

The industrial revolution has drastically changed the relationship between man and the nature. Due to this, it is opined by environmentalists and experts that, by the year 2100, human activities will have changed almost all the essential conditions that have allowed life to thrive on earth. Human activities have been responsible for tampering with the complex interaction between solar energy and its escape from the atmosphere of earth. Due to this situation there has been an increase in the average global temperature and radical shifts in the existing weather patterns. This has led to alteration of the global climate and the resultant climate change.

### **GLOBAL WARMING**

The earth receives solar energy in abundant qualities. This energy reaches the earth in the form of short-wave radiation, which in turn heats up the earth's surface. Sufficient quantities of heat energy are absorbed by the earth's mantle. Some quantities of heat are re-radiated back into the space. Certain gases, known as Green House Gases (GHG), that include carbon dioxide, methane, nitrous oxide, ozone, and water vapour prevent the heat from escaping the earth's atmosphere. This leads to an increase in the atmospheric temperature, known as greenhouse effect.

The greenhouse effect has its own positive effect, as without its effect earth would have been covered with ice and the temperature much cooler. However, due to certain human activities the quantity of GHGs has increased manifold. For example, burning of large amounts of fossil fuels, deforestation, mining activities, industrial activities and agricultural activities have increased the overall concentration of GHGs. Further, the reduction in green coverage reduces the capacity of the earth to absorb carbon dioxide through photosynthesis. Certain natural process like volcanic eruptions also contributes to GHG emissions. Chlorofluorocarbons (CFCs) like methane released from human and animal waste, garbage dumps and rice fields, etc. have caused large scale depletion of the ozone layer.

The percent of GHGs that contribute of global warming is carbon dioxide (61%), methane (15%), chlorofluorocarbons (11%), nitrous oxide (4%) and other gases (9%). Thus, it can be seen that CO<sub>2</sub> is the most significant greenhouse gas that contributes to global warming.

The abnormal increase in the concentration of GHGs has led to a situation, wherein the global temperature has become warmer. The average temperature of the global has become warmer over the last 100 years. This warming is not uniform all over the globe. While the temperature is getting warmer in some places, in certain other places, it has become cooler. But it is a fact that the overall temperature of earth's atmosphere has got warmer. It is said to have become warmer by about 0.6° C (1.3° F) over the last century. Evidences show that the warming of environment is happening much faster than they have in the past. Further, there is a new and stronger evidence suggesting that most of the observed warming over the last 50 years is attributable mainly to human activities. It is opined that, if the GHG emissions continues at this rate, by 2030 the temperature will rise by 1.5° C – 4.5° C. The Intergovernmental Panel on Climate Change (IPCC) states that the human induced change in atmospheric chemistry will increase temperatures by 1.4° C – 5.8° C by the year 2100.

GHGs include carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), chlorofluorocarbons (CFCs), nitrous oxide (N<sub>2</sub>O), ozone, etc. Global warming is an after effect of enhanced levels of GHGs.

1. **CO<sub>2</sub>**: CO<sub>2</sub> is released as a result of combustion of fossil fuels like coal, petroleum products, mineral oils and natural gas. The concentration of CO<sub>2</sub> has been increasing steadily in the atmosphere. It has increased by 25% since 1850.
2. **CH<sub>4</sub>**: CH<sub>4</sub> is generated from garbage dumps, paddy fields, swamps, etc. The concentration of CH<sub>4</sub> has also increased considerably in the near future. It is estimated that CH<sub>4</sub> has eleven times higher global warming potential than CO<sub>2</sub>.
3. **CFCs**: CFCs are a family of inert non-toxic, non-inflammable, and easily liquefied artificially produced chemical compounds composed primarily of carbon, fluoride and chlorine. CFCs are used as refrigerants, aerosols, sprays, and in the production of foams. They cause large scale deterioration of stratospheric ozone. As in the case of CH<sub>4</sub>, the global warming potential of CFCs is very high at 1600-15000 times to that of CO<sub>2</sub>. It is estimated that over 15 million tones of CFCs has been released into the atmospheres and the concentration of CFCs is increasing at the rate of 5% annually. The world over, efforts are being made to reduce the emission of CFCs.
4. **N<sub>2</sub>O**: N<sub>2</sub>O is a stable gas with an average life of 150 years. In addition to acting as a GHG, it is also an ozone destroyer. Source of N<sub>2</sub>O include fertilizers, burning forests, grasslands and biomass, oceans and other water bodies and lands, etc. The global warming potential of N<sub>2</sub>O is 270 times higher than CO<sub>2</sub>. The concentration of N<sub>2</sub>O has also increased drastically in the recent past.

***Global Warming Potential***

Global Warming Potential (GWP) is an index that describes the radiative characteristics of well-mixed GHGs. It represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infra-red radiation. GWP is the amount of CO<sub>2</sub> in kilograms that would cause global warming equivalent to 1 kg of the substance emitted. The index approximates the time integrating warming effect of a unit mass of given greenhouse gas in today’s atmosphere, relative to that of CO<sub>2</sub>.

Gases	Sources of GHGs	
	Equation	Sources
Carbon dioxide	CO <sub>2</sub>	Combustion of fossil fuels, deforestation, respiration, etc.
Methane	CH <sub>4</sub>	Wetlands, anaerobic decomposition of organic wastes
Nitrous oxide	N <sub>2</sub> O	Natural soils, fertilizers, combustion of fossil fuel, etc.
Ozone	O <sub>3</sub>	Photochemical reactions in troposphere, diffusion from stratosphere
Chlorofluorocarbons 11 and 12	CFC-11 and 12	Manufacturing of foams, aerosol propellant, refrigerants, etc.
Chlorofluorocarbons 113	CFC-113	Electronics solvent
Hydro chlorofluorocarbons 33	HCFC-22	Refrigerant, production of fluoro-polymers

Carbon tetra chloride	CH <sub>2</sub> CCl <sub>3</sub> CCl <sub>4</sub>	Industrial degreasing solvent Intermediate in production of CFC-11, CFC-12 solvent
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### Effects of Global Warming

Global warming will have a number of adverse effects on the climate, agriculture and human beings. Some of the effects could be unpredictable, and will be of astronomical proportions.

#### Some Facts about Global Warming

- 2003 was the hottest year in 150 years with the average world temperature being 0.45 C higher than the normal.
- The ozone hole over Antarctica has reached all time high.
- According to NASA, the biggest ice cap in the arctic region, the Ward Hunt Ice Shelf broke into fragments as a result of global warming.
- Adelie penguin populations in Antarctica shrink by 33%.
- The average receding of shoreline in Fiji is half a foot per annum.
- About 20%-30% of the world's reefs have already been wiped out.
- The corals in Lakshadweep will bleach and world heritage site of Sunderbans will be submerged dealing a deadly blow to the rich biodiversity of India.

### Effects on Climate

Global warming can lead to a number of effects on the climate. They include increase in global temperature, severe and extreme weather conditions, disruption of rainfall pattern, warmer oceans, warmer winters, melting of glaciers, and rising sea levels.

