

# The Greenhouse Effect, Global Warming and Climate Change creating hazardous Cascade Effects on Humans

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**ABSTRACT:** The Paper begins with an introduction in which some of the historical aspects followed by review of literature giving some detailed theoretical study of the subject. Anthropogenic emissions creating enhanced greenhouse effect responsible for climate change has been extensively dealt with in the conclusion followed by climate audit specially designed by author. Other than the review of literature from eminent authors, the author has referred material from elementary to advanced books. The reader will find the material in the Paper ideal for a student of Geophysics and specially for the Climate Physicist.

**KEYWORDS:** Albedo, Climate change, Climate catastrophe, Climate forcing, Global climate audit, Global energy balance, Greenhouse effect, Global warming, Global warming potential, IPCC, Ozone layer, Solar spectrum.

## I.INTRODUCTION

Global Warming and Climate Change is the most important environmental challenge of the 21<sup>st</sup> century faced by humans today and the same need to be tackled on a war footing. The Handy Science Answer Book [6] even though an elementary book, is a source book as well as reference book because what is elementary is what is not known and the same is something like, "No wonder if a mathematician forgets Arithmetic". Greenhouse effect is a warming near the Earth's surface created by trapping of heat of the Sun by the atmosphere. The Greenhouse effect was first described in 1861 by John Tyndall (1820-1893). But, the Greenhouse analogy was given in 1896 by the Swedish chemist. Svante Arrhenius (1859-1927). The Earth is made habitable because of the presence of Water Vapor, Oxygen and Carbon dioxide in the atmosphere.

Julie Lambert et.al.[11] have briefed on what is Greenhouse effect. Most of the Sun's solar radiation reaches Earth as visible and near visible wavelengths. Land, water and vegetation absorb a small percentage of this short-wavelength solar radiation. The remaining is reflected or radiated back from the Earth into the atmosphere as long-wavelength infrared radiation. Most of this infrared radiation is absorbed by water vapor, carbon dioxide, methane and few other gases present in the atmosphere and re-emit as heat back into Earth's surface. This process is commonly called the "Greenhouse Effect". The gases in the atmosphere work like a blanket and maintains the surface temperature of Earth to about 14°C. Without this atmospheric blanket, the average temperature of the Earth would have been some -19°C.

Over the last few decades it has been observed that there is an increased build-up of carbon dioxide caused by the burning of fossil fuels and this is a matter of concern. The causes, however, are multifold. Volcanic activity, destruction of rain forests, increased industrialization, emission from motor vehicles, use of aerosols may be some contributing factors.

Climate is characterized by mean air temperature, humidity, winds, precipitation and frequency of extreme weather over a lengthy period of time, 30 to 40 years. Climate change includes both natural variability and atmospheric changes. It has been accepted by researchers that the global warming created during the last century is due to both

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 3, March 2017

natural and anthropogenic changes. According to the report of Intergovernmental Panel on Climate Change (IPCC) of the United Nations, the anthropogenic changes are the main concern and have to be worked on globally by all nations. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as the change of climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Climate change can be detected by many variables the prominent of which is the temperature. Climate changes are predicted by climate models based on assumed greenhouse gas emission scenarios. The scenarios range from CO<sub>2</sub> concentrations 550 ppm\* to 800 ppm. It has been further predicted that the global average temperature will increase by 1.8°C to 4.0°C by the end of the present century (2100).

Climate changes may be attributed to natural processes or to human activity. Among the natural factors are the Earth's internal processes such as volcanic eruptions, the rotation and revolution of the Earth. The solar luminosity is another natural factor. Anthropogenic activity includes greenhouse gases and aerosol<sup>@</sup> emissions. Computerized models have been devised to distinguish natural and anthropogenic causes. On a million year time scale, tectonic drift is taken as the main cause for climate change.

In the literature that follows, we shall see some theoretical aspects, past and present findings on the topic, Greenhouse effect, Global Warming and Climate change.

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$$\text{*Parts per million (by weight)} = \frac{1\text{mg}}{\text{L}} = \frac{1\text{g}}{\text{m}^3}$$

@A collection of airborne solid or liquid particles with typical size between 0.01 and 10 μm and remaining in the atmosphere for long time.

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## REVIEW OF LITERATURE

### II. GLOBAL TEMPERATURE

**2.1 Preamble:** Gilbert M. Master [13] et.al .in their exhaustive book on "Introduction to Environmental Engineering and Science" have extensively dealt with Greenhouse Effect and Climate Change. The authors have started with global temperature, the evidence for which as given by climatologists lies in historical documents, tree rings, changes in ice volume and sea level, fossil pollen analysis and geological observations related to glacial movements. One of the most fruitful approaches, however, lies in the analysis of concentrations of various stable isotopes of hydrogen and oxygen as found in ice cores and sea floor sediments. The separation of light isotopes from heavier ones is temperature-dependent and forms an important historic measure of global temperature. By dating marine sediments extracted from deep sea cores and observing the ratio of the two oxygen isotopes in their carbonates, a historic record of the volume of ice storage on Earth can be established.

