday.

Last year the United Nations' Intergovernmental Panel on Climate Change said that the world needed to work harder to retain the land's ability to absorb and store planet-warming greenhouse gases and prevent it turning from a carbon sink to a source.

Just the first metre of soil around the world contains as much carbon as is currently in the atmosphere, locking up the CO2 sequestered in trees as they decompose and return to the earth.

A new paper in the journal Nature Sustainability analysed the potential for carbon sequestration in soils and found it could, if properly managed, contribute a quarter of absorption on land.

The total potential for land-based sequestration is 23.8 gigatonnes of CO2-equivalent, so soil could in theory absorb 5.5 billion tonnes annually.

Most of this potential, around 40 per cent, can be achieved simply by leaving existing soil alone – that is, not continuing to expand agriculture and plantation growth across the globe.

"Most of the ongoing destruction of these ecosystems is about expanding the footprint of agriculture, so slowing or halting that expansion is an important strategy," said Deborah Bossio, principal study author and lead soil scientist for The Nature Conservancy.

She said that soil restoration would have significant co-benefits for humanity, including improved water quality, food production and crop resilience.

"There are few trade-offs where we build soil carbon and continue to produce food," she told AFP.

The IPCC said in August that humanity was facing tough choices between how land – Earth's forests, wetlands, savannah and fields – is used to provide food and material and how it is used to mitigate climate change.

There is simply not enough space to feed 10 billion people by 2050 and limit catastrophic climate change, its 1,000-page study warned.

Agriculture already contributes as much as a third of all greenhouse gas emissions and vast amounts of food are wasted, driving global inequality.

Bossio said governments needed to ensure that agricultural practices seek to provide us with more than just food.

"Shift the incentive structures in agriculture towards payments for the range of ecosystem services, food, climate, water and biodiversity that agriculture can provide to society," she said. AFP

- Mumbai Mirror dated 18th March, 2020

2. Methane – Methane, or marsh gas, is a gaseous pollutant, in minute quantity in air, about 0.0002% by volume. In nature this is produced during decay of garbage, aquatic vegetation, etc. This is also released due to burning of natural gas and from factories. Higher concentrations can cause explosions. The excess of water seepage in filled up well and pits may lead to excess production of methane which bursts with high sound and may cause local destruction. At high levels in absence of oxygen, methane may become narcotic to man.

3. CFCs – Chlorofluorocarbons (CFCs) are widely used mainly in aerosol propellants, refrigeration, air-conditioning, plastic foams and solvents for cleaning electrical components. CFC is also used in fire extinguishing equipment. They escape as aerosol in the stratosphere. Jet engines, motor vehicles, nitrogen fertilizer and other industrial activities are responsible for emission of CFCs. The threat to ozone is mainly from CFCs which are known to deplete ozone by 14% at the current emission rate. The chlorine in CFCs depletes the ozone layer in the stratosphere. CFCs are the first generation gases used as coolants. Some countries decided to shift to second generation coolant gases, partially hydrogenated CFCs, called hydrochlorofluorocarbons (HCFCs), the second generation coolants. Though less than CFC, they were also found to damage the ozone. Industrialized countries phased out CFC in 2000 and now have to phase out HCFC by 2020. The alternatives to HCFCs are expensive products, hydrofluorocarbons (HFCs), the third generation coolants. The HFCs are already in use in developed nations. But HFCs are "supergreenhouse gases", with an externally high global warming potential. These can cause greenhouse effect thousand times stronger than carbon dioxide.

4. Nitrogen oxides (NO_x) – Even in unpolluted atmosphere, measurable amounts of nitrous oxide (N_2O), nitric oxide (NO) and nitrogen dioxide (NO_2). These are produced by combustion of oxygen and nitrogen during lightning discharges and by bacterial oxidation of ammonia in soil. No contact with air and combines with oxygen or even more readily with ozone to form the more poisonous nitrogen dioxide. Fossil fuel combustion also contributes to oxides of nitrogen. About 95% of the nitrogen oxide is emitted as NO and remaining 5% as NO_2. In urban areas about 46% of oxides of nitrogen in air come from vehicular exhaust and 25% from electric generation and the rest from other sources. In metropolitan cities, vehicular exhaust is the most important source of nitrogen oxides.

5. Other gases – These include carbon monoxide, sulphur compounds, ozone, photochemical products, etc. The chief source of carbon monoxide is automobiles, though others involving combustion sources such as stoves, furnaces, open fires, forest and bush fires, burning coal mines, factories, power plants, etc. Higher animals break down haemoglobin and produce CO. Some CO is also liberated from bile juice. Breakdown of photosynthetic pigments in algae also release some CO. On an average, plants release 10^8 tons of CO every year. The major sources of SO_2 emission are burning of fossil fuels in thermal power plants, smelting industries (smelting of sulphur containing metal ores) and other processes as manufacture of sulphuric acid and fertilizers. These account for about 75% of the total SO_2 emission. Most of the rest 25% emission is from petroleum refineries and automobiles. Similarly, decaying vegetation and animal matter, especially in aquatic habitats release hydrogen sulphide (H_2S). Sulphur springs, volcanic eruptions, coal pits and sewers also give off this gas. Industries emit about 3 million tons of H_2S every year. Such kind of human activities, especially automobiles, also release enormous amounts of ozone (O_3), photochemical smog, PAN, PB_ZN, etc. all of which contribute to some extent in causing greenhouse effect and global warming.

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No solutions to aviation's carbon emissions problem

Fossil fuel-hungry airlines are feeling the heat from climate activists, but new technology – from biofuels to lithium-ion batteries – is not evolving quickly enough to help the industry clean up its act

Adam Vaughan
2019, Tribune Content Agency

It is a bad time to be working in aviation. The past year has seen Greta Thunberg travel the world while shunning planes, climate protesters occupying airports and the Flygskam (flight shame) movement on the rise.

The aviation industry has been under pressure to cut its climate change impact for some time, but the pressure is growing. At a meeting near Geneva airport in Switzerland last month, the International Air Transport Association (IATA) warned that, without faster action on emissions, the industry faces a shift in public attitudes and countries unilaterally imposing environmental taxes.

France has already put a modest eco-tax on outward-bound flights beginning this month, and Sweden imposed one last April. Even the UK, the third biggest departure country in terms of aviation carbon dioxide emissions, saw frequent flyer taxes proposed in the recent general election battle. Environment pressures don't yet pose an existential threat to the industry, but it is anxious.

The problem isn't so much current aviation emissions, even though at between 2 and 3 per cent of the global figure they account for more emissions than the whole of Germany. The real issue is the rate of growth. China and India's flight numbers are increasing 10 per cent a year. Global aviation CO2 emissions have climbed 27 per cent in the past five years, to 936 million tonnes in 2019.

There are signs that Greta and Flygskam are having an impact. Emissions from flights in Sweden – a proxy for flight numbers – fell in the first half of 2019. Alexandre de Juniac, CEO of the IATA, rejects the idea that Flygskam is solely to blame, arguing that it isn't possible to tease out its effects from those of Sweden's aviation tax and weak economic growth.

However, figures from the Netherlands show the same trend, and recent numbers reveal that flights between German cities were down 12 per cent in November compared with a year before, while rail trips were up.

Faced with these headwinds, aviation is turning to technology and carbon offsetting to clean up its act – and ward off more regulation.

The industry thinks biofuels will be a big part of the answer. The IATA prefers the term sustainable aviation fuel: biofuels that don't compete with food production. Such fuels can cut emissions by 70 or 80 per cent when raw versus fossil fuel-based kerosene, with which they are blended.

Some of these fuels are made from waste animal fat and used cooking oil but others contain controversial materials, such as palm oil, which is linked to deforestation. Henrik Erämetsä at Neste, which makes biofuel for European and US airlines, says they don't use palm oil because customers don't want it. But attitudes differ globally. The chief executive of AirĄsia recently said the airline is a "big supporter for palm oil".

Even if greener fuels can avoid environmental side effects, they still face two big problems. The first is scale. About 220,000 flights have used the fuels since 2008, which sounds like a lot until you consider that there were 39 million flights in 2019. Biofuel accounts for just 0.01 per cent of all aviation fuel used today. The IATA says the share could rise to 2 per cent by 2025, but only if governments provide incentives.

Price is the other hurdle. Biofuels typically cost three times the price of fossil fuels. Asked when greener alternatives will reach price parity with kerosene-based jet fuel, Erämetsä is blunt. "The short answer is never. We just have to appreciate the fact the renewable fuels are more expensive."

What about embracing electrification instead, as car manufacturers are rapidly doing? The only electric planes in development today are a long way from commercial jumbo jets. Models such as the Alice by Israeli start-up Eviation will carry nine passengers. Rolls Royce hopes its ACCEL model will set the speed record for an all-electric plane in the first half of the year; it has a single seat. The firm is one of a group working to certify an electrified version of a nine-seater Britten-Norman plane by 2022.

The reason companies are starting small is simple: weight. The kerosene jet fuel powering the gas turbine engines on today's planes is much more energy dense than batteries, says Duncan Walker at Loughborough University, UK. Kerosene holds around 42 megajoules per kilogram compared with at most 1 megajoule per kilogram for a lithium-ion battery. And unlike batteries, as fuel is burned during the flight, the weight decreases, boosting efficiency.

