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Climate Change - An Overview

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Abstract: Long term changes in Earth's climate or weather pattern over a region is called climate change. Climate change is more than global warming because global warming refers only to the rising temperature of Earth's surface whereas climate change includes warming along with its side effects like melting of glaciers, rising sea-levels, frequently occurring droughts, heavy rainstorms etc. The rise in average temperature is only one indicator of broader changes also translating into extreme temperatures, drought, flooding, storms, rising sea levels, impacts on food production, and infectious diseases. Climate change could be natural or man-induced or seems natural but triggered by anthropogenic activities. The anticipated rate of anthropogenic climate change is greater than the natural rate. Carbon dioxide is the principal anthropogenic greenhouse gas and is major contributor to climate change.

Keywords: Greenhouse effect • Fossil fuel • Solar cycle • Renewable energy.

Introduction

Climate change is the subject of how the changes in weather pattern is taking place over decades or even longer. The examples cited below indicate the latest variations in weather as experienced by the people in different parts of the world.

The residents of United Kingdom were surprised with the extreme heat waves and mercury touching 40°C in July, 2022. Neither the people nor the technology was prepared for such a high temperature since it had never gone beyond 35°C in UK. Forest near Oslo (Norway) experienced forest fires in the beginning of this year, similar is the situation in parts of Portugal where temperature reached 45°C and forest fires (which require high temperatures, dry conditions and high winds) broke out. Record breaking temperatures are shown in the data collected by NASA for Africa, Asia and Europe in July, 2022 (Otto, 2022).

The climatic situation is no way better in 2021. US experienced hurricanes, Canada addressed to heatwaves, droughts in Africa, severe floods in Asia and Europe, to name a few. There is a series of climate disasters which takes the life of around five million people each year (provide reference). Going by the records, US alone has lost $1.875 trillion from the 285 climate disasters, which have occurred from 1980 onwards (Times Evoke, 2021). These events and data clearly indicate the danger posed on the world due to change in climatic conditions over past years. This has driven the concern over climate change and has given rise to extensive debate and discussions among the intellectuals and scientific community across the globe.

This article describes the causes and consequences of the climate change along with the physics behind the factors contributing to climate change. It also discusses the impact of climate change on society and economy and measures required for its mitigation.

Climate Change (CC): The climate of Earth undergoes long-term changes i.e. the pattern of weather over a region on Earth changes over decades or even longer than it. This is called climate change and it leads to Sea-level rise

and enhancement in global temperature. Small changes in climate are adaptable for the survival of flora and fauna, but when the climate change is too fast, it disturbs the ecosystem and hence, adaptation becomes too difficult, sometimes impossible for certain species.

Looking at the past history, Earth's climate has changed many times. It has even undergone ice-age cycles. This took place naturally owing to the changes in orbital motion of Earth and changes in the axial tilt of the Earth. Ecosystem tends to adapt to these changes as they took place slowly and gradually. But after Industrial revolution in 1750, the climate is changing very fast leading to significant damage to living beings and ecology. Fig.1 depicts the variation in global surface temperature, which is increasing continuously after 1950.

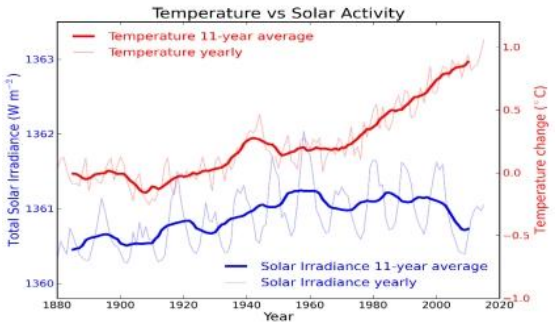

Fig. 1: Variation in Earth's global surface temperature (Red line) and Solar contribution (blue line) [source: climate.nasa.gov]

Sea-level rise: It can happen due to two factors: (i) More water is released into the ocean because of melting of land ice and glaciers. (ii) Expansion of ocean due to increase in its temperatures. Both of these factors cause risk to the lives of millions of people living near coastal region.

Enhancement in global temperature: The Earth receives energy from the Sun through radiation. The temperature of Earth's surface is calculated by the difference of absorption and emission of this radiation. It is calculated in terms of net energy per unit time per unit surface area or Watt per square meter (W/m^2) and is called radiative forcing (RF).