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**2.2 Simple Global Temperature Model:-** We shall find the surface temperature of Earth as it existed without any anthropogenic emissions and with a very clean atmosphere irrespective of location or time. In Fig.1 is shown solar energy passing a 'hoop' with the same radius as that of the Earth and hitting the Earth. Radiation that misses the hoop also misses the Earth. From the figure we can write Rate at which energy from the Sun received by

$$\text{Earth} = S\pi r_e^2 \text{ Joule per sec or Watt. . (1)}$$

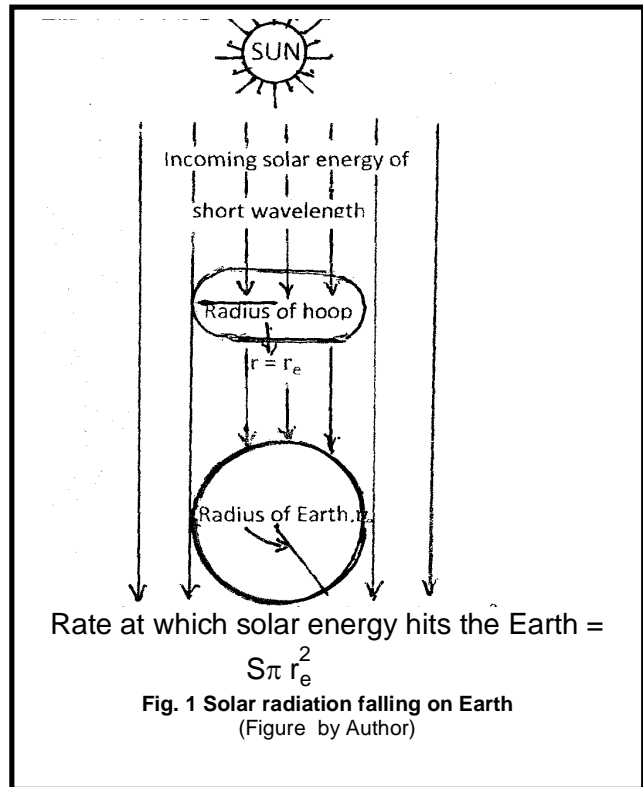
where S is the solar constant the value of which is  $1370 \frac{W}{m^2}$  and  $r_e$  is the radius of Earth

Some part of the incoming energy is absorbed by the Earth and the remaining is reflected back into space and is called as the *albedo* denoted by  $\alpha$  and expressed as a percentage. The value of  $\alpha$  for Earth is about 31% (Fig.2). The albedo does not contribute to heating. The radiation other than reflected is all absorbed by Earth and hence if  $\alpha$  is the albedo for Earth, then we have

$$\text{Energy reflected by Earth} = S\pi r_e^2 \alpha \dots\dots (2)$$

$$\therefore \text{Energy absorbed by Earth} = S\pi r_e^2 (1 - \alpha) \dots\dots (3)$$

\*Fraction of solar radiation reflected by a surface often expressed as a percentage.



As no other mode of transmission of heat such as conduction and convection is possible, whatever heat absorbed by Earth  $S\pi r_e^2 (1 - \alpha)$  will be radiated into space. We can very well apply Stefan's law of radiation which states that "heat energy radiated from a surface is proportional to the area of the radiating surface and 4<sup>th</sup> power of absolute temperature." That is the energy Q radiated back into space by Earth is

$$= \sigma 4\pi r_e^2 T^4 \dots\dots (4)$$

Where  $\sigma$  is the Stefan's constant the value of which is  $5.67 \times 10^{-8} \frac{W}{m^2 K^4}$  and T is the effective black body temperature for Earth. Now, equating (3) and (4), we get

$$S\pi r_e^2 (1 - \alpha) = \sigma 4\pi r_e^2 T^4 \dots\dots (5)$$

$$\therefore T = \left( \frac{S(1 - \alpha)}{4\sigma} \right)^{\frac{1}{4}} \dots\dots (6)$$

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Substituting values we get,  $T = \left[ \frac{1370(1 - 0.31)}{4 \times 5.67 \times 10^{-8}} \right]^{\frac{1}{4}} = 254^{\circ}\text{K} = -19^{\circ}\text{C} \dots (7)$

This temperature,  $-19^{\circ}\text{C}$  is too cold for habitability on Earth. The average global temperature, however, is  $15^{\circ}\text{C}$ . . i.e.  $288^{\circ}\text{K}$ . This is where the Greenhouse Effect comes in. The atmosphere is a mixture of various gases the prominent of which is Nitrogen. Oxygen, Carbon dioxide and water vapor. How the temperature is made suitable for life on Earth is by means of the Greenhouse effect, which follows next section

**2.3 Greenhouse Effect:-** When the average surface temperature of the Earth is  $15^{\circ}\text{C}$  and what we obtained from

Equation, (7) is  $-19^{\circ}\text{C}$ , it means that there has to be some natural agency making the surface temperature  $\theta$  such that  $\theta = 15 - (-19) = 15 + 19 = 34^{\circ}\text{C} \dots (8)$

**Fig.2 Global Temperature Model**

(Figure modified by Author)

which is known as the magnitude of the Greenhouse effect. This agency is nothing but the atmosphere of the Earth rather the constituents present in the atmosphere of the Earth.