1. **Increase in global temperature:** With global warming, the average global temperature has increased steadily during the last 100 years. It has increased by about 0.6° C. this increase in temperature has occurred in almost all regions around the world. The IPCC has predicted that the temperatures will increase by 1.4° C – 5.8° C by the turn of the present century.
2. **Severe and extreme weather conditions:** Global warming will lead to changes in the flow of ocean currents and the air circulation patterns and the consequent effect on weather across the world. There may be changes in the distribution of solar energy which can bring about unpredictable climatic conditions. There may be severe drought at places which used to get abundant rainfall. It may rain heavily at deserts. This may lead to destruction of the natural habitat of the respective places. Deserts will expand at an accelerated pace. There will be more stronger and frequent storms. Hurricanes, cyclones, and tornadoes may occur at close frequencies leading to large scale destructions. It is reported that over the past 50 years, while very hot days and nights are occurring more often, very cold days and nights are occurring less often. Further, the heat waves have become longer and hotter over most of the land areas.
3. **Disruption of rainfall pattern:** There will be change in rainfall worldwide, due to changes in surface temperatures of oceans and land areas. Warm temperatures will lead to more evaporation and the resultant increased precipitation, with heavy rainfalls at certain places leading to flood damages. While some regions will receive much higher levels of rainfall, other regions

will receive less rainfall and will have to suffer longer and more frequent droughts. Further, the seasons or times of year when rainfalls will change. Rainfall may occur at different times and for shorter or longer periods than it used to be in the past. It is also reported that, globally the areas experiencing drought, or periods of extremely dry weather, have increased since the 1970s.

4. **Warmer oceans:** As the global temperatures increase, the oceans will become warmer. Warm ocean surfaces can cause more damage, and it will have a cascading effect on global warming with temperatures continuing to climb. Warmer ocean waters will sound the death knell of a number of marine beings. Coral reefs will be the first to be affected, and they will be weakened and will die. Useful and edible fish varieties may be replaced with useless varieties of fish. Fishing will come down drastically and can affect food security.
5. **Warmer winters:** The winters will become longer. Since the 1960s this has been observed in Europe with spring plates blooming earlier and the fall colours coming earlier. There is a positive effect in the winters getting warmer that the growing season in these areas will last longer which may lead to better crops and harvest. There will also be reduced wintertime deaths due to this. However, there is a possibility that the heat wave conditions in other areas may become more intense.
6. **Melting of glaciers:** The climate at the earth poles – both north and south, is very cold with the surface being covered with ice. The ice also covers parts of the adjoining seas. These areas of ice are called glaciers. Glaciers are also found on very high mountains. Global warming will result in the melting of more and more glaciers. This melting ice will lead to global changes in water circulation and the patterns of deep ocean currents. There is another side-effect of melting polar ice. There are said to be large quantities of methane trapped under the frozen Polar Regions. When the snow and ice melts, the methane will be released into the atmosphere. This release of methane into the atmosphere will lead to further aggravation of global warming process.

Many mountain glaciers are also melting because of warmer temperatures and exposing the dark surface which will result in further rise in the temperature. The glaciers of the Himalayas are said to have receded considerably in the recent past exposing the hitherto unexposed land area. Field investigations in the Himalayas in the five year period from 1998-2003 have revealed that the Chhota Shigri glacier has receded by over 800 m. Similarly, other larger glaciers have shrunk by 12% and around 127 small glaciers by over 30%.

Trends of Glacier Retreat			
Region	Glaciated area	Changes	Sectors impacted
Africa	Rwenzori Mountains, Mount Kenya, Kilimanjaro	82% reduction in glacier area over the last century; 50% glaciers disappeared and larger ones fragmented	Water resources, agriculture
New Zealand	Southern Alps	11% net ice volume lost in the last three decades. Irrigation	Irrigation, hydropower generation

South America	Tropical Andes, Patagonian ice fields	3.4% of area lost in the last 50 years. Current thinning rates is around 30 m/year	Water resources
Tibetan plateau	Tibetan plateau and surrounding regions of China	Loss of 20% area since the 17 <sup>th</sup> century with 90% of glaciers retreating	Mountain forest ecosystem, biodiversity and hydropower
Central Asian Tien Shan and Pamirs	Tien Shan, Pamirs	25-30% reduction Tien Shan, 30-35% reduction in the Pamirs, over 50% reduction in northern Afghanistan	Agriculture, water resources
Russia	Arctic islands and mountain ranges	50% retreat in the North Caucasus over the last century	Water resources, biodiversity
European Alps	Caucus mountains	50% area loss in the last 150 years	Tourism, water resources
North America	Ice fields in Canada and Alaska	25% area lost in western Cordillera	Water resources, biodiversity, agriculture

7. **Rising sea levels:** Sea level is the height of the surface of the ocean. In the last 100 years, the average global sea level has risen about 6 inches. Sea levels have risen because warmer temperatures cause the oceans to expand, and the polar ice to melt. The melting ice adds considerable quantities of water into the oceans causing sea levels to rise. Rising sea levels are now threatening communities in the coastal areas and some island countries like Maldives, Kiribati and Tuvalu due to flooding and washing away of coastal land. For the coastal communities, especially those in these small islands, increasing sea levels will lead to loss of way of life and for certain others there will be loss of habitability. Further, the sites for habitation and infrastructure may dwindle, availability of freshwater and indigenous food sources may diminish, and normal economic activity will be made impossible as a result of the threats to the coastal region. Higher sea levels can also cause salt water to get into rivers affecting the quality of water supplies. This problem has severely affected the Ganga-Brahmaputra delta of Bangladesh and India.

Coastal areas are said to contain some of the world’s most diverse and productive ecosystems, which include mangrove forests, coral reefs, and sea grasses. Low-lying deltas, coral atolls and reefs are highly sensitive to changes in the frequency as well as intensity of rainfall and storms. Though corals will grow fast enough to keep pace with rise in sea level, the warmer seas may damage them. According to Byrne et al (2001), the sea level will continue to rise for the next two centuries, regardless of future GHG emissions. This shows the extent of the lag effect between emissions and the response of the climate and ocean systems.

**What does Rising Sea Level mean to Small Islands?**

Though not of their making, small islands will bear the worst harms from global warming and rising sea waters. The coastal and marine ecosystems will be severely affected and settlements, communities, and islands will have to be

abandoned. Rising sea levels are already contaminating underground fresh water supplies in the small atolls scattered across the Pacific and Indian oceans and the Caribbean Sea. It has also affected some of the world's most productive deltas such as China's Yangtze Delta, the Vietnam's Mekong Delta and the Ganga-Brahmaputra Delta.