Apart from sea level rise and global temperature enhancement there are other sectors which are also affected by climate change like quality of air, human health, water resources, energy and land use, forestry, agriculture etc. (Magnan et al, 2021).

Reasons of Climate Change: A large number of factors affect the climate of the Earth. Some are natural while some others are influenced by human activities i.e. anthropogenic. Since 1750, when Industrial Revolution took place, climate change is strongly contributed by the emissions of Aerosols and Greenhouse gases (GHGs), resulting in a rise in global temperature. Deforestation, mining, artificial cloud seeding, excessive land use etc. led to other problems such as an increase in frequency and intensity of storms, droughts, floods, landslides, decline of ice sheets, melting of glaciers etc. (Akbari et al, 2001; Bala et al, 2007; Crutzen et al, 2000).

Therefore, apart from natural and man-induced climate change, there could be one more category where the cause of CC appears to be natural but actually it is triggered by the cumulated effects of anthropogenic activities.

Factors contributing to Climate Change: The most important factors are energy received from the Sun, Volcanic eruptions, concentration of GHGs in the atmosphere, and Aerosols emitted from industries.

Solar Activity: Sun is a dynamic body which constantly undergoes changes, the manifestation of which is termed as Solar activity; this is but a consequence of the interplay of three factors viz. the magnetic field, the internal convection of heat and the differential rotation of the Sun (Raizada, 2009). Several features like Solar Flares, Coronal Mass Ejections, Active Prominence and Disappearing Filaments etc. are produced at the solar surface due to solar activity, which

is decided on the basis of number of Sunspots present over the solar disk.

The sunspot number increases from minimum to maximum in an average period of 5 years and then decreases to a minimum value in next 6 years. This is known as 11year sunspot cycle. The sunspots are produced as a result of very intense magnetic field of the order of 2000 to 4000 gauss, and have temperature 2000°C lesser than its surrounding area. Along the magnetic field lines, solar energetic particles (SEPs) in plasma state bounce back and forth. Due to the collision of these particles with each other, there energy goes on increasing, until it reaches to a situation of inequilibrium, when the magnetic field lines break. With the breaking of field lines magnetic field and SEPs are thrown in outer space in all directions.

The cloud of magnetic field and SEPs, which move towards Earth, enters the magnetosphere and atmosphere creating lots of problems like significant ozone depletion, affecting satellites (which in turn affect communication system, power grids), enhancement in the ionospheric total electron content etc. Strong solar activity affects spacecrafts and onboard instrument groups. Electronic upsets, housekeeping and science noise, proton degradation to solar arrays, changes to orbit dynamics, high levels of accumulated radiation and proton heating are observed. Radio blackouts influence the navigation system, leading to interruption in the radio contact. The highly energetic protons penetrate into the mesosphere and stratosphere where they produce excitations, ionizations, dissociations and dissociative ionizations (Raizada, 2017).

Volcanic Eruptions: A volcano is an opening in the Earth's crust from which eruptions occur. Volcanoes expel large quantities of magma in the form of hot, dangerous gases (like Sulphur dioxide, Carbon dioxide etc.), lava, ash and rock, rapidly and forcibly. Large quantity of sulphur-rich gases is injected into the stratosphere due to volcanic eruptions. These gases produce veils of dust particles which stays there for several years and produce cooling effect on earth's surface. These dust veils also warm the stratosphere by absorbing solar radiations. The net effect of these temperature changes in the stratosphere and at earth's surface has cooling effect (Robock, 1991).

Greenhouse effect: When solar radiations strike the Earth's surface, some of them are absorbed while others are reflected back but with a lower energy (or with lower frequency, to be more precise). This reflected energy falls in the infra-red (IR) region of electro-magnetic spectrum and is absorbed by the GHG molecules present in the atmosphere. As a result, these molecules start vibrating. Later on these molecules emit this energy in the form of IR photons, which are not allowed to escape the atmosphere. Hence they return to Earth's surface. These GHGs trap the radiation in the form of heat. This phenomenon is known as Greenhouse Effect.

It is natural and very much essential to sustain life on Earth. Otherwise the temperature of Earth would have been 33°C lower than its present value (CIA, 2015). But in recent years, human activities have enhanced the GHGs (mainly by burning fossil-fuels), thereby contributing significantly to global warming and climate change (Andreae et al, 2001; Yue and Gao, 2018).