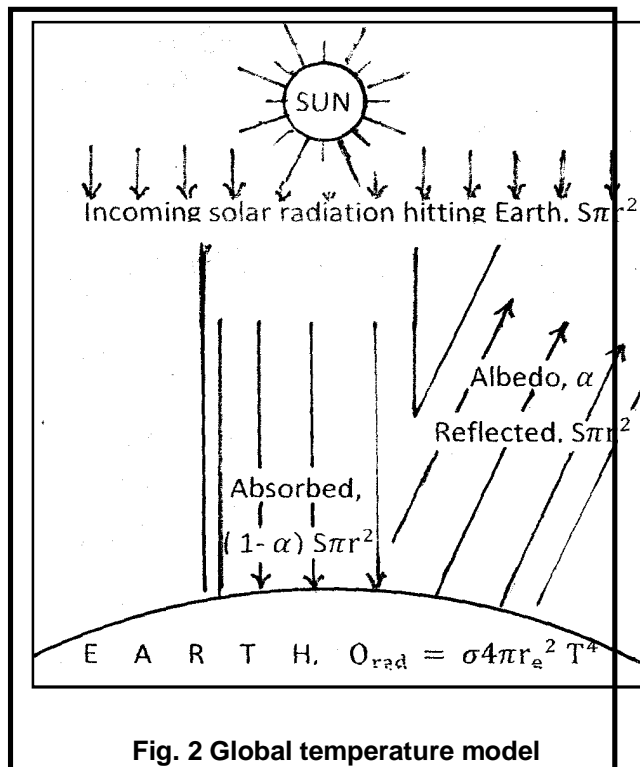


Fig. 2 Global temperature model

The energy absorbed by Earth and radiated towards the atmosphere as long wave infrared radiation is of importance in the Greenhouse effect. As radiant energy from the Earth tries to pass through the atmosphere, it is affected by various gases and aerosols. They may be of either natural or anthropogenic origin present in the air. These constituents do the following :

- They let the radiant energy to pass through unaffected.
- They scatter the energy by reflection and
- They can stop it by absorption.

The key phenomenon of interest is the ability of gases to absorb radiant energy. In the Fig. 3 is shown the absorption spectra for some prominent Greenhouse gases such as Carbon dioxide ( $\text{CO}_2$ ), water vapor ( $\text{H}_2\text{O}$ ), Nitrous Oxide ( $\text{N}_2\text{O}$ ), Methane ( $\text{CH}_4$ ) and Ozone ( $\text{O}_3$ ). The outgoing infra-red radiation from the Earth is absorbed by a combination of these radiatively active gases.

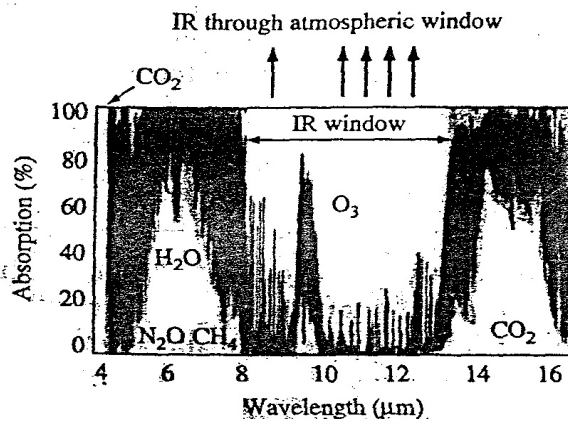


Fig.3 Passage of Long-Wave (IR) radiation From the Earth passing through the Atmosphere (Figure Credit:[13,p.516 ])

From the figure it is seen that there is a relatively clear sky for outgoing thermal radiation of wavelength between 7 to 13  $\mu\text{m}$ . The passage through which the radiation of these wavelength escapes through the atmosphere is termed “*Atmospheric radiative window*”. Radiation with wavelengths other than these is fully absorbed by the Greenhouse gases. Such an absorption heats up the atmosphere, which in turn radiates energy back into the Earth and to space as shown in Fig.4. These gases work as a thermal blanket and increase the surface temperature of Earth beyond the value of  $-19^{\circ}\text{C}$  calculated earlier and as per the magnitude of Greenhouse Effect given by equation (8). Thus the Greenhouse effect adds  $34^{\circ}\text{C}$  of warming to the surface of Earth.

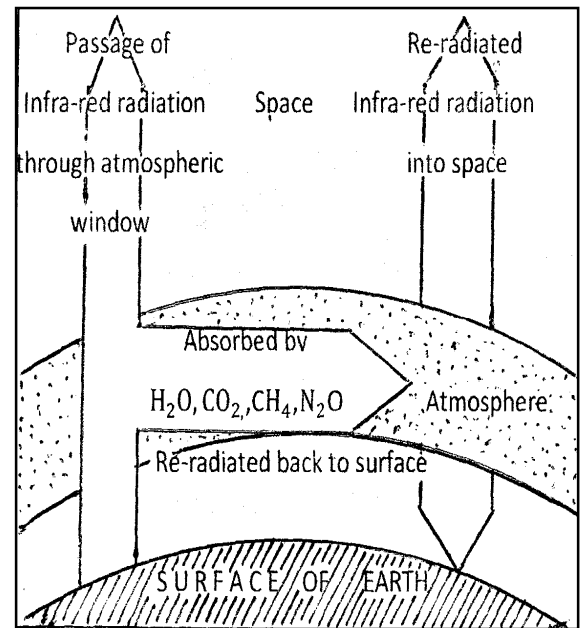
**2.4 Global Energy Balance:-**The Greenhouse effect is illustrated in Fig.5 by a simple model with the process of reflection, absorption and emission from three regions: the surface of Earth, the atmosphere and outer space: The figure is self-explanatory. Whether it is reflection, absorption or radiation, it has to be per unit area of the surface and hence following equation (1). We can write

$$\frac{\text{Incoming solar radiation}}{\text{Surface area of Earth}} = \frac{S\pi r_e^2}{4\pi r_e^2} = \frac{S}{4} = \frac{1370}{4} = 342 \frac{\text{W}}{\text{m}^2} \dots (9)$$