Electrifying small planes will do little to reduce aviation's CO2 emissions, says Walker, but he thinks they are a legitimate stepping stone for testing the technology. Richard Goodhead at Rolls Royce sees promise in electrification at all scales, but says it will be difficult. "The bigger the aircraft is, and the longer it flies, the more challenging it is to use a purely electric solution," he says.

A key test for electrified planes will take place in 2021, when Airbus hopes to fly the E-Fan X, a plane the size of a regional airliner, with one of the engines swapped out for an electric motor, albeit powered by a gas turbine in the plane's fuselage. It will allow the firm to test voltages much higher than normal in planes, to keep electricity losses to a minimum. The low pressure and high altitude environment of a plane mean high voltages pose technical challenges, including higher temperatures and electric discharge.

With today's technology, a pure electric plane would have no space for passengers, says Sandra Bour Schaeffer at Airbus, because the batteries would take up the entire structure. But she says the firm will have a fully "decarbonised plane" ready by about 2035, which could involve other technologies, potentially even hydrogen.

Realistically, hybrid electric and fully electric planes are about 40 years away, says Walker. This is partly because the safety-focused production cycles of the big plane makers mean it takes some 20 years for the likes of Airbus and Boeing to produce a new model.

There are other ways aviation can cut emissions. But they are either incremental – more efficient engines, better management of air traffic and ways to cut fuel during take-off – or unlikely to happen for reasons of cost, such as advanced planes that look radically different from today's fixed wing designs.

The industry may want to get less heat for its climate change impact but the technology just isn't mature enough to fix its footprint any time soon. Quick, deep cuts in carbon emissions only look likely to come from people following Greta's example and the industry accepting slower growth. During three and half hours of debate in Geneva, that idea was never aired.

No silver bullet

Starting this month, airlines will have to offset any growth in their carbon emissions, although not their existing, sizeable emissions. It is part of a 2016 deal brokered by the UN. The industry says airlines will fund reforestation and clean energy projects worth about $40 billion over the next decade.

Kai Landwehr at Swiss offsetting group MyClimate says carbon offsetting isn't a silver bullet for the aviation industry. "But it is a proven and impactful and measurable system. It buys us time before we are ready to decarbonise."

Some airlines are also choosing to offset passengers' flights for them. British Airways has started offsetting all domestic flights this year. Easyjet recently began offsetting all its flights.

Landwehr calls Easyjet's move bold, saying its cheap offsets, which cost just £3 per tonne of carbon dioxide, may not guarantee the money goes to new projects, which is crucial for real offsetting.

"We have a rigorous process to select the schemes we buy credits from," says an Easyjet spokesperson. "These accreditors check projects to ensure the carbon reductions they are claiming would not have happened without the offsets."

In 2021, Airbus hopes to fly the E-Fan X, a plane the size of a regional airliner, with one of the engines swapped out for an electric motor

-Mumbai Mirror dated 13th January, 2020 [Include points from this article]

OZONE LAYER: -

Ozone in the stratosphere layer of atmosphere protects us from the harmful U-V radiations. It also acts as a pollutant near the ground (i.e. troposphere) forming a dense cloud in the industrialized areas having immense emissions. Such smog produced is called photochemical smog. Most of the ozone is present in the stratosphere, where some harmful substances are leading to its depletion. This depletion is not only harmful for human health but also causes hazardous effects on forests, wildlife and climate of the area through global warming.

About 90% of the atmospheric ozone is found in the stratosphere extending from about 12 or 50 km above the earth's surface. This concentration is greatest in the lower stratosphere (15 – 30 km) and this layer is called as '**good ozone**' due to its protective role for living beings by filtering out about 95% of the sun's harmful UV radiation. Only 10% of the ozone found near the ground in the troposphere is a harmful pollutant as a component of urban smog. This is popularly known as '**bad ozone'**. In fact, this phytotoxic air pollutant causes more damage to vegetation worldwide than all other air pollutants combined (Ashmore and Bell, 1991). According to Izuta (2006), chemical characteristics that are at the basis of this behavior of bad ozone are: high oxidizing power, diffusion coefficient similar to the one of carbon dioxide (and consequently a certain facility to penetrate the plant tissues), solubility in water being ten times higher than carbon dioxide and tendency to react with water in sub-basic environment. The temperature decreases with increasing altitude in the troposphere, while it increases with increasing altitude in the stratosphere. This rise in temperature in the stratosphere is caused by the ozone layer. The effect of this temperature inversion is interesting. It limits the vertical mixing of pollutants, thereby causing the dispersal of pollutants over larger areas and near the earth's surface. This is the reason why a dense cloud of pollutants usually hangs over the atmosphere in highly industrialized areas causing several unpleasant effects. Ozone alone and in combination with other pollutants like SO_2 and NOx, is causing crop losses of over 50% in several European countries. Ozone can cause foliar injury, changes in crop quality and reductions in plant growth and productivity (Schenone *et al*, 1992 and Heagle *et al*, 1998). With elevated ozone levels, changes such as reduced stomatal conductance, rates of photosynthesis (Inclan *et al*, 1998) and pigment concentrations (Alonso *et al*, 2001) have also been reported. Consequently, many of the world's most productive agricultural and forested regions are currently exposed to harmful elevated levels of ozone.

Ozone also reacts with many fibres especially cotton, nylon and polyester and dyes. The extent of damage is affected by light and humidity. Ozone also hardens rubber. At higher concentration, ozone damages human health also.

CFCs and biogenic emissions of methane and nitrous oxides chiefly cause stratospheric ozone depletion. In the stratosphere, the formation and destruction of ozone is a continuous phenomenon. The rate of formation and the rate of destruction are equal under complete natural conditions if anthropogenic activities are absent.

The first CFC was discovered by Thomas Midgley in 1930. Many other groups of such freons were soon developed by chemists later and were used as cooling agents in refrigerators and air conditioners. Later in 1974, two chemists, Sherwood Rowland and Mario Molina, at the University of California, indicated that CFCs were lowering the average concentration of ozone in the stratosphere. Rowland and Molina's work led to four major conclusions:

(i) CFCs remain in the troposphere because they are insoluble in water and chemically unreactive.

(ii) For over 11 – 20 years, these heavy compounds rose into the stratosphere mostly through convection, random drift and turbulent mixing of air in the troposphere.

(iii) Once they reach the stratosphere, the CFC molecules break down under the influence of high energy UV radiations. This releases highly reactive chlorine atoms and fluorine atoms which accelerate the breakdown of ozone (O_3) into oxygen (O_2) and nascent oxygen (O) in a cyclic chain of chemical reactions. As a result, ozone is destroyed faster than it forms.

(iv) Each CFC molecule can last in the stratosphere for 65 – 385 years, depending on its type. During that time, each chlorine atom released during the breakdown of CFC can convert hundreds of ozone molecules into oxygen.

Rowland and Molina received Nobel Prize in Chemistry for their work in 1995. Ozone depletion is a catalytic process. Ozone loss was first detected during 1950s in the stratosphere over the Antarctica by scientists at the Halley Bay Research station. The British Antarctica survey team, led by Joe Farman in 1985 reported that ozone layer over Antarctica had shrunk each year since 1970's. This thinning of ozone layer (i.e. depletion of ozone concentration) was referred to as the '**ozone hole'**. It regularly occurs above Antarctica during spring each year. This spring time ozone layer thickness above Antarctica has declined rapidly from 280 – 325 Dobson Units (DU), between 1956 and 1970 to about 94 DU in 1995. In September 1998, the hole was biggest (25 million km^2) in area.

The First Global Conference on ozone depletion was held in Vienna in 1985. A multinational agreement called as Montreal Protocol was adopted in 1987 in Montreal, Canada on ozone – depleting substances. Industrialized countries of the North agreed to take action to stop the cause of ozone depletion, which would be followed by those in the South.