Greenhouse Gases (GHGs): Carbon dioxide, methane, water vapour, and other human-made gases are the GHGs found in Earth's atmosphere. Owing to the high frequency (or energy) of the solar radiations, they are allowed to enter the atmosphere but the radiations reflected from the Earth's surface have low frequency (or energy), and are obstructed by GHG molecules. More heat is trapped if more number of GHG molecules are present in the atmosphere.

Burning of Fossil fuel (FF): Fossil fuel is a hydrocarbon present in Earth's crust and is formed naturally by the burial of dead plants and animals over thousands of years. FF include coal, oil and natural gas and is extracted from the offshore areas and ground. They are the non-renewable energy resources and fulfil 90% demand of electricity. By burning FF, Carbon dioxide gas is released along with other pollutants, like sulphur dioxide, fine particles, trace metals, nitrogen oxides, etc. (Buoncore, 2020), thereby increasing more GHGs in the atmosphere and contributing significantly to CC.

Aerosols: Sulphate aerosols are light coloured particles emitted by industries. They reflect light and create haze over the industrialized areas. They tend to cool the surface of the Earth (as opposite to GHGs) by blocking the solar radiations to enter the earth's atmosphere (Andreae et al, 2001). Aerosols resulting from industrial emissions remain concentrated near their sources whereas the GHGs i.e. methane and carbon dioxide get evenly distributed throughout the atmosphere. Thus, the cooling effect from aerosols does not balance the warming effect of GHGs.

Quantitative Analysis of Climate Change: Carbon dioxide is the principal anthropogenic GHG while methane is the next substantial contributor. In 1960, the concentration of carbon dioxide was 278 parts per million (ppm) which has increased by 44% (401ppm) in 2015(CIA, 2015). 60% of the anthropogenic radiative forcing (RF) is represented by carbon dioxide, which is mainly produced by burning of fossil fuels(provide reference). Methane emission has number of other sources like waste disposal, agricultural activities, coal mining, waste water treatment etc. along with burning of FF. Carbon dioxide remains in the atmosphere until it is absorbed by the biosphere and oceans whereas methane gets oxidized in a decade or so. Thus, methane has a shorter lifetime as compared to carbon dioxide. Since carbon dioxide is emitted in large quantity and has a longer life time in atmosphere, it is the GHG of main concern.

Solar eruptions moving towards Earth are also argued to increase global warming. But the fifth annual report of Intergovernmental Panel on Climate Change (IPCC) rules out this possibility by stating that during 1750 and 2011, solar contribution is only 0.1 W/m^2 whereas anthropogenic activities have contributed 2.3 W/m^2(CIA, 2015). Fig.1 shows some similarity between global surface temperature and solar irradiance till 1940. But after that, there is no correlation between the two. Since solar contribution seems to be negligible from Fig.1, it rules out the possibility that Sun is responsible for global warming.

Impact of Climate change:

Social impact: Climate change is expected to lead to acute rainfall, heat waves, forest fires, severe floods, droughts, hurricanes, storms etc. Thousands of people were killed and millions were displaced in India, Bangladesh and Nepal due to floods caused because of excessive monsoon rains in 2007. Further increase in temperatures will intensify these events and they will occur more frequently (Williamson and Guinder, 2021). Quality of water may get lowered due to warmer environment leading to deficit of clean drinking water. More precipitation and evaporation will decrease the water supply. This will affect the working of industries, agriculture, ecosystem etc., thereby creating insecurity of food, water and energy. Since these are the basic necessities, they will give rise to social conflicts and other problems (Brooke, 2008). Population growth, industrialisation, rapid urbanisation, inefficient use of water and energy are already causing shortage of electricity, water, fuel etc.in developing countries like India, Pakistan, Nepal and Bangladesh.

Impact on Human Health: Water-borne diseases like cholera and diarrhoea will

become more frequent due to warmer climate. Diarrhoeal diseases eg salmonellosis, cryptosporidiosis and giardiasis are a major cause of mortality and sickness in the children in south asian countries. In Bangladesh and Latin America, plankton blooms and cholera have been a cause of concern during spring and summer. Deficit of food and poor quality of water will give rise to malnutrition which may result in physical disability and deaths in long run (Amelung et al, 2019; Tong and Ebi, 2019). Extreme weather conditions will make people to migrate to other places. They may find it difficult to adapt to new surroundings. This stressful situation may result in mental disorder (Handmer and Nalau, 2018). People from financially weaker sections are the ones who will suffer the most. Thus, environment alterations will directly affect the human health and ecosystem (Magnan et al, 2021).