The South Pacific Regional Environmental Programme, reports that rising sea levels have already swamped several small islets in the islands of Kiribati and Tuvalu. It has destroyed coastal roads and bridges, and caused traditional burial places to collapse. Higher sea levels could also cause extreme events such as high tides, storm surges, and seismic sea waves (tsunami). The United Nations Department of Public Information (1999) predicted that for a 20 cm rise in sea level, 18 million additional people worldwide will experience yearly storm surges, and at an 80 cm rise, 65% of the Marshall Islands and Kiribati will be inundated. It is estimated that a 100 cm rise in sea level could inundate 70% of the landmass of the Seychelles. Maldives will be completely wiped from the face of earth. The irony is that island communities can have little impact on global carbon dioxide emissions, because their per capita emissions are small and their populations low.

8. **Effects on agriculture:** The unusual weather patterns will lead to droughts affecting certain regions and heavy rainfalls at certain regions resulting in widespread flood damages. The tropics will see intensified heat and will become unsuitable for agriculture as the soil and water resources will also get degraded. Crops will get damaged by higher temperatures coupled with water shortages. All these will have an impact on the crop yields with productivity fluctuating considerably. Since the crops are already near to their maximum heat tolerance, added heat stress and other problems like shifting monsoons, and drier soils may reduce the yields by one-third in the tropics and subtropics. Certain weeds, rodents, insects, bacteria and viruses will multiply rapidly and colonize more areas. This will lead to transmission of diseases to new areas adding to the risk of crop losses and creating havoc to the already stressed agricultural resources.

According to the Climate Change information Kit (2002), due to global warming mid-continental areas such as the US grain belt, vast sections of mid-latitudes Asia, sub-Saharan Africa and parts of Australia are expected to experience drier and hotter conditions. However, longer growing seasons and increased rains in the temperate regions of UK, Scandinavia, Europe and North America may boost yields. Based on a model the information kit suggests that a global warming of 1.4° C – 5.8° C over the next 100 years will cause increased evaporation and precipitation. There will also be an increase in the frequency of intense rainfalls. Due to this some regions may become wetter, and the intensified hydrological cycle will lead to increased erosion and loss of soil moisture. Some regions that are already drought-prone may suffer longer and more severe dry spells.

The fisheries sector will also be affected as there will be species changes in almost all areas, threatening food security of countries that are highly dependent on fish. There could also be upsets in the established reproductive patterns, migration routes, and ecosystem relationships of fishes.

9. **Effects on human beings:** Human beings are sure to suffer untold miseries due to the adverse effects of global warming. This suffering will be wide ranging, with public health implications being on the top of the list. Public

health depends on sufficient food, safe drinking water, secure shelter, good social and environmental conditions, and social setting ideal for controlling of infectious diseases. Due to the effect of global warming all these factors will be severely affected.

Greater number of people would be exposed o deadly diseases. Further, due to the redistribution of insect vectors that transmit diseases, various tropical diseases like dengue fever yellow fever, malaria have been found spreading to the higher altitudes and latitudes. Warmer temperatures will also lead to increase in the level of ground ozone which can cause irritation of the respiratory systems and eyes.

As stated earlier, a larger number of communities will be displaced due to the after effects of global warming, and these communities, stands on an increased risk of various infectious, psychological, and other illnesses. The disruption of the systems for sanitation, storm water drainage and sewage disposal would also have serious health implications. The Climate Change Information Kit (2002) presents a number of disease conditions that may occur as a result of global warming. Some of them are the following:

1. **Cardiovascular, respiratory and other diseases:** Heat wave conditions are linked to these, and these diseases are expected to increase, especially among the elderly and the poor. Further, climate-induced changes in the formation and persistence of pollens, spores, and certain pollutants could promote more asthmatic and allergic disorders.
2. **Diseases associated with malnutrition:** The decline in food production in vulnerable regions would lead to malnutrition and hunger in children that can have long-term health consequences. Heat waves, flooding, storms, and drought can cause deaths and injuries, famine and displacement of populations.
3. **Diarrhoeal diseases:** The reduced fresh water supplies will affect the sanitation facilities very badly. Over stressed sewer systems may contribute to higher concentrations of bacteria and other micro-organisms and the consequent poor quality of water. These factors could result in an increased incidence of diarrhoeal diseases.
4. **Vector borne diseases:** Vectors like mosquitoes, ticks, fleas, house flies and rodents would expand to wider areas in a warmer world. This can lead to vector borne diseases like malaria, dengue, plague, elephantiasis, encephalitis, etc.
5. **Psychological disorders:** Communities displaced due to the after effects of global warming like floods, storms, heat waves, and droughts will suffer from stress, strain and a number of other psychological disorders. The poorer communities will be more vulnerable to these problems.

### *Dealing with the effects of global warming*

As stated earlier global warming is caused by the emission of GHGs. The main GHGs are CO<sub>2</sub>, CFCs, CH<sub>4</sub>, N<sub>2</sub>O, and so on. These gases are produced mainly from the burning of fossil fuels. The most effective way of controlling the GHGs is emission control. Steps towards this direction can be taken at the international, national and local levels.

At the international level, the United Nations Framework Convention on Climate Convention (UNFCCC) was formed as the foundation of global efforts to

combat global warming. The convention conducted in 1992 at the Rio de Janeiro (also known as Earth Summit), had its objective as:

...the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

In the Convention, most member countries of the Organization for Economic Cooperation and Development (OECD) and the states of Central and Eastern Europe (known collectively as Annex I countries) committed themselves to reduce their greenhouse gas emissions to 1990 levels by the year 2000. The targets for the past 2000 were addressed by the Kyoto Protocol in 1997. In the Kyoto Protocol, the parties to the Convention agreed by consensus that developed countries should accept a legally binding commitment to reduce their collective emissions of six greenhouse gases by at least 5% compared to 1990 levels, by the period 2008-2012. The Protocol also establishes an emission trading regime and a Clean Development Mechanism (CDM).

The post Kyoto arrangements were discussed at the Durban Conference (COP 17) during December 2011. The Conference aims at reducing the aggregate emissions of GHGs of Annex I parties by at least 25.40% below 1990 levels by 2020. The commitment period would begin on 1 January 2013, and end either on 31 December of 2017 or 2020. The end date would be decided by the Adhoc Working Group on further commitments.

The conference also decided to designate the Green Climate Fund as an operating entity of the financial mechanism of the Convention. The fund aims at supporting projects, programmes, policies and other activities in developing countries, so as to attain the goals set by the international community in combating climate change as well as achieving the ultimate objective of the UNFCCC. The fund is also expected to promote a paradigm shift towards low-emission and climate-resilient development so as to attain sustainable development. The developing countries would be provided with support to limit or reduce their GHG emissions and adapt to the impacts of climate change, after considering their development needs particularly those vulnerable to the adverse effects of climate change.

At the national level, the Convention requires the member countries to submit national communications about GHG emissions to the Conference of the Parties (COP) on a regular basis. The COP is considered as the supreme body of the climate change convention. This information about national GHG emissions, national activities and international cooperation is reviewed periodically so that the parties can track the Convention's effectiveness and draw lessons for the future national and global actions. National inventories of GHG emissions and removals are to be submitted by the members annually. The inventories are prepared by using agreed methodologies of data collection, and are subjected to an annual technical review by experts.

