Introduction

Greenhouse Effect

The Earth's temperature is maintained at a level where it can sustain life by a balance between heat from the sun, and cooling from reflecting some of the heat by the Earth's warm surface and atmosphere back to space (Agarwal, 2001). Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which it is emitted. In the troposphere, the temperature generally decreases with height. Effectively, infrared radiation emitted to space originates from an altitude with a temperature of, on average, –19°C, in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average, +14°C. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere, and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect (Solomon *et al*., 2007).

Greenhouse gases, CO_2 and Global Warming

CO_2 (77%), N_2O (8%), and CH_4 (14%) are the three main GHGs (Fig-1) that trap the infrared radiation and contribute to climate change (Scherr and Sthapit, 2009). Atmospheric CO_2 concentration is one of the most important factors likely to determine the climate of the twenty-first century (Houghton *et al*., 2001). Among the major and minor GHGs CO_2 is most important having a contribution of more than 50% of the total warming in the Earth's atmosphere (Goel *et al*., 2008).

Measurement of CO_2 in the atmosphere which began in Antarctica in 1957 and Mauna Loa in 1958 indicate clearly that the concentration of CO_2 in the atmosphere is increasing rapidly since the start of industrial revolution. The ice core studies showed that the CO_2 concentration was about 205ppm some 20,000 years ago. Pre-industrial value was 280ppm during past 10,000 years. Prior to 1860 the value was 274ppm whereas prior to 1900 the CO_2 concentration was 290ppm. Mauna Loa studies also observed that from 1958-1982 there was an increase of 1ppm CO_2/year. The value of atmospheric CO_2 Is currently increasing at the rate of 1.5-1.8ppm (Uprety, 1998) and was recorded to be as high as 375ppm in 2005 (Lindinger, 2007). In total humans emit around 32 Gt of CO_2 each year. While CO_2 is only responsible for 20% of the natural greenhouse effect (GHE) it accounts for about 60% of the anthropogenic greenhouse effect that is causing the latest wave of Global warming (Zwick, 2007).

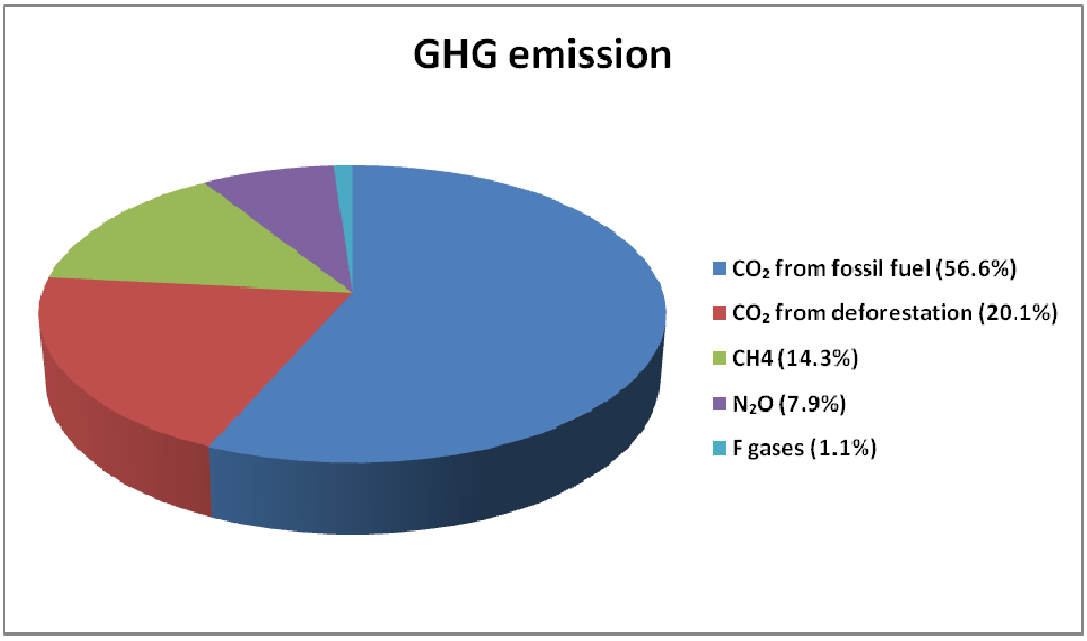

Figure-1: Amount of GHGs emitted (Smith et al, 2007)