Increase in dysentery, typhoid, cholera and diarrhoeal disease are of major concern in developing countries. For example, after floods in West Bengal, led to outbreak of diarrhoea which resulted in deaths of hundreds of people, in 1988. Floods can also give rise to rodent borne and many other infectious diseases. Stagnant water collection creates conducive environment for mosquitoes, which can lead to spreading of malaria, dengue etc. If flood water gets contaminated with animal or human waste, it increases the rate of faecal-oral transmission of disease causing viral and bacterial infections to flourish.

Economical impact: The impact of climate change on human health will require more and better healthcare system. Thus, extreme weather events will increase the demand of hospitals and medical practitioners manifold. Insurance industry is the one which will be directly affected. Agriculture, fisheries, forestry and tourism are some of the sectors which are weather sensitive and will have to pay the price. Not only this, higher temperatures will hinder the proper functioning of transportation infrastructure, electricity grids etc. and will result in poor productivity and development.

In 2021, the global insurance company, Swiss Re, estimates that extreme weather losses have exceeded $100 billion. According to the reports of World Meteorological Organization, India lost $87 billion whereas China lost $238 billion to extreme weather events in 2020 (Times Evoke, 2021). The US Fed and other central banks are raising interest rates and the cost of financing globally. Developing countries with debt burdens, rising energy costs, food prices and inflation are already at the sufferer end (The Economic Time, Nov. 7, 2022). Now, taking measures to curtail CC provides further burden on their economy.

Remedial solution: The United Nations (UN) climate concern body analyses that the dominant source of GHG emissions is energy sector. This could be curtailed by decreasing the rate of emission of GHGs. This is called mitigation. This can be done either by reducing the consumption of energy or by using efficient technology for the production of energy or by shifting to energy resources which do not produce GHG emissions (Anisimov et al, 2018; Fletcher, 2001; Weyant, 2009). And the answer to this, lies with Renewable Energy Resources. Wind, geothermal, sunlight, tidal energy etc. are naturally replenished resources of energy and are free of carbon emission (Moser, 2010; Sorlin, 2012).

Several environment programmes are run by United Nations (UN) to facilitate countries so that they can tackle issues related to climate change. For example, UN project has projected the production of incandescent lamps in Vietnam which will reduce the emission of GHGs. A collaborative project between UN environment and Korea International Cooperation Agency works on clean energy technologies and how to transfer these

technologies through better regulation and improved policies in central Asian countries.

In India, core mission of many companies like JPMorgan Chase, ITC, Flipkart, Ernest & Young (EY) Genpact etc. are focussing on initiatives based on environmental sustainability. ITC has adopted a sustainability vision and turned plastic neutral in 2021-22. Its low carbon growth strategy includes increasing the share of renewable energy, promoting regenerative agriculture practices and strengthening green building footprints. EY is running several initiatives for energy conservation, water management and afforestation. The firm is also offering solutions and services to clients for decarbonising their businesses. Flipkart is investing heavily in R&D to find solutions for sustainable packaging materials. Genpact has implemented green IT solutions at offices to reduce energy consumption and has mandated that green building codes are to be complied at all new sites (The Economic Times, Nov. 5, 2022).

Apart from other measure, more and more trees should also be planted to reduce carbon footprints, which is the major GHG and is of primary concern. Plants and trees absorb carbon dioxide from atmosphere during photosynthesis. Therefore, growing forest is another way of reducing carbon dioxide from atmosphere. This is called biological carbon sequestration (Fawzy et al, 2020)

Example of impact of Climate Change : Slight analysis of the climate changing pattern over a period of fifty years, has been done taking Dehradun city as an example. The purpose of doing this analysis is to make the readers feel about the existing scenario of climate change. This analysis can be extrapolated, visualised and generalised at a much larger global level, so as to estimate the threat due to changing climate on the existence of life at our planet Earth.