Member countries are also expected to take urgent and cost-effective steps to rebuild the damaged public health infrastructure. Strategies should be adopted for the surveillance of infectious diseases, maintenance of proper sanitation programmes, preparation to face disasters, improved water and pollution control. Certain other steps like public education directed at personal behaviour, training of researchers and health professionals, introduction of protective technologies such as housing

improvements, air conditioning, water purification and vaccination will also go a long way in this direction.

Another step that is being used and can be used by national governments is the imposition of taxes on those who make substantial emissions. Tax can be imposed on the carbon content of oil, coal and gas. This could discourage the use of fossil-fuel, and hence, can lead to reduction of carbon dioxide emissions. This tax has been tried in a number of industrialised countries and evidence show that carbon taxes have enabled reductions in CO<sub>2</sub>.

The maximum quantity of GHGs emissions are made as a result of meeting the energy requirements. The combustion of fossil fuels like coal, oil and natural gas accounts for about 80 percent of all CO<sub>2</sub> emissions. The extraction and combustion of these fossil fuels also emits methane, carbon dioxide, and large quantities of carbon monoxide and other air pollutants. It is estimated that the industrial sector accounts for 43% of the global CO<sub>2</sub> emissions from fossil-fuel combustion, building sector 31%, transport 22% and agriculture 4%. These emissions can be reduced significantly through a combination of new technologies and appropriate policies.

New approaches to forestry and agriculture will also help in reducing the emission as well as storage of carbon. For this, deforestation should be prevented and forests are to be protected. Further, the sustainable management of forests will enable generation of forest biomass, which can be used as a renewable resource. This biomass can also be used as a substitute for fossil fuels, which will in turn facilitate reduced carbon emission. Other options that will enable the reduction of emissions are tradable emissions permits, phasing out or counter productive subsidies, information and education programmes, and voluntary programmes. Changes in practices and lifestyles, ranging from better urban transport planning to personal habits like better energy management at homes can go a long way in this direction.

Farmers can also aid in reducing the emission of various GHGs, by changing farming practices. Methane emissions can be reduced to a very large extent by using sodium sulphate or coated calcium carbide to the urea-based fertilizer, or by replacing urea with ammonium sulphate. Another strategy is to match the timing and amount of nitrogen supply to the crop's specific demands. Further, the interaction of fertilizers with the local soil and climatic conditions can also be influenced by optimizing the tillage, irrigation and the drainage systems. This will also facilitate cutting emission rates. Another potential technique is the storing of carbon in agricultural soils. This can be done by resorting to reduced tillage, increased vegetative cover, and greater use of perennial crops and reducing periods when fields are left uncultivated. This technique will also help in preventing erosion and improving the quality of water and air. However, care must be exercised to ensure that the carbon storage does not lead to higher nitrous oxide levels, which may occur as a result of increased soil moisture or fertilizer use.

Methane emissions from livestock can be reduced drastically by using new and improved feed mixtures. This can be achieved by adding additives that can increase the efficiency of animal feed and boost animal growth rates, leading to a net decrease in methane emissions.

### **Climate Change**

As seen in the earlier section, GHGs contribute to the greenhouse effect and enhance global warming. Climate change is an after effect of global warming. Climate change is referred as the change in normal weather patterns around the world over an

extended period of time, typically decades or longer. Chowdhury (2007) says that climate change is –

“any systematic alteration or statistically significant variation in either the average state of the climate elements such as precipitation, temperature, winds, or pressure; or in its variability, sustained over a finite time period (decades or longer). It can be referred to as the long-term change in global weather patterns, associated especially with increases in temperature, precipitation, and storm activity.”

Often, climate change is used interchangeably with global warming, and the greenhouse effect. However, presently the term climate change is used to denote only any change or changes in modern climate systems, whether due to natural variability or as a result of human-caused activity, including an increase over a period of time of the average temperature of the Earth’s atmosphere and oceans, known as global warming. Before discussing climate change, let us discuss about weather and climate.

### **Weather**

Weather is defined as the temperature, rainfall, or storms in a specific place on a specific day or over a very short period, like one season. For example, a person is talking about whether when he says that it is a warm today or it is raining today. The weather measures aspects like temperature, rainfall, wind and cloud conditions that happen on a day or a season. There can also be extreme weather conditions like heavy rains, storm and hurricane.

### **Climate**

Climate is the average weather or weather conditions that occur over a considerably long period of time. It is a very complex natural process that includes the interaction of the air, water and land of a particular area. Climate can be influenced by a number of factors like the direction of the air in the atmosphere, the water currents and distance from mountains and oceans. When climate is measured, it takes into account a number of aspects like the average temperature, the average rainfall or snowfall and the storms, in an area or over a long period of time. The time factor may be of a number of decades or even centuries. For example, when someone says, south-western monsoon occurs during the month of June or it never snows in the plains, he is talking about the climate of that place.

Climate is a very complex natural process that includes the interaction between the air, water, and the land surface. The patterns of the movement of the air through the atmosphere and the movement of water through the oceans have a profound impact on the temperature and the rainfall. There are a number of phenomena or processes that affect and change the climate on earth. Some of these are natural, and others are man-made. While volcanic eruptions, the amount of solar energy coming to the earth, are natural, there are a number of human activities that lead to the climate change.

Climate change is now an important environmental problem that has received wide attention. It is an issue that has global, regional, national and local implications. According to IPCC, human beings are altering the earth’s natural climate system at a very large scale and if this continues, it could lead to profound consequences for the economy and the quality of life of humans, the future generations and all living beings. The main reason for climate change can be attributed to the increased use of fossil fuel consumption, which is causing exceedingly high concentration levels of GHGs, especially CO<sub>2</sub>.

### *Causes of climate change*

Climate change is caused due to that impact the natural composition of the global climate elements (natural causes), and anthropogenic activities (man-made causes). The natural causes that lead to global warming are as follows:

1. **The sun's energy:** The quantum of solar energy that reaches earth varies over a period of time, and makes an impact on the temperature. Earth becomes warmer or cooler based on the solar energy it receives. This will ultimately result in changes to the climate.
2. **Atmospheric gases:** Certain gases (GHGs) have a strong effect on the climate. These gases trap the heat in the earth's atmosphere. Climate change is due to the trapping of sun's heat energy by the GHGs in the atmosphere. This trapped energy is then radiated or redistributed on the earth's surface altering the temperature and climate. Among the GHGs, CO<sub>2</sub> has a major role to play in driving climate change. A continuous build up of GHGs will significantly change the climate with widespread ramifications for periods to come.
3. **Ocean currents:** The water in oceans is constantly in movement in regular patterns due to the activity of winds. These movements of water in oceans are called ocean currents. This movement plays a significant role in heating up of the globe. For example, when water moves up from the colder, deeper parts of the ocean to the warmer surface, the heat is carried around the globe. In this manner, ocean currents have big impact on earth's climate. When the normal path of the ocean current is disturbed, climate change can happen, with such incidents like extremes of rainfall or drought. The phenomenon of El Nino is a classic example of the impacts of change in the path of ocean currents.
4. **Volcanic eruptions:** The eruption of volcanoes release tiny particles, dust, fumes, etc. into the atmosphere. These particles on reaching the upper parts of the atmosphere and staying there for fairly long periods can directly affect the earth's temperatures and climate.
5. **Snow and ice:** The earth has a cover of ice and snow at the poles and at mountains, as glaciers. The snow and ice being light in colour have the ability to reflect solar energy back out to the atmosphere. When snow and ice melt as earth's climate warms up, less energy will be reflected and this will lead to further warming.