Factors Contributing to Climate Change

Climate change is basically resulting owing to the uncontrolled emissions of the greenhouse gases due to the industrialization, deforestation, burning of the fossil

fuels, and many natural causes like volcanoes, death and decomposition of organic matter etc. So the factors can be put under two categories: (1) natural causes; and (2) anthropogenic causes.

Natural Causes

Microbes, plants, animals and humans, in fact all living forms contribute naturally to global warming. They contribute to CO_2 emissions by respiration and through their death and decomposition. The plants on defoliation cannot absorb the available CO_2 and contribute to CO_2 emissions from the respiring branches. A significant part of the earth's climate variability is also caused by changes in the solar radiations (Tiwari and Ramesh, 2007). Various causes that govern climatic variability at different time-scale have been identified, which can be mainly grouped into internal and external causes. Internal causes involve; i) oscillations in ocean-atmosphere system (eg. Thermohaline circulation changes that redistribute heat between the tropics and polar regions), ii) volcanic eruptions (The 1991 volcanic eruption of Mount Pinatubo in Philippines released 20 million tons of SO_2 into the atmosphere cooling the Earth by 1°F (0.33°C) (Agarwal, 2001), iii) changes in Earth's atmospheric concentration of GHGs (CO_2, CH_4, NO_2, CFCs, O_3 that absorb the outgoing long-wave radiation), iv) water vapour and low altitude clouds that form an important feedback mechanisms and v) ice cover and vegetation extent (that control the albedo). The external causes include i) variations in the incoming solar radiation due to change in the sun-earth geometry (Melankovitch cycles) and ii) variation in the incoming solar irradiance at various wavelengths due to changes in the solar activity itself is thought to affect the earth's climate on decadal to millennial time scales (Tiwari and Ramesh, 2007).

Anthropogenic Causes

The human activities (Fig-2) resulting in climate change includes.

i. Industrialization: The concentration of CO_2 has increased from pre-industrial concentration of 270 ppm to 392 ppm in 2010. 19.4% of the total GHGs are emitted from industrialization (Scherr and Sthapit, 2009; McKeon and Gardner, 2009)

ii. Deforestation: The world forests are destroying at an alarming rate. More than 37 million acres of forests-the size of New York are destroyed every year (Foerstel, 2009). Deforestation accounts for about 20% of all the CO_2 emissions and 17.4% of the total GHGs emissions (Scherr and Sthapit, 2009) which is 5.9 ± 2.9 Pg CO_2-eq and is being released into the atmosphere per year which is more than from vehicles and airplanes.

iii. Transportation: The vehicular population is increasing. For eg., the vehicular population in India has increased from a mere 350 million at the time of independence to 40 billion vehicles today. The transportation sector contributes to 13.1% (30 billion tons of CO_2/year) of the total GHGs emissions (Scherr and Sthapit, 2009; McKeon and Gardner, 2009).