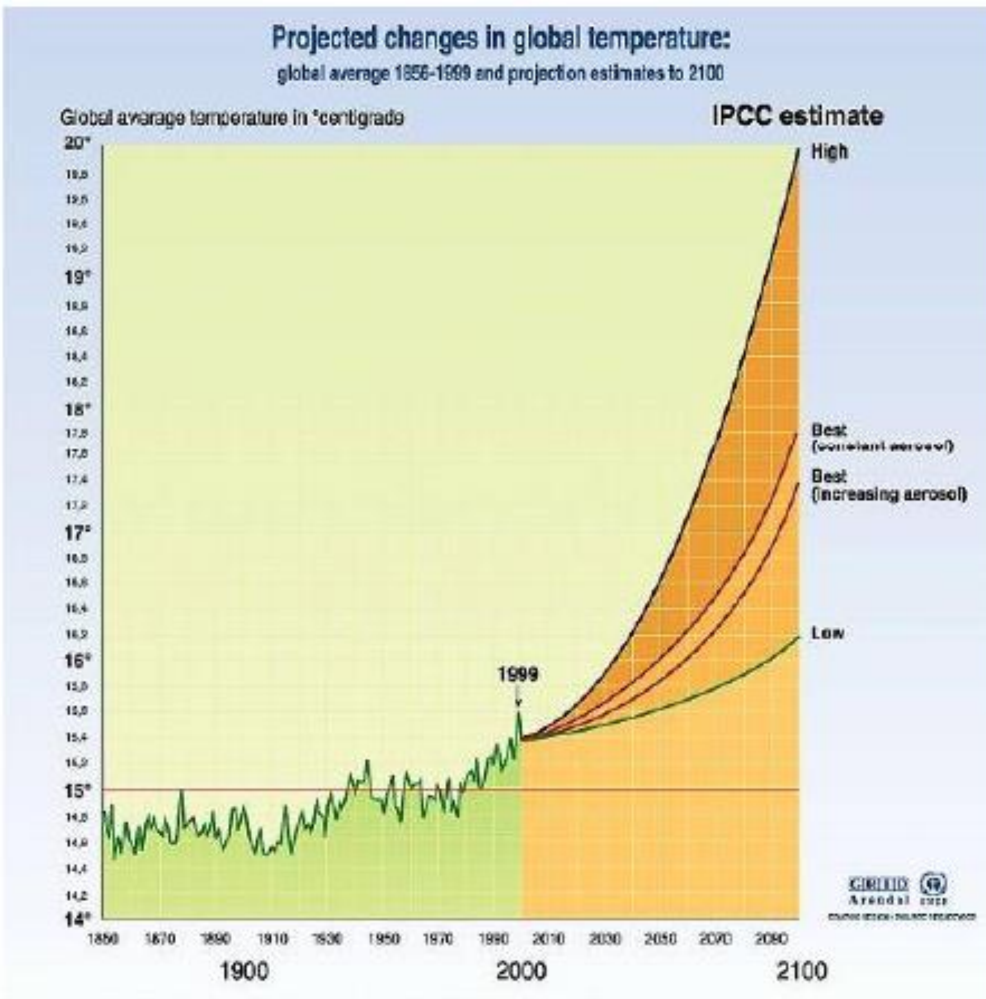
Countries world over decided to phase out CFCs and shift to partially halogenated CFCs called hydrochlorofluorocarbons (HCFCs), which were patented products. This proved to be an interim solution as HCFCs were also ozone – damaging, though less than the CFCs. Industrialized countries phased out CFCs in 2000 and decided to phase out HCFCs by 2020. The plan was that developed countries would begin HCFC phase-out by 2013 and finish it by 2030. India plans to switch to hydrocarbon cyclopentane in its first stage of HCFC phase-out management plan.

CONSEQUENCES OF CLIMATE CHANGE: -

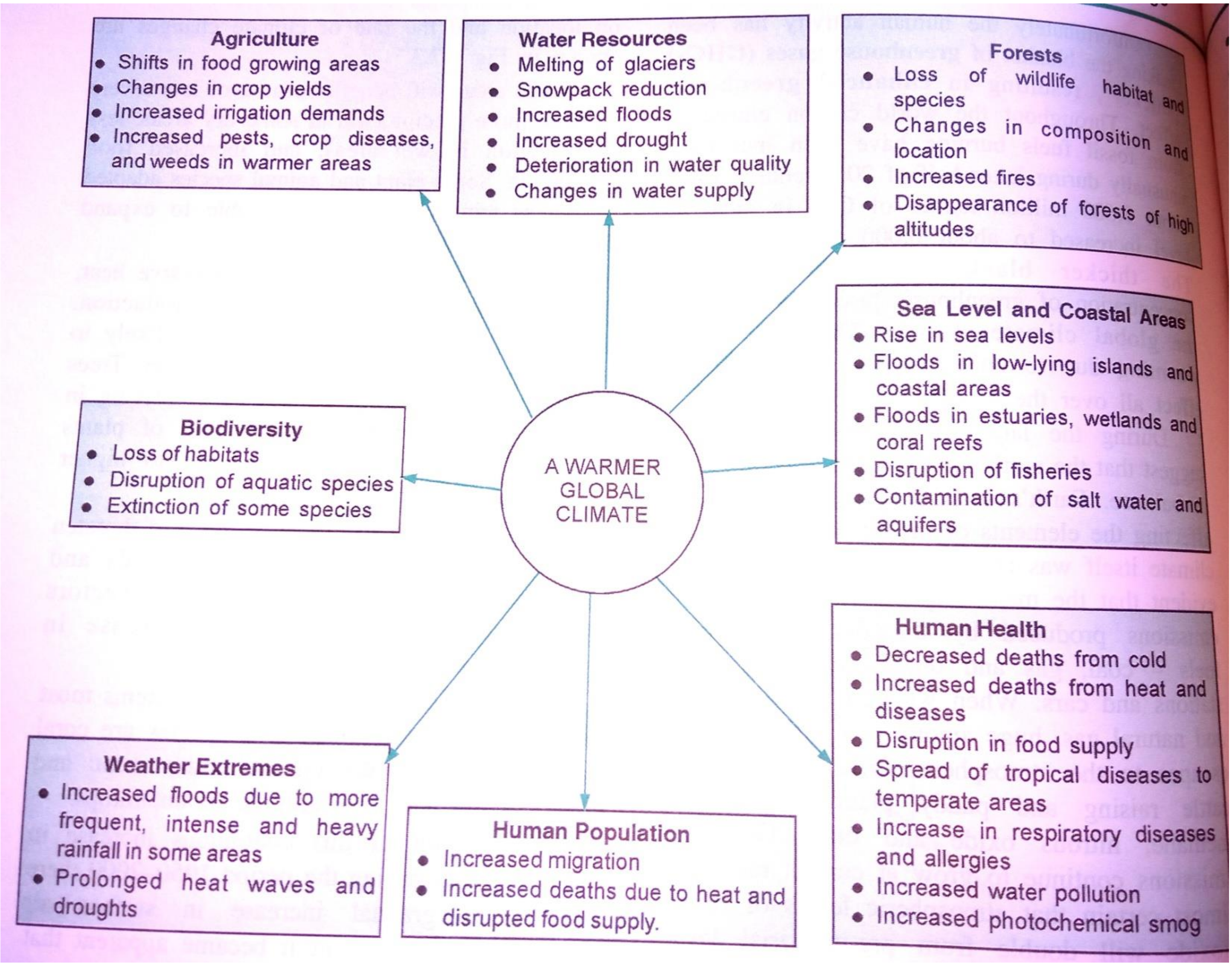
The biggest challenge of humanity today is to protect the world's climate. Increase of the global mean surface temperature of the earth by 2 - 5°C over the pre-industrial times is generally termed as 'global climate change'. It is predicted that this rise in the earth's average temperature is soon going to happen before 2100. A temperature rise of 1°C has already occurred by the year 2015. Though climate change may affect different regions of the world in different ways, it is the poor to suffer the most everywhere. They would not be able to bear the disastrous consequences of climate change in the form of floods, droughts, storms, etc. For instance, the Indian state of Andhra Pradesh was battered with three cyclones in a span of four months recently in 2018 (they were named as Gaza, Titli and Phetta). The world is to prevented from catching this high fever. Climate change has thus become a global cooperative enterprise in which all big and small, rich and poor, powerful and powerless must cooperate to achieve a global objective for the global welfare. The various consequences of this climate change phenomenon are highlighted as follows.

1. Global Warming: -

Slowly, an almost imperceptible rise of about 4 - 5°C in the global temperatures has occurred in the past 20,000 years. However, a rise of about 0.3 – 0.7°C was recorded during the last century alone, which is remarkably faster as compared to the changes in the past. This acceleration in the pace of global warming coincides with a rise in the concentration of greenhouse gases in the atmosphere. The insulation of the earth's surface from the outer space caused by greenhouse gases tends to become more and more effective as the concentration of these gases rises. More heat and infra-red radiations are trapped by the gaseous mantle around the globe which accelerates the pace of global warming.



According to the Second Report (1995) of the IPCC, global warming will lead to a rise in sea levels, fluctuating crop yields and loss of biodiversity. Even if carbon dioxide emissions are maintained at the 1994 levels, its concentration in the atmosphere will reach 550 ppm by the end of the 21st century, almost twice the pre-industrial levels. As per IPCC estimates, global mean surface temperatures would be about 2°C above pre-industrial levels by the year 2030, and by about 4°C above pre-industrial levels by 2090.



According to the observations made by the World Meteorological Organization (WMO) in its 2013 report, 2001 – 2010 was the hottest decade. The decade was the warmest for both the hemispheres and for both land as well as ocean surface temperatures. Arctic sea ice declined rapidly, and there was a loss of mass from the Greenland and Antarctic ice sheets and the world's glaciers. The global mean sea level rose about 3mm per year, compared to an average of 16 mm rise per year for the 20th century. Small islands like the Maldives will be completely inundated by the rising sea level. Countries enlisted as BRICS (Brazil, Russia, India, China and South Africa) will be the worst affected. The average land and ocean surface temperature for the decade 2001 – 2010 was estimated to be 14.47°C which is 0.47°C above the 1961 – 1990 global average and 0.21°C above the 1991 – 2000 global average. Nearly 94% of the reporting countries had their warmest decade in 2001 – 2010.