Certain other causes also lead to climate change. These causes include aspects like changes in earth's orbital variables and certain other natural processes of the earth's climate system.

### **Climate Change History**

The climate of earth has changed drastically over different time scales. A study of the climate change pattern shows that there have been several warming and cooling trends that have occurred in the past 1500 years. These trends have severely affected human beings too. There was a trend of warming from 800 AD to 1200 AD. It was during this period that the Vikings colonized Greenland, Iceland and parts of North America. The Vikings had to abandon their settlements of North America and certain parts of Greenland by around 1400 AD as glaciers advanced during this period.

The trends of the recent period show that since 1750, there has been a history of warming till the 1940s. There has been a phase of cooling since then till 1960s. Since this period, the temperature has been increasing steadily. The mean temperature

of India has increased by 0.2° C – 0.6° C in the 19<sup>th</sup> century. In the past 40 years, the temperature is said to have increased by 0.2° C – 0.3° C.

### *Effects of climate change*

Most of the effects of climate change are similar to that of global warming. There are many who use the term climate change interchangeably with global warming, and the greenhouse effect. However, it is widely accepted that “climate change only connotes any change or changes in modern climate systems, whether due to natural variability or as a result of human-caused activity, including an increase over a period of time of the average temperature of the earth’s atmosphere and oceans, known as global warming” (Chowdhury, 2007).

Climate change will have a significant impact on the global environment. It is generally accepted that faster the climate changes, the greater will be the risk of damage. Climate change will lead to drastic variations in the biospheric ambient temperature and can lead to the following effects:

1. Heat stress
2. Change in rainfall patterns and resultant droughts
3. Melting of glaciers
4. Sea-level rise and saltwater intrusion
5. Loss of biodiversity
6. Habitat loss
7. Freshwater depletion

Most of these effects are also applicable to global warming, and have been described earlier under the effects of global warming. However, since most of the above effects have implications with respect to climate change, and for better understanding, they are restated in this section too.

1. **Heat stress:** Certain climate models have predicted that the global temperature will rise over 5° C by the turn of the century. This projection is the average temperature rise, but the rise at the regional level may vary with certain places having much higher levels.
2. **Change in rainfall pattern:** There will be changes in the precipitation patterns, with accelerated hydrological cycle. This will lead to increased precipitation in some areas and decline in other, affecting the water supplies as the water will end up where it is less needed. Statistics shows increasingly heavy rains and snow in the mid and high latitudes of the northern hemisphere, with decreased rainfall in the tropics and subtropics of both hemispheres. This is evident in a strange phenomenon that exists in most parts of eastern Europe, western Russia, central Canada and California. These regions have been witnessing shifting of peak stream flows from spring to winter since more precipitation occurs as rain rather than snow, and hence reaching the rivers more rapidly. The tropical and subtropical areas in Africa that include large basins of the Niger, Lake Chad and Senegal, have witnessed decrease in rainfall by 40%-60%. It is also predicted that the mean precipitation of the dry regions of central Asia, the Mediterranean, southern Africa and Australia will decline drastically. Certain climate models predict the precipitation to become more intense in certain regions leading to increased runoff and floods, which will reduce the water holding capacity of the soil. According to this model, the northern midlatitudes including the grain producing areas of Europe and North America will have less soil moisture in summer, thereby affecting the food security of the globe.

3. **Melting of glaciers:** Glaciers are an essential part of the earth's natural environment. It is one of the significant and sensitive indicators of climate change. The world's glaciers have been receding, and it is reported that the Arctic sea ice have shrunk by nearly 2.7% per decade since 1978. This is attributed to change in climate elements such as temperature, precipitation, wind speed, humidity, and solar radiation. Melting sea ice will lead to global changes in water resources and circulation, and could speed up warming of the Arctic as water absorbs much more heat than ice. The shrinking of glaciers will make available large quantities of water to the oceans and the atmosphere leading to a significant rise in the sea level.
4. **Sea-level rise and saltwater intrusion:** The sea level has already risen by four to eight inches during the 20<sup>th</sup> century due to the effect of melting ice and thermal expansion of warmer ocean water. It has been predicted by climate change models that the rise in sea level will be even greater in the 21<sup>st</sup> century. The mean sea level is expected to rise about 9-88 cm by the year 2100, leading to flooding of low-lying areas and other related collateral damages. The rising sea levels will lead to subsidence; erosion and submerging of coastal wetlands and mangroves; and intrusion of saltwater into rivers, estuaries and coastal aquifers. Certain other likely impacts are changes in salinity distribution in estuaries, altered coastal circulation patterns, destruction of transportation infrastructure in low-lying areas, reduced fish harvest, and increased frequency in the occurrence of hurricane.
5. **Loss of biodiversity:** Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part". Climate change could lead to increase in the global precipitation and changes in the severity or frequency of extreme events. The climatic zones are expected to shift poleward, disrupting forests, deserts, rangelands, and other unmanaged ecosystems. Consequently, many of the ecosystems will decline or fragment leading to extinction of a number of individual species which will have direct effect of the biodiversity. It is also stated that biodiversity will decrease due to multiple pressures like increased land use intensity and the destruction of natural and semi-natural habitats. This decrease will be in both genetic and species biodiversity and the changes can lead to the breakdown of the structure and functioning of the ecosystem as well as its interaction with the various cycles like water, carbon, nitrogen, etc. According to the IPCC:  
Climate change directly affects the functions of individual organisms (e.g. growth and behaviour), modifies population (e.g. size and age structure) and affects ecosystem structure and function (e.g. decomposition, nutrient cycling, water flows, and species compositions, and species interactions) and the distribution of ecosystems within landscapes; and indirectly through, for examples, changes in disturbance regimes.
6. **Habitat loss:** Climate change is likely to have a significant impact on the various habitats. The rise in mean sea level is expected to cause flooding of low-lying areas thereby damaging fresh water habitats as well as agro ecosystems. The fresh water and estuarine habitats are the breeding ground of thousands of fishes, molluscs, and amphibians. These habitats would be destroyed due to inundation during the high tides. Further, the mangroves, coastal wetlands, beach ecosystem coral reefs, sea vegetation, will also be

degraded in a large scale. In the arable lands, invasion of alien species of plants will lead to destruction of natural habitat and the indigenous species. For example, the *Parthenium sp.* that was accidentally introduced in India with imported wheat has invaded most of the land adjacent to the cultivated fields leading to serious habitat destruction.