Now,

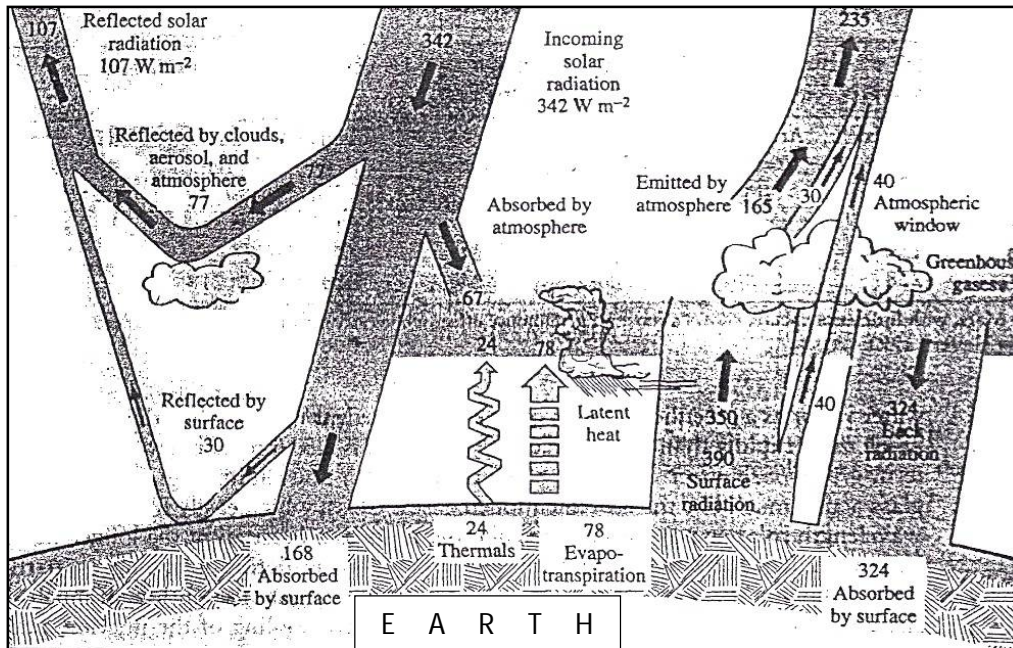
$$\frac{\text{Solar energy reflected}}{\text{Surface area of Earth}} = \frac{S\pi r_e^2 \alpha}{4\pi r_e^2} = \frac{S}{4} \alpha = 342 \times 0.31 = 107 \frac{\text{W}}{\text{m}^2} \dots (10)$$

where  $\alpha=0.31$  is the albedo for the Earth. Of this  $107 \frac{\text{W}}{\text{m}^2}$ , it is estimated that  $77 \frac{\text{W}}{\text{m}^2}$ .



**Fig. 4 Mode of absorption of Greenhouse gases**  
(Fig. by Author)





**Fig. 5 Illustration of Global Energy Balance (Credit: [13,p.518])**

is reflected off at the atmosphere itself while the remaining  $30 \frac{W}{m^2}$  is reflected at the Earth's surface. The solar radiation which is not reflected is absorbed by the Earth and its atmosphere. Let  $Q_{abs}$  be the energy absorbed by the Earth then

$$\frac{\text{Solar radiation absorbed}}{\text{Surface area of Earth}} = Q_{abs} = \frac{S\pi r_e^2 (1 - \alpha)}{4\pi r_e^2} = \frac{S}{4} (1 - \alpha)$$

$$= 342 (1 - 0.31) = 342 \times 0.69 = 235 \frac{W}{m^2} \dots (11)$$

Out of this  $235 \frac{W}{m^2}$ ,  $67 \frac{W}{m^2}$  is absorbed by the surface of the Earth.

According to the principle of conservation of energy, the rate at which the Earth and its atmosphere receive energy must be equal to the rate at which energy is being returned to space. The  $107 \frac{W}{m^2}$  of reflected energy is already balanced. That is,  $107 \frac{W}{m^2}$  hits the Earth's atmosphere and  $107 \frac{W}{m^2}$  is reflected back into space. The Earth and its atmosphere absorb the remaining  $235 \frac{W}{m^2}$ , so the same amount must be radiated back into space. If the surface of Earth were at  $254^0K$ , it would radiate  $235 \frac{W}{m^2}$  which is just enough to balance the incoming energy. But, the Greenhouse gases would absorb most of that outgoing  $235 \frac{W}{m^2}$  so that the required energy balance would not be achieved. Hence, to force enough energy through the atmosphere to create the necessary balance, the temperature of the Earth's surface must be higher than  $254^0K$ .

