Tackling Climate Change: Science and Politics

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Climate change is one of the defining issues of our time. While science is clear about the reality of climate change caused predominantly by human activities, some are sceptical about it, while others are downright "climate deniers". Some others accept the reality of climate change but deny that it is caused by anthropogenic factors.

Climate change refers to long-term changes. Typically, the average over a period of 30 years is chosen to define climate and describe its changes. Climatic conditions are driven by energy exchanges in the atmosphere, and temperature is the most important and most commonly used parameter to characterize the atmospheric energy and, thus, the climate. Thus much of the discussion on climate change is centred on temperature change in the atmosphere.

The term global warming is often used interchangeably with climate change, though global warming is but one aspect, albeit the most important aspect, of climate change. What poses a problem in identifying climate change is the natural variability of weather in different time scales. There is diurnal/seasonal/annual variability. Days are warmer than nights, it may be sunny in the morning and rainy in the afternoon, and summer temperatures are higher than winter temperatures. Again, in some years, summer temperatures are very high, and in other years the summer temperatures are milder. Because of this natural variability, it is a daunting task to detect whether climate change happening and to elucidate its nature on a scientific basis.

Global warming

Reliable instrumental recording of weather parameters like temperature, humidity, precipitation etc., started from the middle of the nineteenth century. Now, thousands of weather stations are spread all around the globe, automatically recording temperature and other data 24×7 and transmitting them to a central hub. Scientists subject a huge amount of data to rigorous statistical analyses to arrive at an average temperature of the globe or of a specified territory during a particular year and construct a time-series curve to depict the variation of average temperature with time (Figure 1).

In such curves, generally, the difference between the measured average in a particular year and the average over a reference time period of 30 or more years is plotted rather than the absolute temperature of a particular year. Analysis of the time-series curves indicates that the average global temperature has increased by about 1.4°C from the 1850-1900 average. At the same time, it is to be noted that even within this overall trend of increase, in short stretches of time, e.g. from 1876 to 1900 A.D., there has been a slight declining trend of temperature. On the other hand, the rate of warming since 1970 is higher than the rate before. The rate of warming over the

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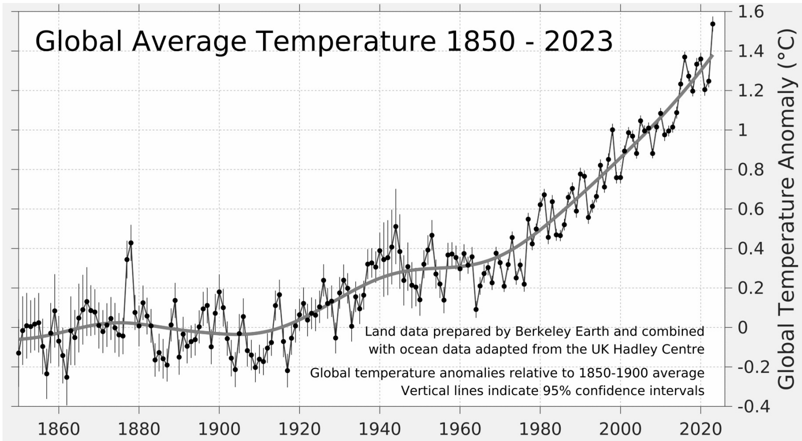

Figure 1: Global Annual Average Temperature Anomaly for the period 1850-2023 relative to 1850-1900 (pre-industrial reference interval). Instrumental measurement data are available from around 1850. Note that the annual average temperature in 2023 is 1.54 + 0.06°C above the average for the reference interval 1850-1900. (Source: berkeleyearth.org)

past thirty years is much higher than the average rate since the start of the 20th century. Therefore, the Earth is warming at a faster rate than before.

2023 has recorded the highest average global temperature in the last 2000 years; it is about 1.54°C above the average temperature from 1859-1900, regarded as the pre-industrial baseline, and 1.18°C above the 20th century average. Each month from June to December in 2023 was warmer than the corresponding month in any previous year. The last nine years stand out as the warmest nine years in the instrumental data record. There is more than a 50% probability that the global mean temperature in 2024 will exceed that in 2023. The warming rate varies from year to year, decade to decade, and place to place. Various factors are responsible for such variation. The warming is non-uniform across the globe. Most land areas have warmed more than most ocean areas, and the Arctic and the high-latitude regions are warming up more than most other regions. This has serious implications for the global climatic pattern. Measurements, therefore, indicate that the reality of global warming cannot be scientifically denied, but is it due to human activities?

Causes of Climate Change

The Earth has experienced many episodes of climate change in the past. During the last 8,00,000 years, there have been several cycles of alternate cold glacial periods, when large areas on the surface of the Earth were covered by snow and ice, and warm interglacial periods when much of the snow and ice had melted. The Last Glacial Maximum (LGM), that is, the temperature minimum, occurred about 26,000 years to 20,000 years ago. After the LGM, the temperature rose steeply until it stabilised about 10,000 years ago at the Holocene Climatic Optimum (HCO), facilitating the beginning and flourishing of human civilization. The temperature was about 0.7°C warmer than the mean 19th-century pre-Industrial-Revolution temperature. Presumably, these past changes were due to natural causes. The mean