- 7. Fresh water depletion:** The world over, precipitation and evaporation patterns will change leading to prolonged droughts. This will result in disparity between the rates of evapo-transpiration against precipitation. As a result of this phenomenon, ground water would get depleted and permanent water bodies would dry up. In India, this will have serious repercussions as majority of the population who reside in arid and semiarid regions will have reduced access to fresh water. This may result in social tensions and unrests.

### *Dealing with the effects of climate change*

Since climate change has in-country, regional and global implication, the preparedness for the future, adaptation and mitigation strategies must include mutually beneficial frameworks of cooperation among all concerned. In order to adapt to the effects of climate change, there should be a good understanding of the socio-economic and natural systems, their sensitivity to climate change, and their inherent ability to adapt to changes.

Nations around the world are putting in their best efforts to stop climate change, help their people adapt to the already occurred changes, as well as to prepare the likely changes. Most of the efforts taken in this direction by the Governments are in association with international organizations. They jointly work to make policies with respect to important issues pertaining to climate change.

### *National efforts*

Governments the world over are putting in their best efforts, to mitigate climate change and for reducing the after effects. These include measures like policy making, adopting of fresh approaches that will allow sustainable development while lessening the impact of climate change. The developed countries are taking steps that will reduce their emission levels of GHGs. The developing countries are being assisted by the UNFCCC and certain specialized international organizations with funds and technology to enable development of sustainable strategies that will reduce emission of GHGs.

Forests have the capacity to absorb CO<sub>2</sub> and store carbon. This process helps in mitigating climate change. Many developing countries have forests that provide invaluable services in this direction. Forests provide critical resources that help in dealing effectively with the impacts of climate change and adapt to problems like rising temperature and sea levels. The national Governments, with the assistance of UNFCCC and other organizations are taking safeguards to protect forests and those ecosystems which help the world mitigate and adapt to climate change.

### *International efforts*

At the international level, the United Nations (UN) is involved in policy making. Since 1979, a number of initiatives were taken up by the UN to address the problems of climate change. This history of the international response to climate change is given in Table below:

Year	Effort	Purpose
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1972	Stockholm Declaration	Laid the foundation of the contemporary environmental policy
1979	World Climate Conference	Issued a declaration calling the world's Governments 'to foresee and prevent potential man-made changes in climate that might be adverse to the well-being of humanity'. Planned to establish a World Climate Programme (WCP) under the joint responsibility of the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), and the International Council of Scientific Unions (ICSU).
1987	Montreal Protocol	Also known as 'Montreal Protocol on Substances that Deplete the Ozone Layer', it dealt with a major group of industrial gases, and chlorofluorocarbons (CFCs). In the Protocol, there was a wide consensus and effective action was mobilized quickly to deal with ozone-depleting substances.
1988	Inter-governmental Panel on Climate Change (IPCC) established	The panel was established by UNEP and WMO. It had the mandate to assess the state of existing knowledge about the climate system and climate change; the environmental, economic, and social impacts of climate change; and the possible response strategies
1990	IPCC released its First Assessment Report	The report confirmed the scientific evidence of climate change. The report had a powerful effect on the policy makers and the general public. It provided the basis for negotiations on the climate change conventions.
1990 December	Approval of the start of treaty negotiations by the UN General Assembly	Based on the approval, the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC) met for five sessions between February 1991 and May 1992.
1992 June	Earth Summit at Rio de Janeiro	The United Nations Framework Convention on Climate Change (UNFCCC) was signed by 154 states and the European Community. The earth Summit was the largest ever gathering of Heads of State. Certain other agreements, the Rio Declaration, the Agenda 21, the Convention on Biological Diversity, and

		Forest Principles were also adopted. The Convention came into force on 21 <sup>st</sup> March, 1994. The Conference of the Parties (COP) was made the Convention's ultimate authority.
1995	The first session of COP (COP-1) held in Berlin from 28 <sup>th</sup> March to 7 <sup>th</sup> April	Delegates from 117 parties, 53 observer States, over 2000 observers and journalists participated in COP-1.
1995 December	IPCC finalizes the second assessment report	The report that was widely acclaimed was written and reviewed by over 2000 scientists and experts from around the globe.
1997 December	Kyoto Protocol adopted	The high profile event (COP-3) in Kyoto, Japan was attended by over 10,000 delegates, observers, and journalists.
2005	Kyoto Protocol	The Kyoto Protocol, the most significant legally binding protocol, came into force on the 16 <sup>th</sup> the February 2005. It provides for quantified emission limitation and reduction commitments for the developed countries, and mechanisms to facilitate review as well as compliance with the targets. Under this protocol, the countries promised to reduce GHG emissions and to look for alternate sources of energy that will lead to lesser CO2 emissions.
2007	Bali Action Plan	This was adopted at the UNFCCC meeting in Bali, Indonesia (COP-13). The countries agreed to a course of action for a new negotiating process to tackle climate change. The goal was to make decisions on aspects like what would be included in a new agreement after the Kyoto Protocol. The UNFCCC countries decided that addressing forest degradation was also important and REDD was formed. Discussions also have been done as to how REDD could be part of a new agreement to reduce GHGs after the Kyoto Protocol ends in 2012. The Conference attracted a great deal of attention as the Fourth Assessment Reports by the Intergovernmental Panel on Climate Change (IPCC) was released.
2008	Accra Declaration	The Accra Declaration of UNCTAD, which took place on 25 April, stated the

		climate change adaptation and mitigation need to be urgently addressed, in accordance with the provisions and principles of the UNFCCC and declared that adequate financing and technology will be critical to help developing countries to meet the challenge.
2009	Copenhagen Accord	The accord which took place at Copenhagen, Denmark, discussed several important points for a future agreement which included commitments to reduce emissions and long-term funding plans for supporting action to stop climate change. Though not a legally binding agreement, this accord is a step toward reaching agreement at the next annual UNFCCC meeting in Cancun, Mexico.
2010 November 29 – December 10	Cancun	The UNFCCC meeting at Cancun, Mexico, took place from November 29 to December 10, 2010. The meeting discussed about differentiated actions and measurable support in the form of finance and technology are required from developed country emitters like the United States, the European Union, the United Kingdom, Germany, Japan and Russia for meaningful actions in the developing countries, so as to achieve science-based emission reduction targets in the short, medium and long-term. Cancun concurred to agreements on measures to establish frameworks for protecting the world’s forests, establish green climate fund to provide poorer countries with the resources they need to adapt to and mitigate the effects of climate change, and also a technology mechanism that is meant to facilitate the sharing of clean technologies.
2011 November – December	Durban	The post Kyoto arrangements were discussed at the Durban Conference (COP 17). The Conference aims at reducing the aggregate emissions of GHGs of Annex I parties by at least 25.40 percent below 1990 levels by 2020. The commitment period would begin on 1 <sup>st</sup> January 2013 and end either on 31 <sup>st</sup> December of 2017 or 2020. The rationalization of Green-Climate Fund

		and making it more effective is also envisaged.
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A few of the above mentioned initiatives are of profound importance in the addressing of climate change and is essential for the study of climate change and mitigation. Some of such initiatives requires further elaboration and is presented as follows:

1. **NFCCC:** UNFCCC or United Nations Framework Convention for Climate Change is a body within the UN that is involved in policy making, and works to organize countries to design climate change policies. It holds annual meetings attended by delegations from member nations, wherein decisions to deal with climate change is made. Though decisions are made only by government delegations, Non-governmental organizations (NGOs), private businesses, and groups with special interest like organizations that work for indigenous peoples' rights, also attend these meetings to make their opinions heard and to influence the decisions.