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As Earth is a black body, we may use equation (.3) to estimate the rate at which energy is radiated from the Earth's surface towards the atmosphere. With the surface of the Earth at its actual temperature 288<sup>0</sup>K (Let us denote the same by T<sub>s</sub>) will radiate the following quantity per unit area. That is

$$\frac{\text{Energy radiated by surface}}{\text{Surface area of Earth}} = \frac{\sigma 4\pi r_e^2 T_s^4}{4\pi r_e^2} = \sigma T_s^4$$

$$= 5.67 \times 10^{-8} \times (288)^4 = 390 \quad \dots (12)$$

Out of this 390  $\frac{W}{m^2}$ , only radiation of wavelengths lying between 7 and 13  $\mu m$  and with intensity 40  $\frac{W}{m^2}$  passes directly through the atmosphere, mostly through the atmospheric radiative window. The remaining 350  $\frac{W}{m^2}$  is absorbed by Greenhouse gases in the atmosphere. The atmosphere then radiates 324  $\frac{W}{m^2}$  back to the surface.

There is also a heat transfer from surface of Earth to the atmosphere by convection, evaporation and condensation of water vapor. Some 24  $\frac{W}{m^2}$  is due to convection and 78  $\frac{W}{m^2}$  due to condensation of water vapor.

As a check point, one can see the following simple arithmetic for an energy balance,

$$\begin{aligned} \text{Rate of energy gain} &= \text{Rate of energy loss} \\ \text{At surface of Earth. } &168 + 324 + 30 = 78 + 24 + 30 + 390 \\ \text{At atmosphere, } &67 + 78 + 24 + 350 = 165 + 30 + 324 \\ \text{At space, } &107 + 165 + 30 + 40 = 342 \end{aligned}$$

Thus there is a total energy transfer of 1383  $\frac{W}{m^2}$ .

**2.5 Global Warming Potential (GWP):-** Global Warming Potential is a weighting factor that permits comparison to be made between the cumulative global warming impact over a specified period of time of some greenhouse gas and a simultaneous emission of an equal mass of gas. GWP is affected by the following factors:

- The radiative forcing associated with the addition to the atmosphere a unit mass of each greenhouse gas.
- The rate at which that unit mass of gas injected, and
- The cumulative radiative forcing created over a period of time and to the future.

**2.5.1 Calculation of GWP:-** Let us assume an impulse function in which 1 kg of the Greenhouse gas in question and 1 kg of CO<sub>2</sub> are emitted into the atmosphere at the same time. As the concentration of each gas decreases with time, so does the radiative forcing associated with the remaining amount of gas. Mathematically we can express GWP as the ratio of two integrals as follows.

$$(GWP)_g = \frac{\int_0^T F_g R_g(t) dt}{\int_0^T F_{CO_2} R_{CO_2}(t) dt} \dots (9.13)$$

where

(GWP)<sub>g</sub> → Global Warming Potential of the gas under consideration

F<sub>g</sub> → Radiative forcing efficiency of gas under consideration in  $\frac{W}{m^2 \text{ kg}}$

F<sub>CO<sub>2</sub></sub> → Radiative efficiency of CO<sub>2</sub> in  $\frac{W}{m^2 \text{ kg}}$

R<sub>g</sub>(t) → Fraction of the 1 kg gas remaining in the atmosphere at time, t

R<sub>CO<sub>2</sub></sub> → Fraction of Carbon dioxide remaining at time, t

T → The time period of cumulative effects (in years)

**III. THE OZONE LAYER AS A PROTECTIVE SHIELD**

Ozone in the stratosphere is beneficial to life on Earth as it protects from dangerous ultra-violet radiation. But, if it is present in the troposphere near the ground, lying over cities, it is harmful. The distribution of ozone in the atmosphere is given in Fig. 6. The stratosphere (altitude between 15 to 35 km) contains about 90% “of the atmospheric ozone. It primarily acts as an ultra-violet radiation shield. The troposphere (altitude from ground to about 16 km) contains about 10% of ozone. It has toxic effects on humans and vegetation. The quantity of ozone is expressed in Dobson Unit (DU). 1 Dobson Unit is equivalent to a layer of ozone 0.01 mm thick at NTP. At mid-latitudes, the ozone overhead is about 350 DU, near the equator it is about 250 DU. The values at the poles, however, decreases to 100 DU.

Before considering ozone as a protective shield, it is worth looking at the solar spectrum shown in Fig.7. The ultra-violet region lies between 100 to 400 nm and the infra-red beyond 700 nm.

The ultra-violet region is divided into 3 regions designated as UV-A,

UV-B and UV-C with their respective wavelengths as shown in the Fig. 7. Most of the UV radiation lies in the UV-A (320 to 400 nm). It is invisible to human eye and hence called as ‘Black Light’ It penetrates deeply into the human skin creates DNA damage

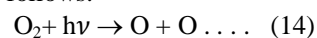
and at times Cancer. It is sometimes useful in supplying vitamin-D to the body. The UV-B radiation (280 to 320 nm) is much more dangerous to human health. It creates reddening of the skin, reduction of vitamin-D to the system, skin cancer, cataract and suppression of the immune system. The UV-C radiation is used as a disinfectant for water treatment and other germicidal applications.