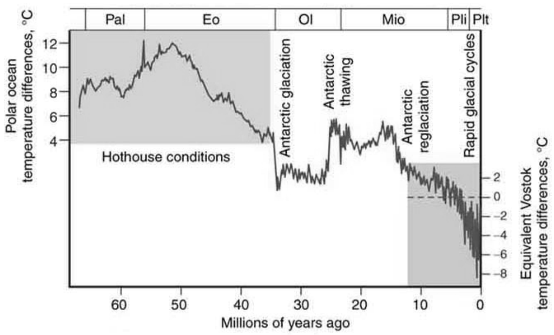

Figure 2: Annual Average Temperature Anomaly (relative to 1850-1900 average) over the past 65 million years. The time spans of the Epochs Paleocene, Eocene, Oligocene, Miocene, Pliocene and Plestocene are shown at thew top. The highest temperature was during Eocene-Paleocene, and the minimum temperature was reached during Pleistocene glaciations. (Source: Wikipedia)

global temperature started to rise rapidly about two centuries ago (Figure 2), which is related to the Industrial Revolution. There have been many other climate changes further back in time, millions of years ago, when the global mean temperature was several degrees higher or several degrees lower than the present-day maximum and minimum temperatures (Figure 3).

Clearly, such past climate changes cannot be human-induced because human beings either did not appear or were not sufficiently advanced technologically to cause climate change. These prove that natural factors can also bring about even extreme climate changes. Among the important natural factors which can bring about climate change are: (i) cyclical changes in the Earth's orbit, its eccentricity, tilt and precession, in cycles of 100,000 years, 41,000 years and 26,000 years, respectively (Milankovich cycles), (ii) changes in total solar irradiance, and (iii) volcanic eruptions which spew CO_2 and other gases into the atmosphere, and (iv) natural fluctuations in the climate system such as El Nino and La Nina. However, natural climate changes take place on a geological time scale, that is, hundreds of thousands or millions of years, while current human-induced changes are taking place within 2 or 3 centuries. Human-induced changes are much faster than natural changes. After the last glacial age the Earth had warmed up by about 4° to 5°C. However, this occurred over a span of 7000 years, whereas the speed of warming over the last 50 years is ten times more than at the end of the ice age; it is the fastest known sustained change on a global scale.

The majority of scientists are convinced that the present phase of climate change is principally caused by the emission of greenhouse gases (carbon dioxide, methane, nitrous oxide, and some other gases in very minor quantities) due to human activities, primarily due to burning of fossil fuels like coal, gas, and oil. They came to this conclusion because the rapid rise in the average temperature of the Earth coincides in time with the rapid rise in the concentration of greenhouse gases in the atmosphere (Figures 3 and 4). Measured decreases in the isotopic fractions of ^{13}C and ^{14}C in atmospheric CO_2 also suggest that the rise in CO_2 concentration is largely due to the burning of fossil fuels, which have low fractions of ^{13}C and no ^{14}C.

Climate models can simulate the changes in global temperatures due to the operation of different natural and man-made (anthropogenic) factors. Such simulations show that if only natural factors are in operation, the simulated temperature variation does not match with the observed temperature variations. Simulations with both natural and man-made factors fit with the observations. Thus, climate models provide evidence that observed global warming is mainly due to anthropogenic greenhouse gas (GHG) emissions.

Greenhouse gases in the atmosphere lead to global warming because they trap the sun's heat in the atmosphere, and with an increase in the GHG concentration in the atmosphere, the atmospheric and the Earth's surface temperatures rise. Among the GHGs, CO_2 is the most abundant (76%), followed by methane (16%) and nitrous oxide (6%); halocarbons and other gases are only 2%; methane has nearly 30 times more potential for global warming than CO_2 and nitrous oxide has nearly 270 times more, but methane and nitrous oxide have very low concentrations in the atmosphere; so their net contribution to warming is less compared to that of CO_2. The warming effect of all GHGs taken together is usually expressed as CO_2 equivalent.

In nature, there is a continuous exchange of CO_2 between the atmosphere, plants and animals through the processes of photosynthesis, respiration, and decomposition. Volcanic eruptions add a very small amount of CO_2 to the atmosphere, and on the other hand, a very small amount is removed by the chemical weathering of rocks. The balance in the natural carbon cycle is disturbed by human activities; burning of fossil fuels adds CO_2 to the atmosphere; deforestation by humans also contributes to the rise of CO_2 levels in the atmosphere. Natural processes that could restore the balance are too slow in removing the CO_2 compared to the rate at which it is put into the atmosphere by human activities. Hence, a substantial proportion of anthropogenic CO_2 remains in the atmosphere and can stay there for tens, hundreds, or even thousands of years, and continue to contribute to warming.

CO_2 emissions come mainly from the burning of fossil fuels for electricity generation and heating, transport, and manufacturing and construction industries. The largest methane sources are livestock, predominantly cattle, and wastewater; other sources are coal mining, rice cultivation, biofuel combustions, landfills, and the use of natural gas, which is majorly composed of methane. It is estimated that human activities currently emit about 10 billion tonnes of carbon dioxide each year. The rise in nitrous oxide concentration is due to changes in the use of nitrogenous fertilisers and land use. Aerosols, which are suspensions of fine solid particles or liquid droplets released by the industry into the atmosphere, can give rise to heating or cooling of the atmosphere, depending on their properties. Trees absorb CO_2 from the atmosphere during photosynthesis. Therefore deforestation and consequent land use change lead to an increase in CO_2 concentration in the atmosphere. Loss of surface reflectivity (surface albedo), like loss of ice cover, is also a factor causing warming. The Amazon rainforest is some-