The UNFCCC assist nations in the process of stopping or lessening climate change and adjusting to the effects that has already happened, or is happening. The assistances are in the form of creation of plans and policies, research, and support to the needy nations with money and technologies so that action can be taken to solve the problems that have arisen due to climate change. Of all the agreement made by the UNFCCC, the Kyoto Protocol has the prime position.

2. **Kyoto Protocol:** The Kyoto Protocol was adopted in Kyoto, Japan, in December 1997, and it came into force on the 16 February, 2005. The Protocol aims at tackling global warming by setting targets for nations to reduce GHG worldwide. In addition to reducing HG emissions, it was also agreed to look for alternate sources of energy that will lead to lesser CO<sub>2</sub> emissions. The developed countries also agreed to transfer technology and funds to the developing countries in order to assist them in stopping climate change and adapting to the changes that have occurred and is likely to occur in the future. The countries made commitments to take these actions within a specific period of time. This period is called a commitment period. The first commitment period of Kyoto Protocol is from 2008-2012.

The emissions target must be achieved by the period 2008-2012. This is calculated as an average over the five years. It was also agreed that cuts in the three most important gases carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) will be measured against a base year of 1990; and three long-lived industrial gases, hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF<sub>6</sub>) are to be measured against either 1990 or 1995 baseline.

The Protocol also encourages the governments to cooperate with one another to improve energy efficiency, reform the energy and transportation sectors, promote renewable forms of energy, phase out inappropriate fiscal measures and market imperfections, limit methane emissions from waste management and energy systems, and manage carbon sinks such as forest, croplands and grazing lands.

Presently, the member countries of the UNFCCC are working to design new policies and agreements for the next commitment period, which starts after 2012. The other important areas that are being discussed include the following:

1. Reduction of the amount of CO<sub>2</sub> and other gases released into the atmosphere.

2. Stopping deforestation and improving forest management and forest conservation.
3. Protecting the communities from rising sea levels.
4. Creating national adaptation plans.
5. Finding out ways to provide expertise, transfer of technology and funds to pay for the above actions.

The aspect of carbon trading came into play subsequent to the Kyoto Protocol, as developed nations agreed to limit their GHG emissions to the levels of 1990 or pay a price to those that do. The idea of carbon credit was to make developed countries pay for their emissions while monetarily rewarding those countries having good behaviour in this regard.

- (a) **Annexure B countries:** They are the 39 emissions-capped countries listed in Annexure B of the Kyoto Protocol. In practice, Annexure I of the UNFCCC and Annexure B of the Kyoto Protocol are used interchangeably.
- (b) **Annexure I countries:** This Annexure include the industrialized OECD countries and countries whose economies are in transition, listed in Annexure I of the UNFCCC. Two countries, Belarus and Turkey are listed in Annexure I, but not in Annexure B. Further, Croatia, Liechtenstein, Monaco and Slovenia are listed in Annexure B but not in Annexure I.
- (c) **Annexure II countries:** Annexure II of the UNFCCC includes all the original members of OECD. However, the countries with economies in transition are not included in this. Annexure II countries are required to provide financial resources to the developing countries so as to enable them to undertake emissions reductions.
- (d) **REDD+:** REDD+ is Reducing Emissions from Deforestation and Forest Degradation plus conservation, sustainable management of forests and enhancement of forest carbon stocks. As per UNFCCC, it involves the 'policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries'. REDD+ deals with the benefits that arise from the conservation and the sustainable management of forests and forest carbon stocks.

REDD+ is a kind of international payment system for ecosystem services that helps in reducing the amount of CO<sub>2</sub> released into the atmosphere as well as conserving the forest so that climate change will be mitigated. The working of REDD+ is such that the developed countries, international funds, or private companies offer financial or other benefits to developing countries, landowners, or communities to take action to reduce carbon emissions from deforestation and forest degradation. For those countries that have their forests intact, benefits will accrue from keeping these forests standing so that it can continue to sequester and store carbon. For countries which cut down trees, benefits could be paid for stopping deforestation practices and restoring degraded forests. REDD+ is supposed to monitor these activities and deal with the flow of funds.

#### **National Action Plan on Climate Change**

Prime Minister on 30 June, 2008 released India's National Action Plan on Climate Change. The Action Plan prepared under the guidance and direction of Prime Minister's Council on Climate Change reflects the importance the Government

attaches to mobilizing the national energies to meet the challenge posed by climate change. The action plan focuses attention on the following eight priority National Missions:

1. Solar Energy
2. Enhanced Energy Efficiency
3. Sustainable Habitat
4. Conserving Water
5. Sustaining the Himalayan Ecosystem
6. A Green India
7. Sustainable Agriculture
8. Strategic Knowledge Platform for Climate Change

### ***Impact of climate change in India***

India is a country whose economy can be impacted adversely by the effects of climate change. A large part of the Indian population depends on climate sensitive sectors like agriculture, fisheries, and forestry for livelihood. These factors make most of the population highly vulnerable to the effects of climate change. Climate change can have serious impact on its crops, forests, coastal regions, which will affect the achievement of the developmental goals. Other possible impacts include effects on food security, water security, health hazards, flooding/inundations, migrations, and so on. Broadly, the possible problems that India may face due to climate change are:

1. Risk of lower agricultural production
2. Risk of sea level rise
3. Risk of extreme events
4. The costs of changing energy strategy

India being a developing economy requires large quantities of energy. It is often stated that higher energy production and consumption is one of the major driving forces of economic development and poverty reduction. Most of the developmental and economic activities depend on energy. As a major part of India's GDP is derived from service sector, the GHG emission levels are not that high (4% of the total global emission). However, its emissions levels are bound to grow in the short and medium term with industrialization catching up. Further, to meet the increasing demands of its growing population (India houses 17% of the global population) the contribution of the manufacturing sector is also set to increase, which will accelerate the level of GHG emissions.