Now-a-days some sunscreens include ingredients that also help to block UV-A. Photons within the UV-C

Portion of the spectrum of wavelength

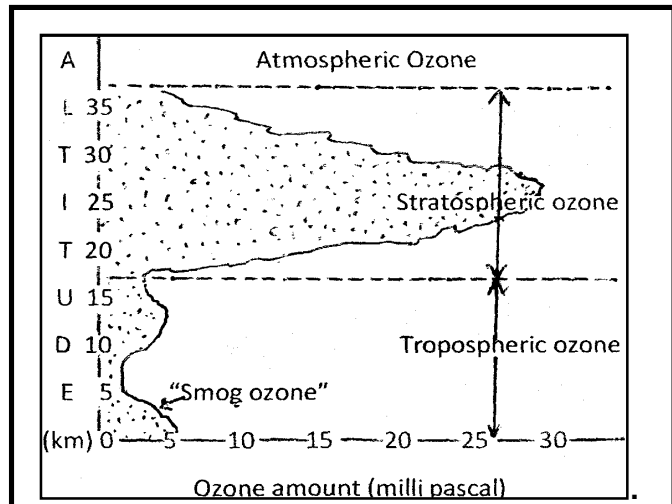
from 100 to 280 nm readily destroy DNA which makes them extremely dangerous.

Now, let us see how ozone is formed in the atmosphere. From the energy of the Sun, the oxygen present in the atmosphere is split into atomic oxygen by a process known as photolytic decomposition as follows:

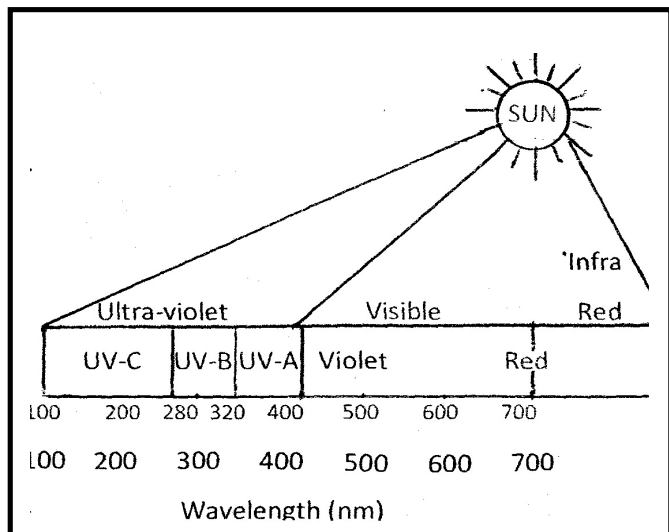


where  $h\nu$  represents a quantum of photon. For this dissociation to take place, the photon must have a wavelength of of 242 nm.

Diatomic oxygen ( $O_2$ ) has maximum absorption at about 140 nm and it effectively absorbs UV-C radiation between 130 and 180 nm. The atomic



**Fig.6 Distribution of Ozone in the atmosphere.**  
(Figure modified by Author)



**Fig..7 The Solar Spectrum**  
(figure by Author)



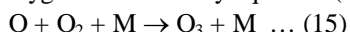
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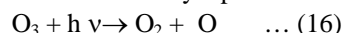
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oxygen so formed by equation (14) combines with a diatomic oxygen to form ozone, thus,



where M is a third body such as a nitrogen molecule to carry away the heat, if at all produced in the reaction. Side-by-side, there is also ozone removed by a phenomenon called photo dissociation, thus

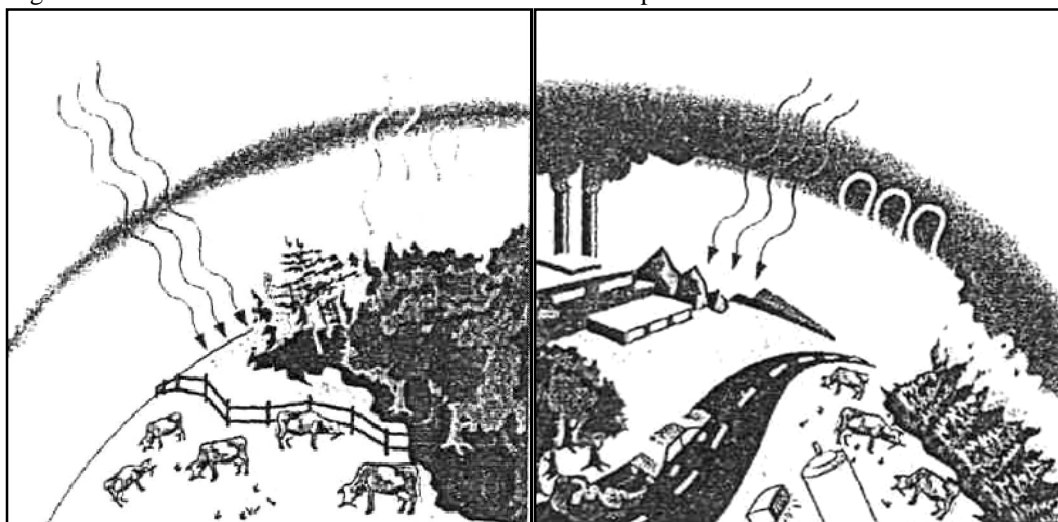


The absorptivity of ozone extends from about 200 to 320 nm and attains the peak at 255 nm. The equation given by (16) helps in removing the UV-B and UV-C radiation before they reach the surface of the Earth.

Now, coming to a conclusion of this part of the topic, the processes that take place between the surface of the Earth and its atmosphere is just a natural process to maintain the surface temperature of the Earth 288°K (15°C). Humans live in the Earth and it is not one man but millions. If each of them add a pollutant and thereby increase the greenhouse gases, the warming of the surface of Earth will result. If this continues over a period of time, it will cause a climate change. This is how Greenhouse effect is linked with climate change.