The rise in global temperatures shall not be uniform all over the earth's surface. Most of the researchers agree that the polar regions of the world undergo larger increase in temperature, about as much as ten to twelve times as much as the tropics. This shall bring unprecedented changes in the wind and precipitation patterns within a span of a single century. In India the deserts of Rajasthan could expand right up to Punjab, Delhi and western part of Uttar Pradesh while the eastern region might experience little change.

The UN-IPCC, in its latest synthesis report has mentioned that, if left unchecked, global warming will have an irreversible impact on people and ecosystem. It calls for near-zero emissions of greenhouse gases by the end of the century. More highlighting evidences are enlisted below:

- Surface ocean (the upper 75 metres) has warmed by 0.11°C per decade between 1971 and 2010.
- Since the beginning of the industrial era, CO_2 emissions have led to ocean acidification. The pH of its surface water has decreased by 0.1 and acidity increased by 26%.
- Between 1979 and 2012, Arctic sea-ice extent decreased by 3.5 – 4.1% per decade, Antarctic sea-ice extent increased by 1.2 – 1.8% per decade.
- Mean sea level rose by 0.19 metre between 1901 and 2010. It is the highest rise in the last two millennia.
- Each of the last three decades has been successively warmer. 1983 – 2012 was the warmest 30 – year period in 1400 years in the Northern Hemisphere.

Sea levels set to rise even if greenhouse gases are curbed

Sea level could rise by at least a meter by 2300 in the event that greenhouse emissions fall to zero in the next 11 years, the target set by the Paris agreement

Just as an oil tanker steaming ahead at full speed cannot stop immediately, so the dramatic rise in sea levels will continue even if the world manages to slash greenhouse gas emissions to zero by 2030, experts warned in a study published on Monday.

Emissions between 2015, when the Paris climate change accord was thrashed out, and 2030 would be enough to raise levels by 3.1 inches by 2100, according to research by experts based in Germany.

They would rise by 7.9 inches by 2300 in comparison with the reference period of 1986-2005, according to the study published in the Proceedings of the National Academy of Sciences (PNAS).

In total, sea level can be expected to rise by at least a meter by 2300 in the extremely unlikely event that greenhouse gas emissions fall to zero in the next 11 years.

And that may be a conservative estimate: UN-backed scientists are already predicting an increase in water levels of between 26 cm and 77 cm by the end of this century alone.

A full quarter of that one-meter rise by 2030 will be due to emissions from China, the United States, the European Union, Russia and India in the preceding 40 years, the authors of the latest report concluded.

By comparison, oceans rose by around 20 cm in the 20th century.

The goal of the study, co-author Alexander Nauels of the Climate Analytics institute in Berlin told *AFP*, was to show that current emissions will have a clear effect on rising sea levels that will be felt over the next 200 years.

"We all focus on the 21st century," he said, warning that "sometimes that can create the false impression that after the 21st century nothing else will happen."

Sea level rise is due to a number of complex phenomena that can play out over extremely long time scales, making its study difficult. It is still unclear why Antarctic ice is melting more slowly than in Greenland.

"When you're looking into the sea level rise problem, it's a very slow and responding system," said Nauels.

"A centimetre doesn't sound like much but it's actually a lot," he added.

In a report published last year, experts from the Intergovernmental Panel on Climate Change (IPCC) said reducing the rise in sea level by 10 centimetres would save 10 million people in coastal areas from being exposed to flooding, storm surges and other risks. **AFP**

DEEPAK TURBHEKAR

File photo: Waves lash against the city's Marine Drive promenade

-Mumbai Mirror dated 6th November, 2019 [Include key points from this article]

Such drastic changes in the climatic conditions due to global warming will have disastrous consequences on the vegetation too. As the climatic belts shift from the equator to the poles, vegetation shall have to shift in the same direction to stay in favourable climatic conditions. Those species, which are unable to do so, shall die. There will be loss of genetic resources on a large scale. Hardy and resistant forms shall come up and survive. An altogether changed biotic spectrum shall replace the earlier ones and almost all the important biomes shall be affected. It has been suggested that some rise in precipitation, however shall be balanced by an enhanced evapo-transpiration and this could lead to water deficit and moisture stress in many regions of the world. Insects and pests may increase as warmer conditions could be more favourable for their growth and coupled with high humidity pathogenic diseases shall multiply. Cycling of mineral nutrients will be affected and with it, leaching and desertification may follow in certain areas. Alterations in cropping patterns shall occur and pest resistant varieties more suitable to warmer conditions shall need to be developed. India is the 13th most vulnerable country to this phenomenon. Since more than 60% of Indian agriculture is rainfed and it hosts 33% of the world's poor, climate change will have significant impacts on the food and nutritional security of the country. In short, this global warming shall bring with it an entirely new environment in which life though not impossible yet its existence shall be tough to maintain.

Consequences of global warming

SATURDAY, 11 JANUARY 2020
MUMBAI
03

CLIMATE CHANGE TRACKER
BIBEK BHATTACHARYA

THIS WEEK: Extreme weather fallout

GETTY IMAGES

Devastating floods in Indonesia left 400,000 people homeless.

The new normal

As I write, the Australian bushfires continue, with the weather company Accuweather reporting around 130 ongoing fires. There was a brief respite in Australia's Victoria and New South Wales (NSW) provinces with some rainfall on 5-6 January, but as temperatures rise again, the flames are only going to get bigger. The fear is that the Victoria and NSW fires are going to merge and create a "super-blaze".

Last week, nearly 500 million animals had died in the inferno. This week, the economic cost of the bushfires has been disclosed. According to the financial services company Moody's Analytics, it's set to be more than $4.4 billion (around ₹31,332 crore). This will be a greater financial loss than the 2009 Black Saturday fires in Australia's Victoria province.

The current bushfires have so far burnt through 8.4 million hectares. Experts say the Australian tourism industry, which contributed 3% of the country's GDP in 2014-15 and posted a record revenue of $44.6 billion in 2019, will need close to $300 million to rebuild.

In all this, yet another "unprecedented" weather calamity slipped through the news last week. Devastating floods in Jakarta and other parts of Indonesia killed 66 people and drove 400,000 people to refugee shelters after their homes were washed away. According to experts, Jakarta is sinking so rapidly that it might be entirely submerged by 2050.

And finally, the India Meteorological Department (IMD) announced on 6 January that extreme weather events driven by climate change had claimed 1,659 lives across India in 2019. Of these, Bihar alone accounted for 650 lives lost; 306 of them during the monsoon floods. As many as 350 people died in heatwaves. According to the IMD, 2019 was also the seventh warmest year on record.

- Mint, dated 11th January, 2020 [Include updates from this article]

1) Wildfires (Australia 2019 & Amazon 2019): There have been fires in every Australian state, but New South Wales has been hardest hit. Blazes have torn through bush land, wooded areas, and national parks like the Blue Mountains. Some of Australia's largest cities have also been affected, including Melbourne and Sydney -- where fires have damaged homes in the outer suburbs and thick plumes of smoke have blanketed the urban centre. Earlier in December, the smoke was so bad in Sydney that air quality measured 11 times the "hazardous" level. Australia is experiencing one of its worst droughts in decades. The country's Bureau of Meteorology said in December that last spring was the driest on record. Meanwhile, a heat wave in December broke the record for highest nationwide average temperature, with some places sweltering under temperatures well above 40 degrees Celsius. Strong winds have also made the fires and smoke spread more rapidly, and have led to fatalities -- a 28-year-old volunteer fire fighter died in NSW in December after his truck rolled over in high winds! In total, more than 7.3 million hectares (17.9 million acres) have been burned across Australia's six states. The worst-affected state is New South Wales, with more than 4.9 million hectares (12.1 million acres) burned. To put that into perspective, the 2019 Amazon rainforest fires burned more than 7 million hectares (about 17.5 million acres), according to Brazilian officials. In California, which is known for its deadly wildfires, just over 100,000 hectares (247,000 acres) burned in 2019, and about 404,680 hectares (1 million acres) in 2018. Rainfall that falls on the Amazon rainforest is recycled when it evaporates back into the atmosphere instead of running off away from the rainforest. This water is essential for sustaining the rainforest. Due to deforestation the rainforest is losing this ability, exacerbated by climate change which brings more frequent droughts to the area. The higher frequency of droughts seen in the first two decades of the 21st century signal that a tipping point from rainforest to Savanna might be close.

2) Volcanic Eruption (Taal Volcano eruption 2020): Researchers found that when glaciers melt, they reduce the pressure on continents, while sea-level rise increases pressures on the ocean floor crust. The change in the pressures on the Earth's crust seems to cause increases in volcanism. An eruption of Taal Volcano in the Philippines began on January 12, 2020. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) subsequently issued an Alert Level 4. It was a phreatic eruption from the main crater that spewed ashes to Calabarzon, Metro Manila, some parts of Central Luzon and Pangasinan in Ilocos Region, resulting in the suspension of classes, work schedules, and flights. The volcano erupted on the afternoon of January 12, 2020, 43 years after its previous eruption in 1977.