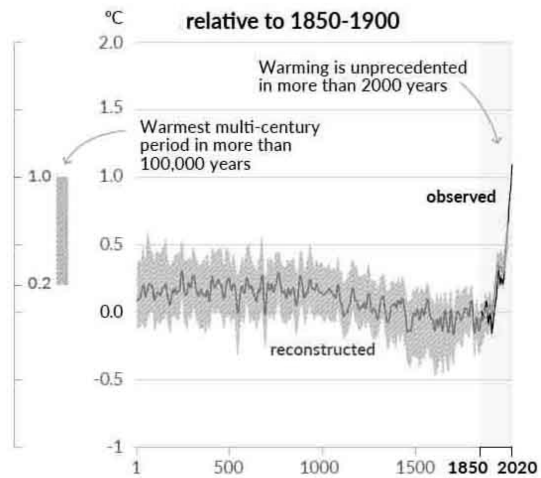

Figure 3: Global Annual Average Temperature Anomaly (relative to 1850-1900 average) over past 2000 years. The temperature was more or less uniform and 0.1-0.2°C above the average temperature during 1850-1900 till 1000 AD. A declining trend starts from about 1200 AD, and this is reversed by the current phase of warming starting about 1700-1800 AD. (Source : Wikipedia)

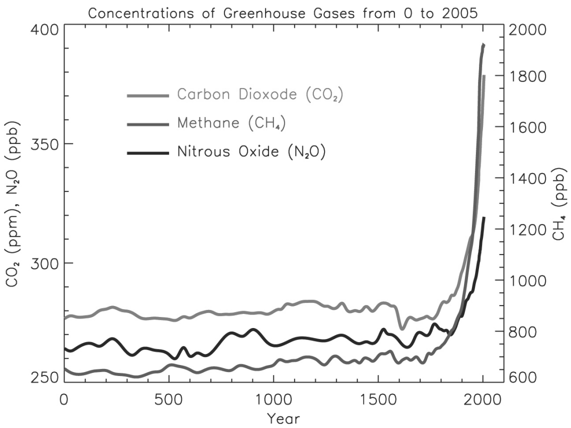

Figure 4: GHG concentrations in the atmosphere during last 2000 years (hockey-stick curve). The concentration of CO_2 is in parts per million, those of N_2O and CH_4 are in parts per billion. Note the rapid increase from 1700-1800 AD. (Source : US Global Change Research Programme; 2009 Report)

times called the lung of the earth because the huge forest absorbs a great amount of CO_2 to keep its concentration optimum in the atmosphere. Unchecked agricultural expansion and reckless felling of trees in the Amazon forest have contributed to global warming. Since the time of Brazilian President Bolsonaro, after 2019, more than two billion trees have been cut down, and it is estimated that by 2022 26% of the forest will have disappeared.

It is also to be noted that CO_2 can be removed from the atmosphere by planting additional trees because trees absorb CO_2 in the atmosphere through the process of photosynthesis. Thus afforestation arrests warming. CO_2 can also be removed by adopting carbon sequestration technology, but this technology is still in the developing stage.

The extent of the climate crisis is revealed by the increase in the CO_2 level in the atmosphere over the course of the past 200 years. For more than 10,000 years, the CO_2 concentration in the atmosphere remained within the range of 260 to 280 ppm; it started to increase from about 1800 AD, and during the last two hundred years, the concentration has skyrocketed to more than 420 ppm giving rise to the well-known hockey stick curve (Figure 4); this value is higher than any attained during at least the previous one million years. The curves for methane and nitrous-oxide show similar jumps (Figure 4). Since pre-industrial times the CO_2 concentration in the atmosphere has increased by over 40%, the methane by over 150%, and nitrous oxide by about 20%. Half of the CO_2 increase took place after 1970, about the time when global energy consumption accelerated]. The increase in GHG concentration is mirrored by the sharp increase in the global mean temperature by about 1.4°C in the post-Industrial-Revolution era. The culprits are the burning of fossil fuels to propel industrialization and deforestation to expand farmlands. It is to be noted that Earth has experienced higher CO_2 levels and higher temperatures than today. 50 million years ago, the CO_2 level in the atmosphere was about 1000 ppm, and the average surface temperature was 10°C higher than today's (Figure 2). Then the Earth had practically no ice, and the sea level was 60 m higher than today.

Impact of Climate Change: Now and in Future

1. A spectacular effect of global warming is the increased melting of the mountain glaciers and the polar ice caps. The area of the Arctic sea ice has shrunk so much that in summer, the passageway from the Atlantic to the Pacific across the Arctic Ocean has become open. Melting of the Arctic sea ice induces further warming because less ice means less reflection of the solar radiation from the surface and more absorption, consequently heating the dark

ocean. Thus the more the ice melts, the hotter the region becomes; this is known as Arctic amplification (feedback effect). Heating in the Arctic region would bring more intense heat waves but would also bring extreme winters in Europe because of the destabilization of the polar jet stream. The disappearance of the Arctic sea ice would cause a weakening or even stoppage of the Atlantic Meridional Circulation, which would have a profound impact on marine life and the global climate pattern, in particular on the climate of the European countries.

2. Melting of the Greenland ice sheet, the Antarctic ice shelves and the mountain glaciers are contributing to sea level rise because all the meltwater eventually finds its way to the sea. Glacier run-off in the Himalayan Mountains will increase up to the mid-21st century; subsequently, the run-off will decrease due to the loss of glacier storage. In the long run, the river systems which are sourced from the glaciers, like the Indus, the Ganges, etc., are likely to dry up.