Dehradun is a valley situated between the Shiwalik range and Himalayan foothills. It is one of the oldest cities of India. It was made the capital city in the year 2000, when Uttarakhand state was formed. It is situated in the North West corner of the state, between the latitudes 29°58' N and 31°2' N and longitudes 77°34' E and 78°18'E. The coordinates of Dehra Dun are 30°19' North and 78°03' East (Sharma et al, 2022). The geographical area of Dehradun city is approximately 200 square kilometre and is situated at an altitude of 640 metres. The population of the city is approximately 15 Lakhs. Seasons in Dehra Dun are classified as Winter (December to February), Summer (March to May), Monsoon (June to September) and Post-monsoon (October-November).

Maximum and minimum temperatures recorded in a particular year from 1970 to 2020 (IMD, 2022), during winter season are plotted in Fig. 2. When the data is analysed for entire winter season in a particular year, the span of winter is the same (as it was earlier) i.e. it is still from December to February. But the trendline in fig. 2 shows increase for both the set of temperatures, indicating that the winters are becoming warmer over a period of time, which clearly reflects that climate is changing.

Similarly, maximum and minimum temperatures recorded during summer season from 1970 to 2020, are plotted in Fig. 3. The maximum temperature during summers, varies between 35°C and 43°C with an average temperature of 38°C and the trendline has slightly decreasing pattern. But on investigating the temperature on daily basis during summer season, it can be inferred that the summers used to be moderately hot before 2000, but now there are few days of heat wave when temperature rises by 5°C to 6°C above the normal value. The duration of summer season has also increased, which now extends till June. Prior to 2000, the minimum

temperature varies between 2.5℃and 10℃ but when Dehradun became capital city, lot of infrastructural development took place. After 2000, the minimum temperature ranges between 7℃ and 11℃, which is pretty high. Thus, the trendline for minimum recorded temperature shows considerable rise in its slope, which is a cause of concern.

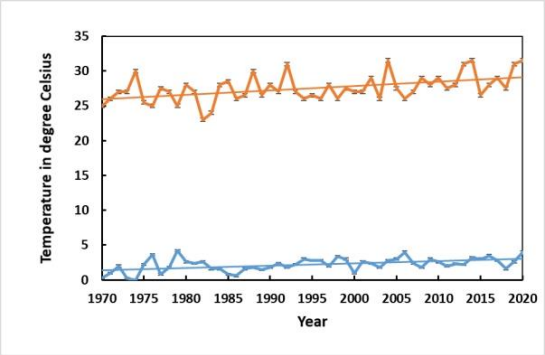

Fig. 2. Maximum (orange colour) and Minimum (blue colour) Temperatures during Winter season.

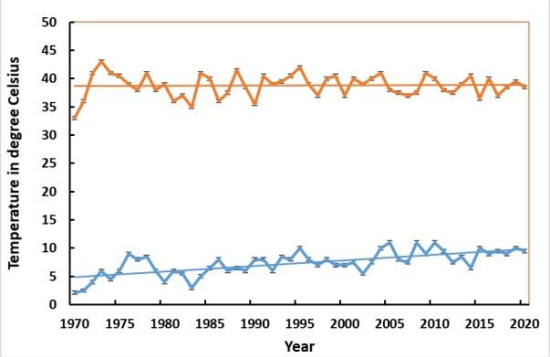

Fig. 3. Maximum (orange colour) and Minimum (blue colour) Temperatures during Summer season

Dehra Dun was once known for its pleasant climate and picturesque landscape. It was famous for Tea gardens, Basmati rice, Litchi, Deodar and Sal forests. There were canals flowing through the city. But when Dehradun became capital city in 2000, the landscape of the city changed drastically. Multi-storeyed buildings, shopping complexes, highways and flyovers were made to mark the development of the region. Lot of job opportunities invited people from nearby areas, making the population denser. This requires surplus land to provide shelter to these people, which is made available by covering the canals and felling large number of trees. Thus, green forests are replaced by concrete jungles, canals have disappeared, tea gardens have shrinked.

All this has also affected the climate of Dehradun. Earlier the summers were moderately hot whereas winters were very cold and marked by mist and we did not observe fog. But now the span of summer has increased and the month of May is very hot. Whereas the duration of winter season has decreased and they are not so cold. Earlier there were few days during monsoon season when it rained heavily and continuously for couple of days. Now the amount of rainfall has also decreased. Greenery of the region has paid the price in the name of infrastructural development, thereby increasing carbon footprints. Thus, the overall climate of Doon valley has become warmer in the past few decades.