3) Melting of Glaciers (Greenland 2019): Melting glaciers add to rising sea levels, which in turn increases coastal erosion and elevates storm surge as warming air and ocean temperatures create more frequent and intense coastal storms like hurricanes and typhoons. Specifically, the Greenland and Antarctic ice sheets are the largest contributors of global sea level rise. Right now, the Greenland ice sheet is disappearing four times faster than in 2003 and already contributes 20% of current sea level rise. How much and how quickly these Greenland and Antarctic ice sheets melt in the future will largely determine how much ocean levels rise in the future. If emissions continue to rise, the current rate of melting on the Greenland ice sheet is expected to double by the end of the century. Alarmingly, if all the ice on Greenland melted, it would raise global sea levels by 20 feet.

4) Effects on weather: The main impact of global warming on the weather is an increase in extreme weather events such as heat waves, droughts, cyclones, blizzards and rainstorms. Of the 20 costliest climate and weather disasters that have occurred in the United States since 1980, eight have taken place since 2010, four of these in 2017 alone. Such events will continue to occur more often and with greater intensity. Episodes of intense precipitation contribute to flooding, soil erosion, landslides, and damage to structures and crops.

5) Flooding: Warmer air holds more water vapour. When this turns to rain, it tends to come in heavy downpours potentially leading to more floods. A 2017 study found that peak precipitation is increasing between 5 and 10% for every one-degree Celsius increase. In the United States and many other parts of the world there has been a marked increase in intense rainfall events which have resulted in more severe flooding. Estimates of the number of people at risk of coastal flooding from climate-driven sea-level rise varies from 190 million to 300 million or even 640 million in a worst-case scenario related to the instability of the Antarctic ice sheet.

According to the analysis, Mumbai could witness a 25% increase in flash-flood intensity events by 2050, with average flood depth rising from 0.46m to 0.82m by 2050. Flooded area (for every 0.05m across the city) would rise from the current 46% to 60%, which would lead to cost escalation for infrastructure damage (capital stock damage) from the current 580 million USD to 920 million USD by 2050.

The analysis also raised an alarm about extreme weather events and storm surges accelerating by 1.5 times rise with 100 km/hour wind speed being the new normal.

-TOI, dated 28th February, 2020

6) Oceans: Global warming is projected to have a number of effects on the oceans. Ongoing effects include rising sea levels due to thermal expansion and melting of glaciers and ice sheets, and warming of the ocean surface, leading to increased temperature stratification. Other possible effects include large-scale changes in ocean circulation. The increase in ocean heat content is much larger than any other store of energy in the Earth's heat balance over the two periods 1961 to 2003 and 1993 to 2003, and accounts for more than 90% of the possible increase in heat content of the Earth system during these periods. In 2019 a paper published in the journal Science found the oceans are heating 40% faster than the IPCC predicted just five years before. The oceans also serve as a sink for carbon dioxide, taking up much that would otherwise remain in the atmosphere, but increased levels of CO_2 have led to ocean acidification. Furthermore, as the temperature of the oceans increases, they become less able to absorb excess CO_2. The oceans have also acted as a sink in absorbing extra heat from the atmosphere. Warmer water cannot contain as much oxygen as cold water, so heating is expected to lead to less oxygen in the ocean. Other processes also play a role: stratification may lead to increases in respiration rates of organic matter, further decreasing oxygen content. The ocean has already lost oxygen, throughout the entire water column and oxygen minimum zones are expanding worldwide. This has adverse consequences for ocean life.

7) Droughts and agriculture: Some evidence suggests that droughts have been occurring more frequently because of global warming and they are expected to become more frequent and intense in Africa, southern Europe, Middle East, most of the Americas, Australia, and Southeast Asia. Droughts result in crop failures and the loss of pasture grazing land for livestock.

8) Pollution: Air pollution and climate change are inextricably linked, with one exacerbating the other. When the earth’s temperatures rise, not only does our air gets dirtier—with smog and soot levels going up—but there are also more allergenic air pollutants such as circulating mold (due to damp conditions from extreme weather and more floods) and pollen (due to longer, stronger pollen seasons).

2. UV Radiation: -

The sun emits radiations at all wavelengths. Of these, the radiations important to our planet are: ultraviolet radiations, light rays and infra-red rays or heat waves. Radiations of infra-red rays and heat waves carry little energy which does not harm the living beings. The energy contents of ultraviolet radiations are however, larger than the limits of tolerance of a living cell and hence are harmful or even lethal to a living system. Though these high energy radiations triggered the biochemical process on which led to the emergence of life on this planet, their continued presence was injurious to the living system. Life, as a consequence had to await the development of an effective shield of atmospheric gases which would check the biocidal radiations in the atmosphere before it could come out on land.

Ultraviolet radiations are usually grouped into the following categories:

- **UV-A:** With a wavelength range between 3150 – 4000 Å which do not cause much harm to the living system. Only a part of these radiations reach the earth’s surface, which are tolerated by living beings.
- **UV-B:** With a wavelength range from 2800 – 3150 Å, these are more damaging than UV-A.
- **UV-C:** With a wavelength range from 2000 – 2800 Å, these carry larger amount of energy. These are most damaging radiations for the biosphere. However, they are almost completely absorbed by the atmospheric gases.

Much of the harmful high energy solar radiations is absorbed at various heights by the gaseous mantle which surrounds our planet. Though oxygen, nitrogen, and a number of other constituents of the atmosphere absorb short wavelength UV radiations, none of these gases can absorb effectively wavelengths greater than 2200 Å. This leaves a gap which is filled by ozone alone. It absorbs all radiations between 2200-2900 Å. Radiations above 2900 Å are not completely absorbed by this gas, which however are considerably diluted by the ozone layer. A depletion of ozone content of the atmosphere results in increased penetration of 2900 – 3150 Å radiations (UV-B), which are very injurious to the biosphere. In extreme cases, radiations with wavelengths lower than 2800 Å may also reach the earth surface.

Laboratory studies have shown that absorption of UV radiations within the range of UV-B by a living cell is largely due to the absorption of energy by nucleic acids, the DNA and RNA molecules. The energy thus absorbed breaks up these macromolecules and affects adversely such vital processes as protein synthesis, growth and reproduction. Alterations in DNA molecules could cause long – range genetic effects which could change the very shape of life on this planet.

CLIMATE CHANGE IMPACTS ON INDIA: -

India is the 13th most vulnerable country to climatic change. Since more than 60% of Indian agriculture is rainfed and it hosts 33% of the world's poor, climate change will have significant impacts on the food and nutritional security of the country. The climate change will affect monsoon and agriculture in South Asia. Increasing variability of the monsoon rainfall, heavier downpours and increase in the frequency of droughts are already causing damage. In the Indian Ocean, the period between 2004 and 2009 showed higher sea level rise. The Climate Change Vulnerability Index 2011 listed Kolkata in India and Chittagong in Bangladesh as two of the six fastest growing cities at 'extreme risk' of climate change impacts.

According to New Delhi-based NGO, Centre for Science and Environment in 2014, the major agro-ecological zones of India will face varied effects of climate change, briefly stated as follows:

1. **The Coast and Islands –** The 7,517 km Indian coast can be divided into the west coast, the eastern coastal plain and the biodiversity-rich Indian islands. The region is already witnessing climate change impacts like frequent severe cyclones and sea ingression due to sea level rise. There were two cyclones one after the other in a fortnight in the west coast of Maharashtra and Gujarat in October 2019, named as Kyarr and Maha respectively. This was followed by another cyclone 'Bulbul' in the east coast of Odisha and West Bengal, which caused extensive damage. It is also predicted that most of the urban areas like Mumbai will be under water by the year 2050 due to sea level rise. A one-metre rise in sea level will displace 7.1 million people in India. Sea level rise will inundate 0.18% of Maharashtra state. The rice yield in Karnataka will decrease by 10-15% by 2050. Sea water intrusion will affect drinking water supply in Tamil Nadu drastically. Recently in 2018, the metropolitan city of Chennai faced extreme water shortage for the first time. Reduction of fish catch will take place in the coastal areas of Andhra Pradesh. Intensity of cyclones will increase in states like Odisha. Due to rise in mean annual temperature over the past 20 years, there have been bleaching events taking place in areas like Andaman and Nicobar Islands. The observed sea level rise in the two main groups of islands have been in the range of 1 – 1.5 mm/year.

Cyclones have risen 32% in 5 years: IMD

India Hit By Six Severe Cyclones In 2018 & 2019

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On average, four cyclones affected India each year during this decade (2010-2019), higher than the average of three in the previous decades since 1980. But the sharp rise in the past five years could be an alarming pointer to the calamitous effects of global warming

Pune: The number of cyclones and severe cyclones in the Arabian Sea and the Bay of Bengal have risen by nearly 11% in the last decade, with an alarming 32% increase recorded in the last five years, data from India Meteorological Department (IMD) reveals.

Back-to-back cyclones have caused havoc and disrupted weather in recent months, but the sharp rise in the past five years in comparison with previous decades could be an alarming pointer to the calamitous effects of global warming, weather officials said.

There were seven cyclones each in 2018 and 2019, the highest since 1985. Similarly, six severe cyclones each hit India in 2018 and 2019, the highest since 1976, when seven were recorded. This year, extremely severe cyclone Fani devastated Odisha and parts of West Bengal in April. Vayu, another very severe cyclone, delayed the monsoon's onset over parts of the country.

On average, four cyclones affected India each year during this decade (2010-2019), higher than the average of three in the previous decades since 1980, Anupam Kashyapi, head of weather, India Meteorological Department, Pune, told **TOI**.