3. Permafrost (permanently frozen ground), which covers large areas in the Arctic regions of Siberia, Greenland, Canada, Alaska, Tibetan plateau, etc., is prone to thawing as the temperature rises. Thawing permafrost would cause instability of the land surface and lead to subsidence and collapse. At the same time, permafrost thawing causes the release of CO_2 and methane as a result of microbial decomposition. The release of these greenhouse gases due to permafrost thawing would further increase global warming (feedback effect).

4. Overall warming leads to more water vapour content in the atmosphere and, consequently, more rainfall. However, the relationship between global warming and rainfall is complex; increases are very likely in high latitudes, the equatorial Pacific, and parts of the monsoon regions, while decreases are likely in subtropical land regions and limited areas of the tropics. Scientists have estimated that every degree Celsius of warming is likely to increase monsoon rainfall by 5%. The monsoon precipitation is projected to go up in the mid- to long-term in South Asia. The increase in rainfall will be more severe over the southern parts of India. Compared to the 1850-1900 level, the rainfall on the southwest coast may increase by 20%. Increased precipitation in the mountainous areas may give rise to glacial lake outbursts, floods, and landslides, as happened in the 2013 Kedarnath disaster and the 2021 Rishi Ganga disaster, both in Uttarakhand.

5. Global sea levels are rising because of two factors: (i) Thermal expansion due to ocean warming and (ii) melting of mountain glaciers and of ice sheets on Antarctica and Greenland. The global average sea level has risen by about 250 mm since 1880. Precise satellite measurements indicate that between 1997 and 2013 the average rate of rise of global sea level was 2.9 mm/year; this accelerated to 4.62 mm/year for the period 2013-2022. Relative sea levels around Asia have risen faster than the global average. Some of the small island countries face the prospect of submergence. Many coastal areas in India, particularly the Sundarbans and parts of the eastern coast, are extremely vulnerable to the impact of sea level rise – land loss and shoreline retreat. Agriculture is also adversely affected by saline water incursion, and millions of people are facing the spectre of displacement from their home territory.

6. An increase in atmospheric CO_2 concentration associated with global warming would cause greater absorption of CO_2 in the ocean and lead to ocean acidification. Models also predict that warm-

ing will lead to oxygen depletion in large parts of the ocean. Another worrisome point is that methane hydrates on the floor of deep oceans would be destabilized by rising temperatures and release methane into the atmosphere, which would lead to further warming (feedback effect). Changes in temperature and resultant changes in the chemistry of the oceans would have devastating effects on marine life, ocean circulation, and global climatic patterns. Mass bleaching of coral reefs has already started.

7. (a) Global warming leads to the storage of more energy in the atmosphere and the oceans. As a consequence, extreme weather events like heat waves, cyclones, excessive rainfall and flooding, and ecological and agricultural droughts become more frequent and intense. The European heat wave of 2003 was associated with never-before-experienced temperatures and led to thousands of deaths. The heat wave in America in 2012 broke all temperature records. India experienced heat waves in three consecutive summers since 2020. In July-August 2022, there were simultaneous heat waves in at least 33 countries across five continents. The Indian Meteorological Department has forecast an unusually high number of heat-wave days from April to June 2024. High humidity often adds to the heat stress. It has been estimated that the areas under heat stress have gone up by 30% to 40% in the past 70 years. Heat waves and humid stress will become more intense and more frequent in South and Southeast Asia during the 21st century. The maximum brunt will be borne by the poor and marginalized people, the slum dwellers in the cities, living in overcrowded tenements.

(b) High temperatures have given rise to devastating wildfires in Australia, Canada, the southwestern United States, Spain, Portugal, Greece, and many other countries. In India, the number of wildfire incidents is also going up because of the heat wave. The tribal people living in the forests are the worst victims.

(c) Warmer oceans provide extra energy to tropical cyclones and make them more frequent and stronger. The Bay of Bengal is notorious as the birthplace of many cyclones. In recent years the frequency of severe cyclones has increased, and they have become more intense and more destructive, e.g., Orissa super cyclone in 1999, Cyclone Nargis in 2008, Cyclone Aila in 2009, Cyclone Fani in 2019, Cyclone Amphan in 2020.

(d) Warm air holds more moisture leading to intense rainfall events. Several localities spread all over the globe have witnessed excessive rainfall spread over a few days, which caused extensive damage to homes and infrastructures and massive losses of lives. The latest example is the unprecedented flood in otherwise arid Dubai in 2024. Several European countries witnessed catastrophic floods following heavy rains in 2021. Well-known extreme rainfall events in our country are the Mumbai floods in 2014 and 2017, the Chennai floods in 2015, and Kerala floods in 2018, and the Assam floods in 2022. Extreme rainfall events are becoming more frequent and more intense and are linked to broader climate changes and the warming of oceans. Extreme rainfall events in mountainous regions may cause devastating landslides, as witnessed in the recent Wayanad disaster in Kerala.

8. Global warming is leading to prolonged droughts in some areas, resulting in water scarcity, which affects agriculture and water supply and poses a threat to food security. Several regions of India, like Rajasthan, Maharashtra, Andhra Pradesh, and Karnataka, have

faced droughts in recent years. Extreme weather events, droughts or floods, devastate crops and livestock, resulting in food shortages. Marginal farmers face ruin from such events.