A study by Kumar and Parikh (2001) estimated that increased levels of carbon dioxide fertilization in India will lead to yield losses for rice and wheat. According to them, the yield loss of rice will vary between 32 and 40%, and that of wheat between 41 and 52%. Even with farm level adaptations, the impacts of climate change on Indian agriculture are expected to be significant. The study also projects that in the temperature in India will rise by 2.5° C - 4.9° C. They estimated that with a temperature rise of 2° C and an accompanying increase of precipitation by 7%, the net farm level revenue would fall by 9%. Similarly, an increase of temperature by 3.5 ° C and resultant increase in precipitation of 15%, will lead to a fall in farm level net revenue by nearly 25%. They also estimate that the GDP would drop by 1.8-3.4%.

Prasad, and Kochher (2009), provided a number of measures that would be ideal for mitigating the climate change. They are:

1. Improving energy efficiency and conservation as well setting up a Bureau of Energy Efficiency
2. Power sector reforms

3. Promoting hydro and renewable energy
4. Promotion of clean coal technologies
5. Coal washing and efficient utilization of coal
6. Afforestation and conservation of forests
7. Reduction of gas flaring
8. Cleaner and lesser carbon intensive fuel for transport.
9. Encouraging mass rapid transport systems
10. Environmental quality management and improving energy efficiency.

### ***Steps taken by India***

India as a country would be severely affected by global warming, has taken a number of steps. Though India's contribution to GHGs is negligible, it has taken concerted efforts in this regard. India has incorporated specific provisions that provides for environment protection in the constitution. For example, Article 48A provides that the State shall endeavour to protect and improve the environment and to safeguard the forests and wild life of the country. Article 51A (g) makes it obligatory for every citizen of India, to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures.

India has recently adopted the National Environment Policy (NEP) in 2006, which is a major step in this direction. The main objectives of NEP are the following:

1. Conservation of critical environmental measures.
2. Intra-generational equity, which provides for livelihood security for the poor
3. Inter-generational equity
4. Integration of environmental concerns in economic and social development
5. Efficiency in the use of environmental resources
6. Environmental governance
7. Enhancement of resources for environmental conservation.

It has also taken a number of other measures and policy initiatives. The Government of India has identified 17 categories of heavily polluting industries, which include cement, thermal power plant, distilleries, sugar, fertilizer, integrated iron and steel, oil refineries, pulp and paper, petrochemicals, pesticides, tanneries, basic drugs and pharmaceuticals, dye and dye intermediates, caustic soda, zinc smelter, copper smelter and aluminium smelter. Mandatory provisions have been made for the submission of an Environmental Statement by the polluting units, seeking consent under legislations like the Water (Prevention and Control of Pollution) Act, 1974, the Air (Prevention and Control of Pollution) Act, 1981, the Environment (Protection) Act, 1986, etc. Further, authorization is also required under the Hazardous Wastes (Management and Handling) Rules, 1989.

Other steps include the National Action Plan on Climate Change which was released by the Honourable Prime Minister of India on June, 2008. The Plan was prepared under the guidance and direction of the Council on Climate Change. The council, which is chaired by the Prime Minister, has been established to formulate policies on climate change mitigation and adaptation. The Council has laid down broad directions for mitigation and adaptation approaches for addressing the impact of climate change. It also provides guidance on bilateral and multilateral programmes for collaboration, research and development as well as related international negotiations. The Council also provides guidance on matters relating to the coordinated action on the domestic agenda, and reviews the implementation of the National Action Plan.

The National Action Plan reflects the importance the Government attaches to mobilizing the national energies to face the challenges posed by climate change. The plan focuses attention on eight priority National Missions, namely:

1. Solar energy
2. Enhanced energy efficiency
3. Sustainable habitat
4. Conserving water
5. Sustaining the Himalayan ecosystem
6. A Green India
7. Sustainable agriculture
8. Strategic knowledge platform for climate change

India has also set up an ozone cell in the Ministry of Environment and Forests, as per its commitment to implement the Montreal Protocol and its Ozone Depleting Substances (ODS) phase out programme. The cell is the apex body that looks after the matters related to ozone depleting substances and activities. Custom/excise duty exemption for ODS phase out projects, duty exemption for new investments with non-ODS technologies, are granted by this cell. Further, the Reserve Bank of India (RBI) has issued directions to all financial institutions and commercial banks to desist from financing new establishments that has ODS technology. A licensing system is also in place to regulate the import and export of ODS.

As seen from the discussions, it can be analyzed that India has been taking considering actions in terms of policies, programmes and projects in the direction of mitigation of climate change. Many of these actions are likely to have positive effects on climate change.

### *Acid rain*

In simple parlance, acid rain denotes all precipitations which are more acidic than normal. Normally water is said to be clean if it has pH upto 5.6, hence acid rain has pH value less than 5.6. Acid rain results when oxides of sulphur and nitrogen from gaseous emissions interact with water vapour and sunlight, and get chemically converted to acidic compounds like sulphuric, sulphurous, nitric and nitrous acids. Acid rains are caused mainly by activities like oil refining, metal smelting, certain industrial activities, coal burning in power plants, motor vehicle exhaust, and so on.

Acid rains can take the form of dry deposition and wet deposition. When these acidic compounds along with other organic and inorganic chemicals are deposited on the surface of earth as aerosols and particulate, it is known as **dry deposition**. When these compounds are carried to the earth by rain drops, snow, fog and dew, it is called **wet deposition**. The dry deposition forms only a small fraction of the total acid deposition that falls on the earth's surface. Acid rain is caused due to the upgradation of environment. Acid rains create a large number of irreversible effects to water, air, soil, vegetation, buildings and structures, etc.

### *Effects on water*

The acid rain that falls on the ground reaches the rivers, lakes and wetlands and makes the water acidic. The acidification of water bodies adversely affects aquatic life. High acidity will kill green algae and other forms of bacteria that thrive in water. These life forms are indispensable for any aquatic ecosystem, and their destruction will result in reduced fish population. Further, the pace of decomposition of organic matter in water bodies will be reduced when the pH value is low. Another

effect of acid rain is that it dissolves the naturally occurring toxic substances like aluminium and mercury and freeing them, thereby leading to increased water pollution.

***Effects on air***

The traces of acid in the air can combine with other chemicals and can lead to production of smog. This is more evident in urban areas. This smog can lead to respiratory problems to humans.

***Effects on soil and vegetation***

When the soil becomes acidic due to acid rain, the micro-organisms are destroyed. This has an adverse effect on plants, as plants depend on micro-organisms for its growth. Another effect of acid rain is the reduction in the availability of nutrients in the affected soil. In addition to this, the waxy coatings of the leaves are damaged by acid rain, causing the leaves to fall down, and affecting the process of photosynthesis. A combined effect of all this will lead to large scale of destruction of plants and vegetation. The destruction of plants and vegetation, in turn, will lead to adverse effect on various species, thereby disrupting the entire food chain in particular, and the ecosystem in general.

***Effects on buildings and structures***

Acid rain, especially dry deposition, can corrode metals and alkaline building materials like metals, marble, limestone, and so on. This can lead to large scale weathering of statues, monuments, structures and buildings. Taj Mahal is a live example of acid rain affecting ancient monuments.