▶ WET WEATHER SEES DRY FISH VANISH IN CITY, P 5

▶ **Winter delayed: IMD, P 10**

-TOI, dated December 29, 2019 [Include key points from this article in the answer]

CLIMATE CHANGE STUDY

'3 million living within a km from Mumbai's coast at risk from floods'

Badri Chatterjee

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MUMBAI: Almost three million people living within a kilometre from the city's coastline (high-tide line) are under "severe" threat from flooding, storm surges and rise in sea level, according to an analysis released on Thursday.

The high-tide line is the corresponding point on land where the tide reaches maximum height.

New research from private group McKinsey & Company Inc. identified risks of multiple hazards with increasing intensity due to climate change from now till 2050 for Mumbai's coast. The analysis builds on a global report titled 'Climate risk and response: Physical hazards and socio-economic impacts' released by McKinsey & Company at the World Economic Forum in January 2020.

Mumbai-specific details were released during the Climate Crisis Conclave hosted by not-for-profit group Mumbai First and the Maharashtra government on Thursday.

CONTINUED ON P8

CITIES AT CRITICAL RISK

With just 50cm of sea-level rise, 150 million people would face flooding in port cities around the world. The table shows Indian cities at risk

CITY	Projected population exposed to flooding after 50cm of sea-level rise **(in thousands)**	Value of assets exposed to flooding after 50cm of sea-level rise **(US$ billion)**
Mumbai	11,418	1,598.05
Kolkata	14,014	1,961.44
Surat	2,020	282.8
Chennai	730	102.16

(Source: IIT-Bombay and IPCC reports)

-Hindustan Times dated 28th February, 2020

2. **The Desert Region –** The Thar Desert, covering 10% of the total geographical area of India, is the seventh largest desert in the world. The region has witnessed unheard of floods in the recent past. Parts of Rajasthan and Kutch region of Gujarat have highest probability of drought occurrence. After Jammu and Kashmir, Rajasthan is the second state in India to witness greatest number of cold waves. Heat stress and water shortage will increase in Gujarat. The severity of drought for the Mahi and Sabarmati rivers will increase between 5% and 20% by 2050. Western Rajasthan will experience severe to very severe droughts.
3. **Central and Peninsular India –** The region covers most of India's rainfed areas that contribute more than 40% of India's foodgrain production. Six of the eleven states will witness a temperature rise of 1°C to 4°C. Maharashtra will record a 3.4°C increase by 2100. Tamil Nadu, Telangana, Maharashtra and Jharkhand will witness increase in the rainfall. The post-monsoon and pre-monsoon increase in rainfall is projected to be more than the increase in rainfall projected for the monsoon period of 2100. The number of days with 'high' or 'very high' rainfall is projected to increase over Maharashtra. Such fluctuating weather will affect the agricultural yield in all the states. Parts of Tamil Nadu, Karnataka and Andhra Pradesh have the highest probability of drought in the region. Western parts of Karnataka may face fewer droughts due to projected increase in the rainfall.
4. **The Indian Himalayan Region –** The Himalayas, which represent about 16.2 percent of the total area of the country, are not only a key watershed of India but also play a crucial role in the monsoon system. Climate change impacts on the mountain range can affect the entire sub-continent. Change in the maximum temperature of most districts in the region is projected to increase by at least 1.5℃ - 2℃. Flash flood due to glacial like outbursts may lead to landslides and affect large-scale food security. Himalayan glaciers are melting faster than any other glacier in the world. The mean temperature of the Himalayas has gone up by 0.6℃ in the past 30 years; the frequency of warmer days is also increasing.
5. **The Indo-Gangetic Plain –** The Indo-Gangetic plain is one of the most populous and productive agricultural ecosystems in the world. Climate change will result in both flood and drought, impacting agriculture in the region. High-intensity precipitation events are projected to increase, leading to floods, particularly in the eastern part of the basin. Western parts of the basin that includes Punjab and Haryana are likely to become vulnerable to drought. Wheat yields may decline by 4.6 – 32% in Punjab by 2021 – 2050. Intensity of cyclones will increase in West Bengal. The sea level rise in this region will be higher than the global average. Sundarbans and Darjeeling hills will have more rain. Rice yields are expected to decline significantly in Bihar. Drought conditions will increase in Uttar Pradesh and Bihar.

Climate change could put 4.5% of India's GDP at risk: Study

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Kolkata: Climate change and global warming may hit India's GDP within a decade, a report published by the McKinsey Global Institute (MGI) has said. By 2030, temperatures in India could reach such levels that outdoor workers may be forced to cut short their daylight working hours to beat the lethal heat waves, the report says.

MCKINSEY REPORT

The MGI report has estimated that the impact of global heating on outdoor work and the resultant loss in productivity could put 2.5% to 4.5% of India's GDP at risk annually.

"As of 2017, in India, heat-exposed work produces about 50% of GDP, drives about 30% of GDP growth, and employs about 75% of the labour force, some 380 million people," the report says. For adaptation in the short term, India can focus on early-warning systems and cooling shelters to protect those without airconditioning. "Working hours for outdoor workers could be shifted, and... at the extreme, coordinated movement of people and capital from high-risk areas could be organized," it suggests. Unless there is an effective adaptation response and de-carbonization within 10 years, 16-20 crore people in India could live in regions exposed to lethal heat waves every year.

In such an eventuality, temperature could exceed survivability threshold in many areas, with just 4-5 hours of outdoor exposure turning fatal for a healthy, well-hydrated human at rest in shade, it says. By 2050, several pockets in India and Pakistan are projected to experience more than 60% annual chance of such heat waves. Hence, the report suggests organized mass climate migration as an adaptive measure. "Reducing exposure in high-risk areas could be one means to manage risk," Mekala Krishnan, one of the authors of the report, said.

Full report on www.toi.in

-TOI, dated 9th March, 2020 [Include in the answer for Impacts of Climate change on India]

CARBON FOOTPRINTING: -

A carbon footprint is "the total set of GHG (greenhouse gas) emissions caused directly and indirectly by an individual, organization, event or product", according to UK Carbon Trust, 2008. A carbon footprint is a measure of the impact our activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day-to-day lives through burning fossil fuels for electricity, heating and transportation etc. The carbon footprint is a measurement of all greenhouse gases we individually produce and has units of tons (or kg) of carbon dioxide equivalent.

The table given below shows the main elements, which make up the total of a typical person's carbon footprint in the developed world.

Contributors	**Percentage**
Share of public services	12%
Domestic fuel	15%
Home - electricity	12%
Private transport	10%
Public transport	3%
Holiday flights	6%
Food and drink	5%
Clothes and personal effects	4%
Car manufacture and delivery	7%
House – buildings and furnishing	9%
Recreation and leisure	14%
Financial services	3%

A carbon footprint is made up of the sum of two parts, the primary footprint and the secondary footprint.

1. The **primary footprint** is a measure of our direct emissions of CO_2 from the burning of fossil fuels including domestic energy consumption and transportation (e.g. car and plane). We have direct control of these.

2. The **secondary footprint** is a measure of the indirect CO_2 emissions from the whole lifecycle of products we use - those associated with their manufacture and eventual breakdown. For eg., in construction of houses and its furnishing.

According to World Bank (2013) data, the average per capita carbon footprint is as follows:

- in the developed world: > 10 tCO2 eq
    - desired for the world: 2 tCO2 eq
    - in India: 1.6 tCO2 eq
    - in African countries: <0.5 tCO2 eq
    - in China: 7.55 tCO2 eq
    - in USA: 16.4 tCO2 eq

It is observed that 40% Urban Indians' per capita carbon footprint is far greater than the 60% rural Indians' per capita carbon footprint.

Individual carbon footprints, if calculated, are alarmingly high mainly due to the following reasons:

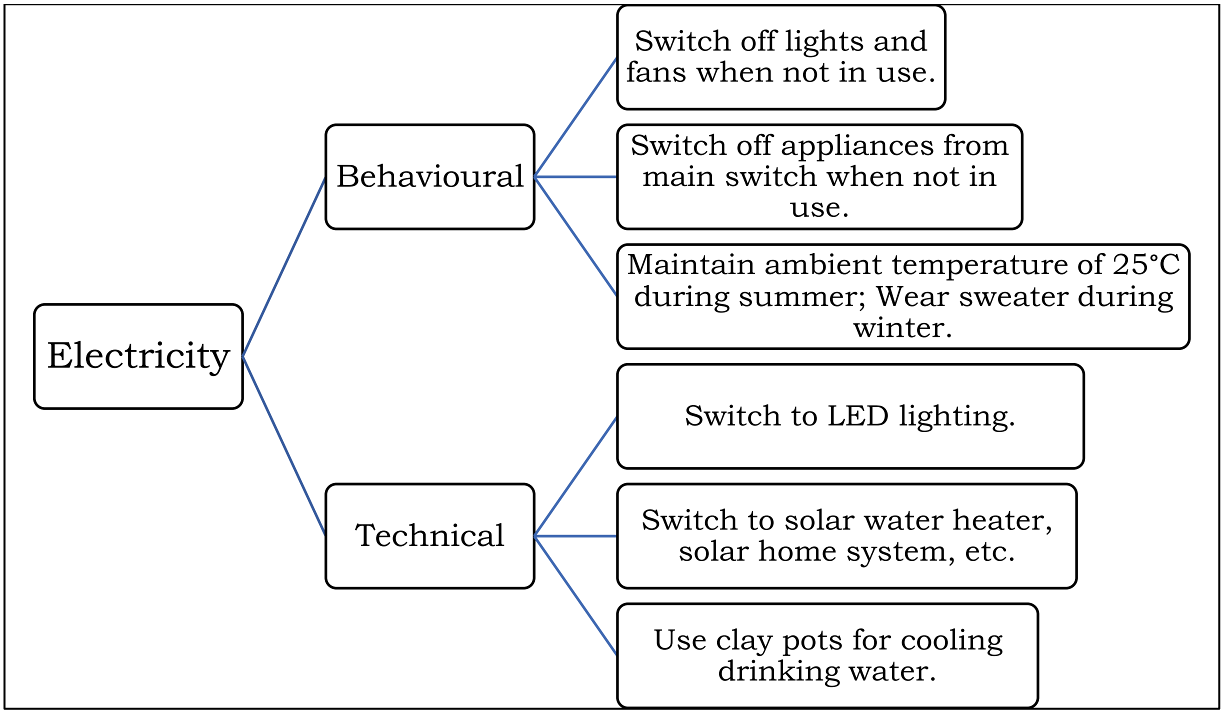
- We cause huge amounts of air, water and land pollution;
- We are incredibly lazy in our home and work habits;
- We produce enormous and completely unjustifiable amounts of waste materials;
- We have been resistant to embrace alternative energy sources;
- We gorge ourselves on animal-based diets that not only destroy our health, but also cause unparalleled amounts of deforestation and shrink our fresh water supplies to nothing.

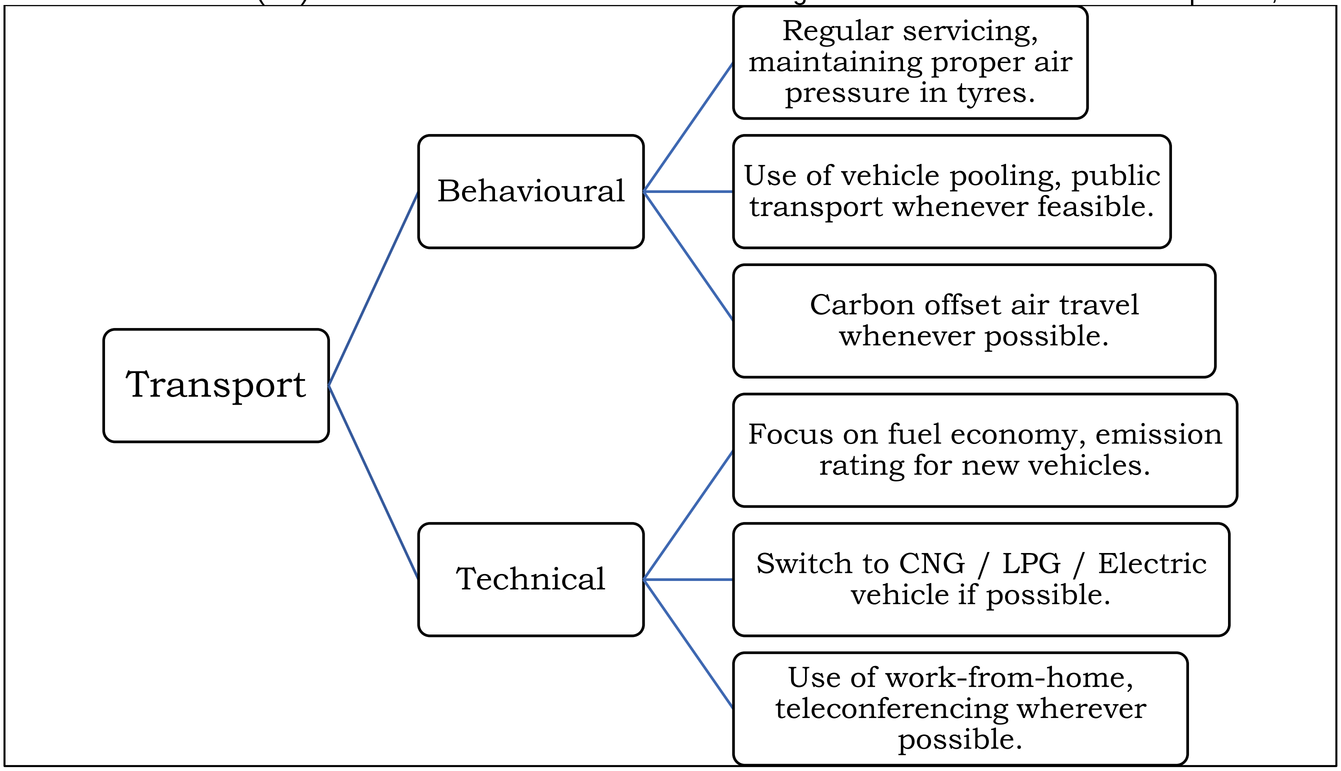
In the Indian scenario, the main sources by which we increase our carbon footprint are the following sectors:

- Energy resources usage
- Food production and processing
- Waste disposal
- Water use and disposal
- Transportation

A lot of activities in our day to day life can be modified with alternative options easily available in order to reduce the carbon footprint and contribute towards a greener planet for a longer time. It is for these reason carbon footprint calculators are available for individuals as well as organizations. Such calculators help one to get a clear figurative idea of the credit and debit of CO_2 equivalent from one's source. It gives a precise idea of the number of trees one should plant in one's life so as to nullify one's carbon footprint. The inputs given for such calculators are in terms of the criteria mentioned above and it has to be true and clear, with appropriate figures in order to receive the correct output of one's carbon footprint.

Strategies to reduce carbon footprint in two main sectors:

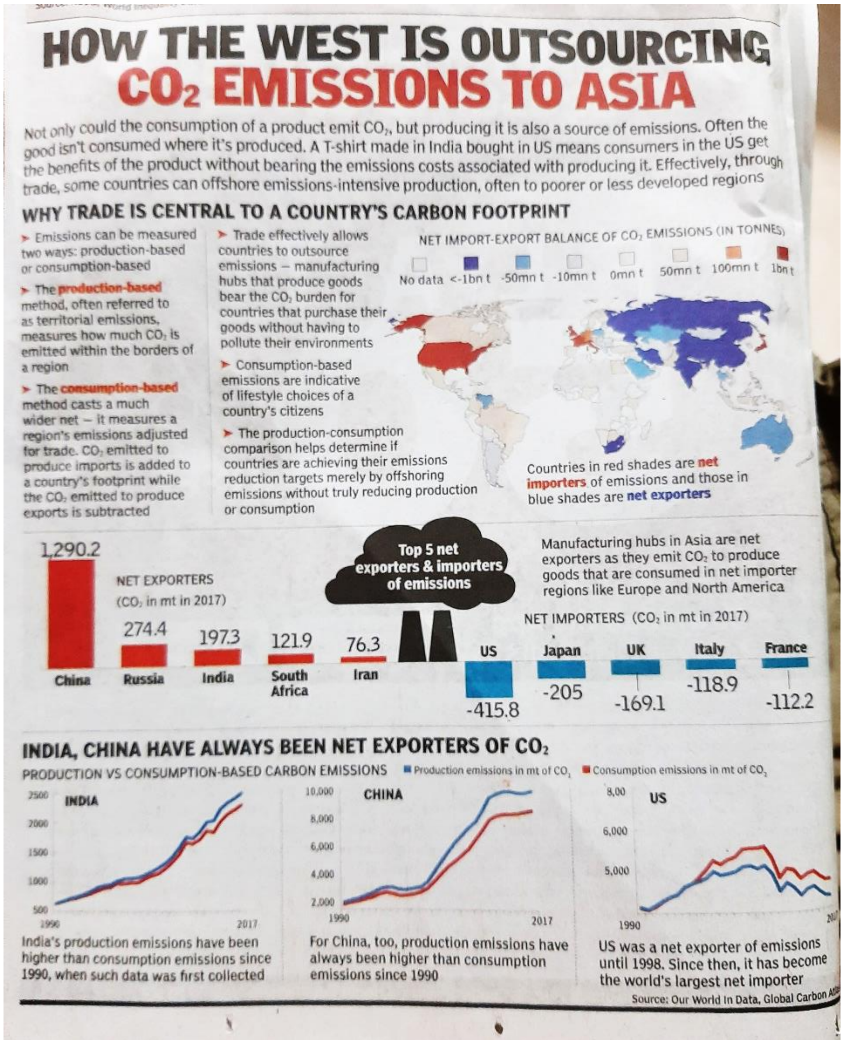




Some other general measures which can be incorporated to reduce one's carbon footprint are as follows:

- Avoiding private vehicles like cars for short journeys. Research shows that one in two urban car journeys are for less than 3 km – a distance that can be easily cycled or walked.
- Over-speeding leads to more consumption of fuel. Driving faster than 120 kmph increases fuel consumption by 30% compared with driving at 80 kmph.
- Fresh, locally grown, seasonal food generally uses less energy to produce and transport.
- Wastage of food should be strictly avoided.
- Recycle organic waste as much possible. Methane released by decomposing biodegradable waste in landfills accounts for around 3% of the European Union's greenhouse gas emissions.
- Avoid air conditioners and room heaters as much possible. A fan is always a better option. Good ventilation of the rooms also helps to reduce unnecessary expenditure of energy.
- One should not place hot or warm food in the fridge as it consumes more energy.
- Identifying and encouraging people to collect and use 'grey water' for secondary purposes like washing and watering gardens and plants.
- Rainwater harvesting must be encouraged.
- Cooking in open pans or vessels consumes more energy as compared to cooking in closed vessels.
- Bottled and packaged drinking water must be avoided as it has lot of environmental concerns.
- Taking a shower instead of a bath consumes up to four times less energy.