9. Climate change adversely affects human health. Heat waves increase the risk of heat-related illnesses, heat strokes, and deaths. Rains and floods cause the spread of vector-borne and water-borne diseases, while prolonged droughts may cause malnutrition and increase the spread of vector-borne diseases. Thus climate change adversely affects public health. There is also the danger of the release of deadly viruses and bacteria due to thawing in the Arctic permafrost regions.

10. Climate change has a profound impact on the biosphere. This includes earlier timing of spring events like leaf-unfolding, bird migration, and egg-laying; and poleward and topographically upward shifts in ranges in plant and animal species. Climate change exacerbates the loss of biodiversity through the extinction of many species. Adaptive mutation can also result in the creation of new species that are harmful to that ecosystem.

11. Climate change impacts the economy not only because of its link with resource mobilization but also because of its effect on productivity. Adverse climatic events result in severe economic losses due to damage to infrastructure, property, and businesses, as well as loss of life. Recovery and rebuilding often pose a big challenge. N. Kumar and D. Maity of the Delhi School of Economics have shown in a study that in India, "on average, one degree Celsius temperature rise has depressed economic growth by approximately 3.89%, with substantial variations across states, sectors and income groups." They further said that the "poorer and less developed states are expected to be more vulnerable than others because of their dependence on agriculture and ecological resources. The GSDP [Gross State Domestic Product] growth is projected to decrease by a range of 5.25% to 24.51% during 2020 to 2100 from the Stringent Mitigation scenario (SSP1 – 2.6) to the Business-As-Usual scenario (SSP5 – 8.5)." (See later for an explanation of these terms)

12. In the context of climate change, scientists have brought up the concept of Tipping Points. They have identified about 16 climate-related systems on the Earth that have certain temperature thresholds or tipping points, which, when crossed, may bring large, accelerating, and often irreversible changes leading to catastrophic consequences. Some examples of such systems with tipping points are the Greenland Ice Sheet, the West Antarctic Ice Sheet, the Amazon Rainforest, warm water coral reefs, Atlantic Meridional Overturning Circulation, and Labrador-Irminger Sea Convection. Scientists aver that several of the systems, like the Greenland Ice Sheet, West Antarctic Ice Sheet, boreal permafrost, and warm water coral reefs, are already very close to their tipping points now when the world is 1.480 warmer than the pre-industrial period. Many others will breach the tipping point as the Earth gets warmer. Scientists have also warned about the possibility of abrupt climate change, in which gradual global warming triggers a sudden shift in the earth's climate, causing parts of the world to dramatically heat up or cool down in the span of a few years.

What does the future have in store?

The Earth is set on a course of global warming and consequent climate change. The scientific evidence also suggests that the present phase of warming started with the Industrial Revolution; since then, human activity has put more and more greenhouse

Table 1: Different scenarios.

Scenario	GHG Emission Features	Estimated warming 2041-2060	Estimated warming 2100	Estimated average Sea Level Rise
SSP1-1.9	Very low emission; Net zero around 2050	1.6°C	1.4°C	0.38 m
SSP1-2.6	Low emission; Net zero around 2075	1.7°C	1.8°C	0.44 m
SSP2-4.5	Intermediate emission; Current level till 2050, then fall, net zero not attained	2.0°C	2.7°C	0.56 m
SSP3-7.0	High emission; Double by 2100	2.1°C	3.6°C	0.68 m
SSP5-8.5	Very high emission; Triple by 2075	2.4°C	4.4°C	0.77 m

gases in the atmosphere.

What will happen in the future will depend on what development strategies we adopt and what aggressive actions we take to reduce GHG emissions. The Intergovernmental Panel for Climate Change (IPCC) has outlined five different scenarios, each of which is an emission pathway paired with a Shared Socioeconomic Pathway (SSP). Each of these SSPs is characterized by certain socio-economic global changes till 2100. These are SSP 1-1.9, SSP 1-2.6, SSP 2-4.5, SSP 3-7.0 and SSP 5-8.5. The last two digits in each of them represent net energy gain by the atmosphere measured in watts/m2 as a result of emission in 2100 A.D. SSP-1 represents Sustainable Development; SSP 2 is designated as Middle-of the Road, SSP 3 as Regional Rivalry, and SSP 5 as Fossil-Fueled Development. The details are given in the IPCC Report. The emission characteristics and the resultant future warming in the different scenarios till 2100 are given in Table 1 and Figure 5.

Future warming for different emission scenarios

Thus, if we do not take any corrective steps, the temperature will rise by > 4°C by 2100, putting the survival of civilization and human society at stake. Scientists aver that a 1.5°C to 2.0°C rise in global mean temperature is the maximum acceptable limit, up to which we can adapt.

Beyond a 1.5°C rise, the climate would become unstable, there would be more frequent extreme weather events, like severe drought, intense heat waves, devastating wildfires, powerful cyclones, and bleaching of corals, the disappearance of the Arctic sea ice, ecosystem disruption, disastrous sea-level rise, disruptions in food production and crop failure and habitat destruction. If we want to keep the warming to the level of 1.5°C to 2.0°C, the current emission must be reduced by 45% by 2030 relative to the 2010 level, and the net zero emission, that is when the GHG added to the atmosphere and the GHG removed from it becomes the same, must be attained by 2050. It is to be noted that CO_2 stays in the atmosphere for many years, and even if the emission stops instantaneously, the temperature will continue to rise before it comes down.