Similar type of climatic change is occurring globally. Unexpected snowfall and rainfall has become part of life. At some places, duration of winters has increased and it has become more severe whereas at some other part of the world, the span of summer has increased and has become very intense. Every now and then, there is a news of casualties due to heat waves or frost bite.

Time to take call: In 1979, a scientific gathering conducted a 'World Climate Conference' and addressed climate change as a problem. They established a programme to look into this serious issue jointly, by the United Nations Environment Programme (UNEP), World Meteorological Organization (WMO), and the International Council of Scientific Unions.

The UNEP and the WMO established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The first assessment report of IPCC in 1990 said that human activities are increasing the concentration of GHGs in the atmosphere. This started lots of debates, discussions and research in this field and laid

the foundation of global climate treaties, summits and protocols. Many international agreements were signed by developed and developing countries and several environment related programmes are started by United Nations, so as to minimize the emissions due to human activities. For example, the Asia Pacific Adaptation Network (APAN), the Southeast Asia Network of Climate Change, Reducing Emissions from Deforestation and Forest Degradation (REDD) etc. which provides information about CC adaptation measures, development and implementation of climate mitigation techniques, how to invest in low-carbon paths for sustainable development etc.

As per analysis of IPCC, the total GHG emissions, between 1990 and 2019, have decreased by 14.8% for developed countries whereas it has increased by 79.2% for developing countries, between 2000 and 2015 (CIA, 2015). It could have happened due to rapid economic and population growth. This is a matter of great concern and need to be addressed without wasting any more time.

Conclusion

According to the reports of IPCC, the global average temperature rise of 2°C is estimated, by the end of twenty first century (relative to 1750, which marks the year of Industrial Revolution). Keeping the rate of global warming under 2°C is a herculean task.

The anticipated rate of climate change due to anthropogenic activities is greater than the natural rate. It has been accepted globally that emission of GHGs especially carbon dioxide, is responsible for this. Deforestation and burning of fossil fuels increase the concentration of carbon dioxide substantially in the atmosphere and need to be checked (Rhemtulla et al, 2009).

Energy resources are limited as compared to demand of energy, which is increasing day by day so as to inculcate the needs of growing population and economic growth of a nation. There is a need to reduce energy consumption and switch over to those resources which does not emit GHGs and are eco-friendly.

This problem can be solved by using renewable energy resources like Wind, Solar, Geothermal, Tidal etc., in place of fossil fuels. But the availability of these renewable energy resources varies as per the geographic location of the place. Change of season and weather conditions also play a major role in its supply. Moreover, this energy has to be made cost effective in terms of production, installation and maintenance. Governments across the globe, are working to promote the field of renewable energy, so as to achieve the goal of reducing carbon footprints.

Large amount of resources and funds have been sanctioned by World bank to carry out research related to mitigation of climate change. A programme called Global environment facility (GEF) was launched in 1991, which deals with major environmental issues and stimulate green growth.

Geographical position and topography of India clearly indicates that solar power has a significant potential in the country and provides a competitive advantage over most of the other countries. Thus, Indian government along with researchers and industrialists are making multiple efforts in the field of solar energy to achieve this goal.

Some large projects have been proposed and a 35000 square kilometre area of the Thar desert has been set aside for solar power projects, sufficient to generate 700 to 2100 GW. Our prime minister has laid down the foundation of 600MW Ultra Mega solar power park at an event in Jhansi (UP) which will provide cheaper electricity and grid stability (The Economic Times, 2021). Indian conglomerates TATA power company limited has pledged to spend Rs. 75000 Crore on renewables in five years (TATA Power, 2022). Thus, besides increasing energy efficiency, India will have to

met its growing energy needs, with green hydrogen and clean electricity (The Economic Times, Nov. 7, 2022).

The government, scientists, researchers and activists are doing their part but awareness among general public is very important. Most of the people consider pollution and ozone depletion as the cause of climate change. They are ignorant about the connection between climate change and GHGs, which are emitted due to anthropogenic activities. Until and unless people understand the seriousness of this climate change problem, no agreement or treaty can work.

Therefore, by using renewable energy resources in place of fossil fuels, reducing our energy consumption and by increasing green cover, we can save our Earth and will leave a sustainable, safe, clean and green planet for our future generations.

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