- Washing machines and dishwashers must be used only when they are full so as to ensure their maximum usage with least possible energy consumption.
- Select products while shopping which comes with the least packaging to reduce unwanted waste.
- Reduce the amount of waste generated, segregate them at the source, resuse as far as possible and recycle efficiently from proper authorities.



Significance of trade between countries in carbon footprinting (TOI, Dec 29, 2019)

EL NINO AND LA NINA: -

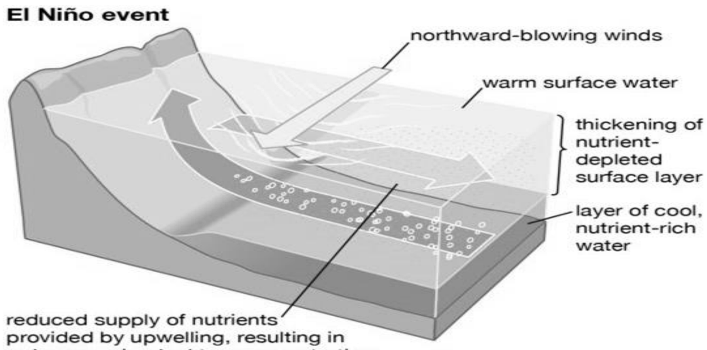
A recurring characteristic of the climate is called Climatic Pattern. The gap between two recurrences may be from one year to as long as tens of thousands of years. Some of the events are in regular cycle, while some are not. When they recur in the form of regular cycles of fluctuations, they are called climate oscillations. The term oscillation is used because such fluctuations are not perfectly periodic. For example, we say that El Nino returns every four and half years. But actually, it may or may not return. Or it may return too early or too late. So, El Nino is quasi periodic.

El Niño and La Niña are opposite phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle. The ENSO is a recurring climatic pattern involving temperature changes in the waters of the eastern and central tropical Pacific Ocean, and changes in the patterns of upper and lower level winds, sea level pressure, and tropical rainfall across the Pacific Basin. El Nino is often called the warm phase and La Nina is called the cold phase of ENSO. These deviations from the normal surface temperatures can have a large-scale impact on the global weather conditions and overall climate.

El Nino

El Nino means 'little boy' or 'Christ child' in Spanish. The phenomenon was thus named because it was first recognized by South American fishermen in the early part of the 17th century. The events, i.e., warm waters in the Pacific Ocean, tended to occur in December, hence, the name was chosen.

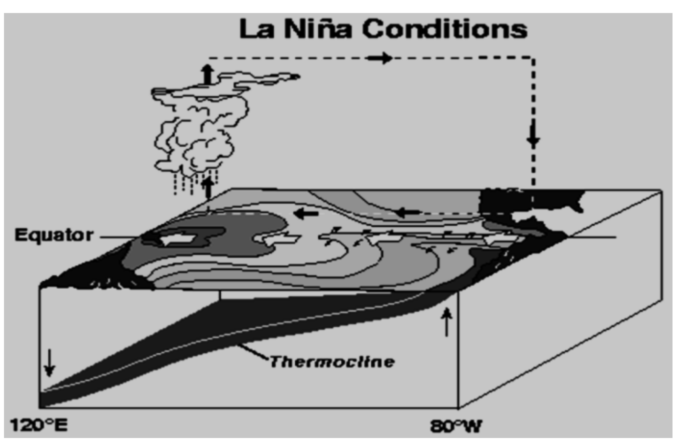
El Nino refers to the large-scale ocean-atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east-central Equatorial Pacific. It is associated with high pressure in the western Pacific. El Nino adversely impacts the Indian monsoons and hence, agriculture in India.



La Nina

La Nina means 'little girl' in Spanish and is also known as El Viejo or 'cold event'. Here, the water temperature in the Eastern Pacific gets colder than normal. As a result of this, there is a strong high pressure over the eastern equatorial Pacific. Now, there is low pressure in the Western Pacific and off Asia. La Nina causes drought in Peru and Ecuador, heavy floods in Australia, high temperatures in Western Pacific, Indian Ocean, off the Somalian coast and good monsoon rains in India. A La Nina is actually beneficial for the Indian monsoon.

Generally, El Nino and La Nina occur every 4 – 5 years. El Nino is more frequent than La Nina. Typically, the episodes last for nine to twelve months.



El Niño was originally recognized by fisherman off the coast of Peru in South America. The ocean off the coast of Peru is one of the world's richest fisheries regions. In most years trade winds flow from the southeast, pushing warm surface water away from the coast. In its place, the cold water comes up on the surface due to upwelling. This cold water is full of nutrients and provides nourishments to planktons. These planktons serve as food for fishes. Fishes in turn provide food to the sea birds. Due to all this, not only there is a good catch of fishes but also good collection of the Guano, the bird excreta, used as a valuable fertilizer. This is what that made Peru number one fishing nation in the world by the early 1970s.

Effects of El Nino

The cool surface water off the Peruvian coast goes warm because of El Nino. When the water is warm, the normal trade winds get lost or reverse their direction. Hence, the flow of moisture-laden winds is directed towards the coast of Peru from the western Pacific (the region near northern Australia and South East Asia). This causes heavy rains in Peru during the El Nino years robbing the Indian subcontinent of its normal monsoon rains. The larger the temperature and pressure difference, the larger the rainfall shortage in India. The main effects of El Nino are as follows:

- Rain & Floods occurs in Peru, Atacama and Southern USA.
- Decrease in the fishery yield in Peru.
- Drought in Northern Australia, Indonesia faces bushfires.
- Storms and Hurricanes in East Pacific.
- Coral bleaching occurs worldwide due to high temperature.
- El Nino decreases earth's rotation rate and decreases Coriolis force and increases length of day.

Effects of La Nina

A fully developed La Niña affects the areas around the tropics and even the northern hemisphere. As a La Niña event forms, the effects are noticed mostly in the tropics and the southern hemisphere. The monsoon rains over India will be a bit heavier than normal and Australia's climate will be warmer than usual.
When La Niña is fully developed it still affects the areas around the tropics, but at higher latitudes, and winter in the northern hemisphere is affected. The area around Indonesia will be wetter than usual and the areas of low pressure in the Gulf of Alaska will be weaker than usual. Alaska and Canada will have colder weather than usual while south eastern parts of USA will be warmer and dryer. Europe and the Nordic countries are hardly affected by La Niña and El Niño. The main effects of La Nina are as follows:

- Too many fishes at Peru coast, oversupply of fishes caused the prices to become dirt cheap.
- Too much rain / flood over Australia and Indonesia.
- Hot, dry and drought conditions in the Southern USA.
- Increase in the earth's rotation rate resulting in decrease in the length of the day.

El Nino and La Nina effects on Indian climate

El Nino and La Nina are among the most powerful phenomenon on the Earth. These are known to alter climate across more than half the planet and dramatically impact weather patterns. Over Indian subcontinent, El Nino during winter results in development of warm conditions. During summer, it leads to dry conditions and deficient monsoon. It also leads to drought in Australia. On the other hand, La Nina results in better than normal monsoon in India. At the same time, in Australia it has caused floods. In the recent past, India experienced deficient rainfall during El Nino years 2002 and 2009 whereas monsoon was normal during El Nino years 1994 and 1997. This so far implies that in about 50 per cent of the years with El Nino during summer, India experienced droughts during monsoon. This implies that El Nino is not the only factor that affects monsoon in India. El Nino caused severe drought in India (2009-10). Sugar price were highest in 30-year history. Since 1950, out of the 13 droughts that India faced, 10 have been during El Nino years and one in a La Nina year. This is because in general, an El Nino means lesser than average rains for India. Indian agriculture is heavily dependent on the monsoons and because of this, lesser rainfall during the monsoons generally translates to below-average crop yields.

SOME IMPORTANT DEFINITIONS: -

1. **"Adverse effect of climate change"** means changes in the physical environment or biota resulting from climate change, which has significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.
2. **"Climate change"** means a change of climate, which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
3. **"Climate system"** means the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.
4. **"Emissions"** means the release of greenhouse gases and / or their precursors into the atmosphere over a specified area and a period of time.
5. **"Greenhouse gases"** means those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorbs and re-emits infrared radiation.
6. **"Reservoir"** means a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored.
7. **"Sink"** means any process, activity or mechanism, which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere.
8. **"Source"** means any process or activity, which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere.

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