For over 6000 years, people have resided in the same climatic niche or temperature range suitable for living with annual mean temperatures between -11°C and 15°C. But in a warming world, if emissions go unabated, by 2070, 19% of the Earth's

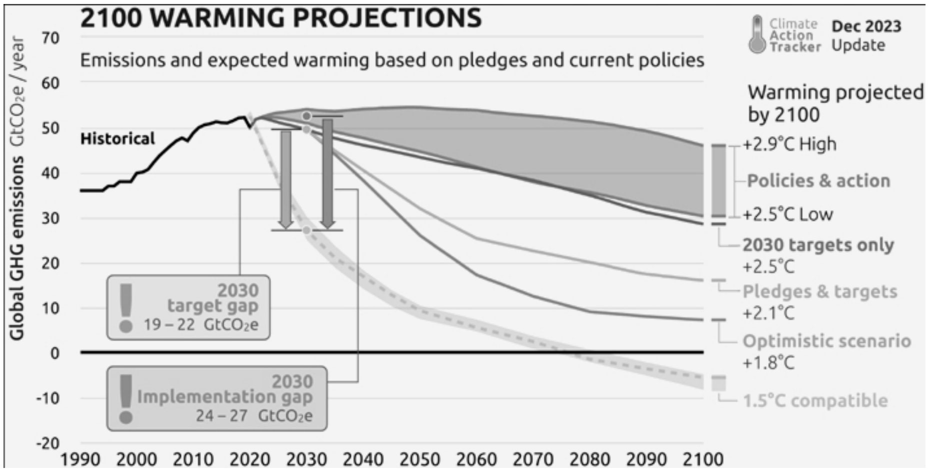

Figure 5: Global GHG concentration, projection till 2100 for different scenarios. Corresponding temperature increases by 2100 are indicated in the right. The gaps between the 1.5°C pathway and the 2030 target and the projected 2030 current policy implementation are also indicated. Current policies presently in place around the world are projected to result in about 2.7°C warming (median value) above pre-industrial levels. NDCs alone will limit warming to 2.5°C. When binding long-term or net-zero targets are included warming would be limited to about 2.1°C above pre-industrial levels. (Source : https://climateactiontracker.org/global/temperatures/)

surface will experience an annual mean temperature of 29°C or more, which would be unbearable. This will affect 3 billion people, mostly from poor countries and drive climate migration. India would be one of the worst-affected countries in Asia. India would become very vulnerable to heat stress. Climate change has given birth to a new phenomenon, that of climate refugees, that is, whole sections of the populations are driven out from their homelands by sea-level rise or by extreme weather events, like excessive heat, severe droughts, storm surges, and inundation. We are already witnessing this in the Sundarbans in Bengal and other regions across the globe.

What can we do to tackle Climate Change?

Global warming is upon us. Thousands of scientists from all over the world broadly agree on what is happening, what is likely to happen, and what we can do. It is too late to avoid damage, but it is not too late to avoid catastrophe. But we have delayed so long that it would need a gigantic social effort and a fundamental change in the way societies and governments think and act.

Scientific research has established that there is a direct relation between the global average temperature and the concentration of GHG in the atmosphere. The carbon budget represents the “maximum amount of cumulative net global anthropogenic carbon dioxide (CO_2) emissions that would result in limiting global warming to a given level”. It is also called emissions budget or quota or allowable emissions. Thus, for a 1.5°C rise in temperature from the pre-industrial value, the median value of atmospheric CO_2 would be 507 ppm, and for a 2°C rise, it would be 618 ppm. This is called the total carbon budget. The average 2023 concentration of 420 ppm is close to these values. The difference defines the remaining carbon budget. To keep climate change in check, the target should be to adopt an emission pathway that would keep the CO_2 within the remaining budget to keep the temperature rise below the threshold value of 1.5°-2°C.

Mitigation and adaptation are the twin strategies used to face the consequences of climate change. As there is a direct relation between global average temperatures and the concentration of greenhouse gases in the atmosphere, the key to the solution to the climate change problem rests in decreasing the amount of emissions released into the atmosphere, that is, reducing the carbon intensity of industrial processes, primarily power generation. This can be done by transitioning to solar, wind, and small hydroelectric power generation, making buildings and appliances more energy efficient, switching to electric cars and public transport, and designing cities so that people have to travel less. Along with it, measures are to be taken to reduce the current concentration of carbon dioxide (CO_2) by enhancing sinks (e.g. increasing the area of forests, developing carbon capture and storage (CCS) technology or carbon sequestration technology). Efforts to reduce emissions and enhance sinks are referred to as mitigation. It has been suggested that the introduction of a carbon tax may provide an incentive to corporates to change over to emission-reducing technology. Alternatively, the Government may fix emission standards for different industries and levy a fine for the violators. The revenue generated from the tax or the fine is to be spent for the welfare of the low-income victims of climate change. Another financial mechanism that has been suggested is carbon offsetting or carbon credits, the so-called cap-and-trade system, though several criticisms from the viewpoint of efficacy in emission reduction and climate justice have been levelled against this mechanism.