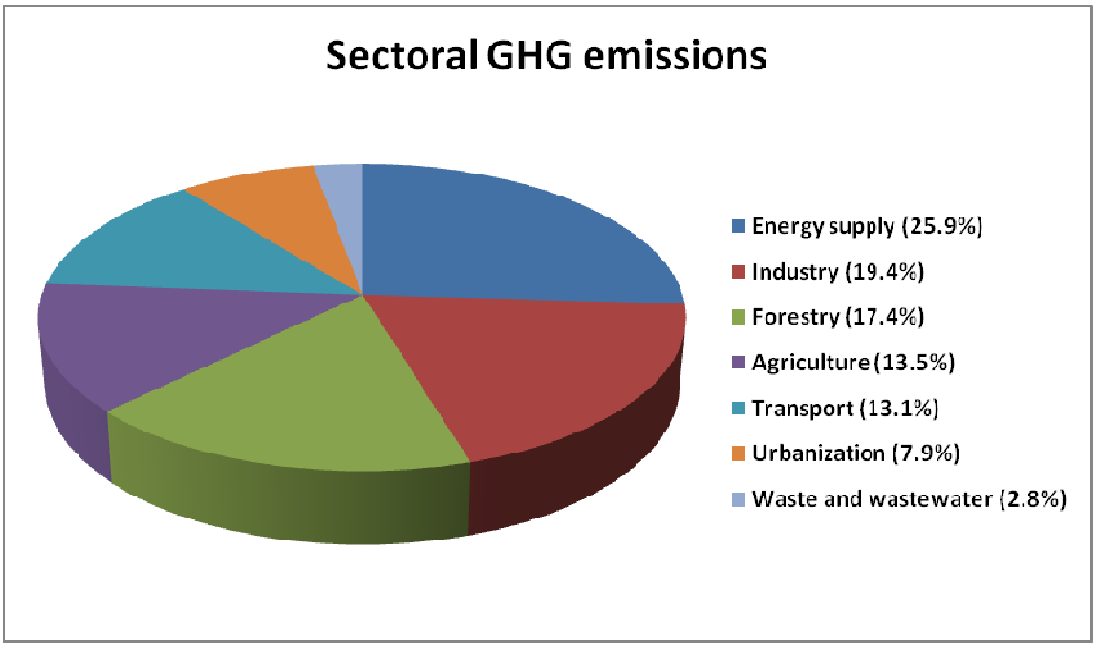

Figure-2: Sectoral GHG emission (McKeon and Gardner, 2009)

iv. Urbanization: It is also expanding fast as the population is increasing leading to the urban heat island effect (UHE) and is responsible for 7.9% of the total GHGs emission (Scherr and Sthapit, 2009).

v. Agricultural practices: The modernization of the agricultural practices with the increase in the use of chemical fertilizers (nitrogenous) along with the increasing

livestocks, manure production and storage causes methane (CH_4) and nitrous oxide (N_2O) to be released, hence causing global warming. The agriculture contributes about 13.5% in the total emission of the GHGs from which it contributes to about 40% of the total CH_4 emissions and 60% of the total N_2O emissions (Smith *et al*, 2007).

vi. Energy supply: This sector is the major contributor of GHGs to the atmosphere contributing to 25.9% of the total emissions as a result of power generation by coal burning (Scherr and Sthapit, 2009; McKeon and Gardner, 2009).

vii. Waste: This sector contributes to around (2.8%) of the total GHG emissions (McKeon and Gardner, 2009).

Scientific models and observations for the past 1000 years provide evidence that global warming is due to anthropogenic increase in greenhouse gases (GHGs) (Pandey, 2002).

Climate Change Policies

To deal with the climate change by reducing GHGs emissions a global framework convention on climate change (UNFCCC) was signed under the auspices of the UN in 1992 (Agarwal, 2001).

The UN Conference on Environment and Development (UNCED) in 1992 at Rio de Janeiro led to FCCC (Framework Convention on Climate Change), which laid the framework for the eventual stabilization of greenhouse gases in the atmosphere, recognizing the common but differentiated responsibilities and respective capabilities and social and economic conditions. The Convention came into force in 1994. Subsequently, the 1997 Kyoto protocol, which came into force in 2005, reasserted the importance of stabilizing greenhouse gas concentrations in the atmosphere and adhering to sustainable development principles. The Protocol laid out guidelines and rules regarding the extent to which a participating industrialized country should reduce its emissions of six greenhouse gases – carbon dioxide, methane, nitrous oxide, chlorofluorocarbon, hydrofluorocarbons and perfluorocarbons. It requires industrialized countries (Annex B countries) to reduce their greenhouse gas emissions by a weighted average of 5.2%, based on the 1990

greenhouse gas emissions. The reduction is to be achieved by the end of the five-year period, 2008 to 2012. The Kyoto Protocol does not require the developing countries to reduce their greenhouse gas emissions (Sathaye *et al*., 2006).