Adaptation involves adjusting the social, economic, and environmental practices to live with the damage caused by climate change. This includes building resilient infrastructure, developing early warning systems for extreme weather, planning for sea level rise like building guard walls, enacting new building codes so that houses are energy efficient and/or flood or storm resistant, constructing of adequate drainage system and its proper maintenance, crafting new financial instruments to take care of losses due to climate-related disasters, promoting behavioural changes like shifting to new agricultural practices, promoting scientific research on tackling climate hazards, etc. The metropolises have now turned into heat islands as a result of global warming. Concrete multi-rises and asphalt roads get heated quickly and retain the heat, so that they do not get cool even in the night. The cities are 20-4°C warmer than the surrounding rural areas. Appropriate adaptation measures for such situations are (i) to have more green cover (at least 20% of the total area), these may be tree-lined streets, parks, grassy lawns, urban forests, etc., (ii) to protect and expand water bodies, (iii) to have better insulated or carbon credited and ventilated buildings (iv) to have energy- efficient air-conditioners and other appliances.

Climate Change and Politics

Climate change is a global phenomenon, and the efforts to combat climate change and its adverse effects should also be global. This realization led to the establishment of the United Nations Framework Convention for Climate Change (UNFCCC) as an instrument for international negotiations. The annual Conference of Parties (CoP) is its supreme decision-making body.

The developed countries have the historical responsibility for the present accumulation of GHG through industrialization using fossil fuels, while the developing countries, which suffer the worst due to climate change, have contributed the least towards GHG accumulation. For improving the quality of life, the developing countries also aspire to tread the path of industrialization and hence increase their GHG emission. The principle of common but differentiated responsibility was accepted in the Rio Summit of 1992, which stated that the developed world would be required to bear the major brunt of emission reduction and to help the developing countries through financial aid, technology transfer, and capacity building so that they can achieve economic progress through new technology with less or no GHG emission and their right to development is not compromised. The developed countries did precious little to reduce their own emissions, provide finance, or transfer technology to the developing countries to combat climate change.

It needs to be pointed out that the developed world reaped all the benefits of industrialization, and it is their affluent lifestyle and rampant consumerism that is responsible for the present elevated GHG concentration. The contribution of the poor developing countries to the total GHG in the atmosphere is minimal, but it is they who are the worst victims of climate change. In all countries, the poor, the marginal people in the cities as well as villages are least responsible for CO_2 emission, but they are the worst sufferers of the adverse effects of climate change, be it intense heat waves or droughts or storm surges or floods or coastal inundation. Therefore, all policies to tackle climate change must keep the questions of equity, justice, and fairness as their central concerns. But this is often not done.

At the Kyoto Conference (CoP 3) in 1997, the developed world agreed to take on legally binding targets to reduce emissions, but the targets set were a pittance and not enough to stop global warming. The USA, a major emitter of GHG, did not even sign the Kyoto Protocol. In the following years, several CoP summits were held, but the climate negotiations did not yield any tangible result. No progress was made on reducing GHG emissions due to the intransigence of the developed countries about emission reduction; the GHG emissions of countries like the USA, Australia, Spain, and Canada progressively rose after 1990.

While talks were going on in the CoPs, the global CO_2 emission rose from 22 gigatonnes (gt) of CO_2 in 1990 to 37.55 gt of CO_2 in 2023. There were acrimonious arguments between wealthy nations and poorer countries about who has the major responsibility to address the issue of climate change and how much support should be provided to the poorer nations to reduce their emission and tackle the adverse impacts of climate change. India and China, with the ambition to develop industry, depend mainly on coal for power generation, and their emissions rose significantly, though their per capita emissions were way below those of the USA and Canada.

The concept of historical responsibility, equity and justice in climate policy was thrown to the wind in the Copenhagen CoP 15 (2009). The Paris Summit of 2015 adopted the goal of keeping the temperature rise below 2°C, preferably below 1.5°C., and called for rapid, deep and sustained reductions in global greenhouse gas emissions, reducing global carbon dioxide emissions by 45 per cent by 2030 relative to the 2010 level and achieving net zero emission around 2050 [Ref]. At the Paris Summit, it was accepted that the countries declare their voluntary but non-binding emission targets, called the Nationally Determined

Contributions (NDC). The hollowness of the NDCs becomes apparent when we note that the cumulated value of cuts by the developed countries amounted to only 0.8-1.8 billion tonnes of CO_2 equivalents, while the developing countries agreed to cumulatively cut 2.3 billion tonnes of CO_2 equivalents by 2020. The fact is that the world's carbon budget has been appropriated by a few wealthy countries, and only crumbs are available for the rest of the world.

The UN warned in September 2021 that the countries' revised targets were too weak and would leave the world on track to warm by 2.7°C. Even the last CoP-28 held in 2023 in Dubai noted with serious concern that progress was too slow across all areas of climate action – from reducing greenhouse gas emissions to strengthening resilience to a changing climate to getting the financial and technological support to vulnerable nations.

Another tricky point is the question of finance. The developing countries aspire to industrialize to improve their standard of living. For this, they need funds from the developed countries to phase out fossil fuels, transition to renewable energy (solar, wind, small hydro), and follow pathways for low-carbon growth. However, the developed countries are not very forthcoming in offering financial help to the poor countries affected by climate change. Wealthy countries promised in 2009 to contribute US $100 billion a year to a Green Climate Fund (GCF) by 2020 to help developing nations, but this did not materialize, and the total portfolio of the GCF stood at only US $13.5 billion in 2022. A positive development at Dubai Summit in 2023 is the formation of a Loss and Damage fund to take care of the crippling losses suffered by countries and communities as a result of climate-change-induced extreme weather events.

Overall it has to be acknowledged that these international summits have not done enough to initiate effective and sustained coordinated action across the globe to restrict global warming below a certain agreed threshold, based on justice, equity, and fairness. Nor is the demand of the developing countries for financial aid to facilitate transitioning to a low-carbon economy effectively addressed. What is urgently needed today is to build strong people's movements in all countries, urging their respective Governments to be proactive both in the national and international arenas in effectively combating the menace of global warming.

The Indian Scene

India is the seventh most affected nation by climate change. We are already witnessing the ravages caused by extreme weather events. Entire North India has experienced unprecedented severe heat waves, with temperatures going up to 500C in some places. Several regions like Maharashtra, Rajasthan, Gujarat, Bundelkhand, and parts of Telangana and Karnataka are afflicted by severe droughts affecting the food supply. Over the years, extreme rainfall events have caused devastating floods in Chennai, Mumbai, Kerala, and this year in Assam. The Himalayan regions are particularly vulnerable to the effects of climate change. Glaciers are melting, profoundly affecting the hydrology in the mountains and the plains. Glacial lake outbursts and extreme rainfall events are responsible for a number of disasters in the mountains. In the Bay of Bengal, tropical cyclones are becoming more severe and more frequent, affecting the livelihood of millions of people. The Union and State Governments need to put in place robust adaptation measures to counter the adverse effects of climate change. Some steps have been taken, but more needs to be done.

A National Action Plan for Climate Change was released on June 30, 2008. It had 8 sub-missions to carry out the task, like the National Solar Mission, National Water Mission, National Mission for a Green India, and National Mission for Sustainable Habitat, etc. India's updated NDC document (2022) committed to the adoption of a climate-friendly and cleaner path of economic development. It was declared that the country would reduce total projected carbon emissions by 1 billion tones by 2030, would create an additional carbon sink of 2.6 to 3 billion tonnes of CO_2 equivalents through afforestation, would meet 50% of its energy requirement by renewable sources by 2030, would reduce the carbon intensity of its economy by more than 45% by 2030, and would achieve zero emission by 2070.

India's climate policy was announced by Prime Minister Narendra Modi at the Glasgow Cop 2021. But there is a disjunct between promises and ground reality. India's electricity plan includes adding substantial new coal power capacity in the following five years, and the government is pushing for increased domestic coal production. Coal India Limited (CIL), the near-monopolistic coal company in India, produced 622.63 million tonnes (mt) of coal in 2021-22 and 773.64mt in 2023-24, an increase of 24% in 2 years, and the target for 2024-25 is 838.00 mt, an increase of 35% from 2021-22. Moreover, the import of coal increased during the same period from 208.93 mt to 261.00 mt. India's oil consumption is projected to rise to 7 billion barrels per day (bbd) in 2030 from 2 bbd in 2022 (Data from International Energy Agency (IEA).

India is also making arrangements to increase its Liquefied Natural Gas (LNG) imports. The IEA's analysis projects that India's total energy-related emissions will peak around 2035, while emissions from the power sector will peak around 2030. Thus, far from phasing out the use of fossil fuel, as envisaged in Glasgow CoP, India has boosted its fossil fuel usage. India's progress in solar power installation is good, but there is a shortfall between the target and the installed capacity. In 2022, there will be a shortfall of 32 GW from the target of 100 GW. India's projected power capacity by 2030 is 900 GW. Increasing the renewable capacity to 450 GW from the current installed capacity of 172.5 GW in seven years is a big challenge.

To achieve net zero emissions, an important task is the preservation and extension of forest cover. The target was set up to create an additional carbon sink of 2.6 to 3 billion tonnes by 2030 through afforestation and reforestation. However, the new Forest (Conservation and Augmentation) Act of 2023 would lead to more conversion of forestlands. The Act is promulgated with a view to facilitating commercial exploitation of forests; it exempts a host of infrastructural projects in forest areas from environmental scrutiny, and it also allows some non-forest activities on forest lands, like running zoos and 'eco-tourism' facilities. Faced with criticism, the Government says that any destruction of the forest must be compensated by planting trees elsewhere, but a scientific study shows the carbon sequestration potential of natural forests is 40 times greater than that of plantations. Moreover, cutting down forests also results in a loss of biodiversity. The performance of the Indian Government does not inspire confidence that it would be able to honour the promises made at Glasgow CoP.

Though there have been some positive developments in terms of climate change mitigation policies, the non-government agency Climate Action Tracker (CAT) has rated India's climate targets and action as "Highly insufficient", signifying that India's climate policies and commitments are not consistent with the Paris Agreement's 1.5°C temperature limit. CAT has also rated India's current policies and actions as "Insufficient" in the context of the Paris Agreement and has remarked that "India needs to adopt stronger targets that will drive actual emissions reductions and accelerate climate policy implementation. The country will need international support to get onto a 1.5°C pathway."

In conclusion, science is clear about the reality of climate change and about the anthropogenic causes that are responsible for it. We emphasize that it is the capitalist mode of production with its insatiable lust for earning maximum profit that has been historically responsible for the uncontrolled emission of GHGs resulting in the present climate crisis. We are now standing on the edge of a precipice, and if we fail to act, the entire human civilization will be at peril, and the survival of mankind will be at stake.

However, science has also suggested ways of mitigation and adaptation to tackle climate change, and there is still time to take corrective actions. Here also, capitalist relations of production, profit motive, capitalist competition and rivalry are standing in the way of concerted united action. The need of the hour is an organized drive to make the people conscious and to build up movements in all countries so that Governments and states are forced to take up science-based coordinated action to meet the adverse effects of climate change and arrest its catastrophic progress. Climate action needs to be integrated with such struggles.

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