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period usually decades. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. According to Article-1 of United Nation’s Framework Convention on Climate Change (UNFCCC), climate change is defined as a “change of climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The UNFCCC, however, makes a distinction between ‘climate change’ attributed to human activities altering the atmospheric composition and ‘climate variability’ attributable to natural causes.

The Handy Science Answer Book [6] has diagrammatically shown in Fig.8 an atmosphere with natural levels of Greenhouse gases and a one with increased Greenhouse effect. In the picture on



**Fig.8 An atmosphere with natural levels of Greenhouse gases (left) and an atmosphere with increased levels of Greenhouse gases (right) (Picture Credit: [6, p.209])**

the left is shown a portion of a forest, grass lands with grazing cattle and a clear sky with hardly any smoke. In the figure on the right is seen heavily smoking chimneys from industries and cattle on bare ground adjacent to a road traffic. The following are some of the Greenhouse gases:

Carbon dioxide ..... CO <sub>2</sub>	Nitrous Oxide ..... N <sub>2</sub> O
Methane ..... CH <sub>4</sub>	Carbon tetra chloride ..... CCl <sub>4</sub>
Chlorofluoro Carbon ..... CFC <sub>s</sub>	Hydrochlorofluoro Carbon ..... HFC <sub>s</sub>
Hydrofluoro Carbon ..... HFC <sub>s</sub>	Methyl Chloroform ..... CH <sub>3</sub> CCl <sub>3</sub>

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Perfluoro Carbon ..... PFC<sub>s</sub>

Sulfur Hexafluoride ..... SF<sub>6</sub>

In the following Table-1 is shown emissions of Greenhouse gases in the United States from 1990 to 2000 (Expressed in million Metric Tons of Gas).

**Table 1** (Credit: [ 6 , p.210])

Name of gas	Y		E		A		R
	1990	1995	1996	1997	1998	1999	@2000
Carbon dioxide	4969.4	5273.5	5454.8	5533.0	5540.0	5630.7	5805.5
Methane	31.7	31.1	29.9	29.6	28.9	28.7	28.2
Nitrous Oxide	1.2	1.3	1.2	1.2	1.2	1.2	1.2
HFC <sub>s</sub> , PFC <sub>s</sub> , and SF <sub>6</sub>	*	*	*	*	*	*	*

@Preliminary data

\*Less than 0.05 million metric tons of Gas

## IV. CLIMATE CHANGE – A GLOBAL CONCERN AND AN INTERNATIONAL RESPONSIBILITY

**4.1TheGlobal Concern:** Problems of global warming and stratospheric ozone depletion are inter-linked to create a climate change. They are problems whose solutions requiring international attention and cooperation. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP) to carry out the following tasks:

- To collect and assess available scientific information on Climate Change.
- To assess the environmental and socio-economic impacts of Climate Change.
- To formulate appropriate response strategies and
- To suggest and carry out remedial measures.

The IPCC provided the technical documentation that resulted in the formation of the United Nation’s Framework Convention on Climate Change (UNFCCC) on 9 May 1992 and opened for signature at the UN Conference on Environment and Development in June 1992 at Rio de Janeiro, where it received 155 signatures. The Convention came into force on 21 March 1994, on receipt of 50<sup>th</sup> ratification. By January 2003, it has been ratified by 187 countries. The Kyoto Protocol is a by-product of the UNFCCC.

Earlier in 1987, the Montreal Protocol was signed due to the efforts of WMO and UNEP Subsequent meeting were held in London (1990). Copenhagen (1992) and Vienna (1995). One such IPCC meeting held in Shanghai during January 17-20, 2001 is shown in Fig..9.

Ghassem Asrar, et.al.[1] have described the principles adopted by NASA Earth Science Enterprise in formulating a comprehensive 2002-2010 research strategy for Earth System science and focused on the multi-disciplinary component, the climate. According to authors, the climate is basically controlled by the carbon cycle and the water cycle. The global Earth environment can be understood only as an interactive system concerning the atmosphere, ocean and sea ice, glaciers and ice sheets as well as marine and terrestrial eco-systems. The NASA Earth Science Enterprise (ESE) makes



**Fig. 9 An IPCC Meeting in progress**

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a detailed study of this. The United State Global Change Research Program (USGCRP) in conjunction with the National Research Council (NRC) brought out an action plan by answering a series of questionnaire. NASA's contribution was to provide space-based global observing systems and long-range space-borne observing facilities. The ESE has initiated a focused application program to facilitate relevant applied research activities with the government agencies and private sector. In their research strategy, NASA has been fortunate enough to gain wide support from United States and other countries as well. The various topics discussed by the authors in the paper are:

- (i) A strategy for climate research:- Three fundamental issues are considered here.
  - The presence or absence of significant variations in climate and the global water cycle.
  - The extent to which the current or predicted climate change induce predictable changes in the frequency, intensity and geographical distribution of weather system.
  - What climate data is in store for the future.
- (ii) Climate variability and trends:- Here, the authors have considered three major components.
  - The global water cycle leading to increased global precipitation, faster evaporation, study of floods and droughts.
  - Global ocean circulation. About 85% of water present in the atmosphere is from the oceans in the tropics. Computer models of the ocean general circulation that simulate all key ocean processes have been developed.
  - Mass balance of polar ice sheets, alternatively and advanced and retarded during glacial cycles causes variation in global mean sea-level.
- (iii) Climate Forcings:- Under this are considered;
  - Solar radiation to the Earth system : Solar radiation is the only cause for climate change.
  - Greenhouse gases and the global carbon cycle : NASA and contributes to the study of concentration of long-lived trace constituents that absorbs infra-red radiation such as CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub>. This is done from surface stations.
  - Aerosols:Tropospheric aerosols can influence climate indirectly by modifying the microphysical properties and life cycles of clouds and facilitate precipitation.
- (iv) Climate responses and feedback mechanisms:- NASA chose 4 mechanisms for the study of climate change. They are:
  - Controlling Earth radiant energy balance
  - Land surface hydrologic process and their effects on large scale soil water storage and water resources.
  - The fresh water budget of the upper ocean and global ocean circulation.
  - Polar ice sheets and their effects on global mean sea- level.
- (v) Consequences of climate change :The climate weather connection. Connecting weather and climate is a major challenge. Climatologists strive for understanding the physical, chemical and biological processes that govern climate weather connection.
- (vi) Weather and climate prediction: NASA is determined to follow the advice of National Academy of Science to apply the discipline of forecasting atmospheric chemistry, climate and space weather research.

Kevin Jardine [9] has given an extensive report titled: "The Carbon Bomb : Climate Change and the Fate of the Northern Boreal Forests". The Boreal Forests consisting almost a third of the Earth's forests covering about 15 million square kilometers and ranging across Russia, Canada, the United States, Scandinavia and parts of the Korean Peninsula, Mongolia and Japan. According to the report, if the CO<sub>2</sub> level in the atmosphere is doubled in the next 30 to 50 years, about 50 to 90% of these forests will disappear thereby accelerating a climate change. This will create extinction of forest lives, wild animals and birds. The Siberian tiger is almost extinct. Unless the atmospheric concentration of Greenhouse gases goes unchecked, these boreal forests will be turned into simple grasslands. It is estimated that burning of these forests will release about 225 billion tons of extra carbon into the atmosphere which will accelerate the rate of climate change. All countries should seriously look into these aspects and satisfy the requirements of UN Climate Convention signed by them in 1992.

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In the report is stressed:

- Climate change and severe forest decline should be halted
- A planned and orderly global phase-out of fossil fuels and replacing them by clean renewable energy sources
- End of deforestation and ecologically based reforestation.
- Immediate phase-out of CFC<sub>s</sub>, HFC<sub>s</sub> and HCFC<sub>s</sub> which damage the ozone layer.

**4.2 The climate catastrophe:-** Before the industrial revolution, the concentration of CO<sub>2</sub> was 300 ppm, but it got increased to 355 ppm in 1992. It is feared that it may go up to 600 ppm in less than 50 years. The expected dangers are:

- Large-scale disruption of forests, agriculture and fisheries.
- Extinction of plant and animal life both on land and sea.
- Affecting rainfall.
- Rising of sea levels creating loss of land.
- Affecting water supply.
- Affecting human health.

According to IPCC, the rate of change of temperature predicted is 15 to 30 times faster than any global temperature change ever known before.

**4.3 Fossil Fuels and Deforestation:-** It is found that humans release about 7.6 billion tons of carbon every year. Out of this, about 6 billion tons from fossil fuels and the remaining 1.6 billion tons by deforestation.

Forests-A vast Natural Resource:- The Northern Boreal forests, 'Taiga' occupies about 1.5 billion hectares or about 11% of Earth's land. Apart from being home for tribal, animals and birds, the forests regulate the climate of the Earth.

Thermostat for the planet:- Forests regulate the carbon cycle, protect from winds and floods and control climate. Trees extract carbon from the atmosphere through photosynthesis. Humans and animals release CO<sub>2</sub> by process of respiration.

Forest is a great reservoir of carbon. Forests contain about 2000 billion tons of carbon.

How climate shapes the Boreal forests? This: "Climate shapes the forests" and in turn, "Forests shape the Climate". The temperature in winter goes down -40°C in Boreal regions bordering Tundra and a pleasant temperature in Summer. The tribes, animals, birds and all other living organisms adjust to this cycle of seasons.

**4.4 Carbon balance:-** The estimated total carbon-balance from 1850 to 1990 is shown in Table-2.

**Table 2**

Estimated Total Carbon Balance 1850-1990 (Credit: [9, p.55-56])	
<b>SOURCES</b>	
Fossil Fuels	200 billion tons
Deforestation	120 billion tons
Total:-	320 billion tons
<b>SINKS</b>	
Atmosphere	130 billion tons
Ocean Diffusion	90 billion tons
Residual Sink	100 billion tons
Total:-	320 billion tons
Estimated Annual Carbon Balance	
<b>SOURCES</b>	
Fossil Fuels	5.4 billion tons
Deforestation	1.6 billion tons
Total:-	7.0 billion tons

The Ozone Threat:- The northward expansion of the boreal forest is likely to be delayed by exposure to ultraviolet radiation due to ozone depletion.

How to stabilize the climate and save the forests?

- Reduce anthropogenic Greenhouse gases.
- Phase out Fossil Fuels.
- Avoid deforestation.
- Cut subsidies for Dirty energy (Energy from fossil fuels and nuclear is taken as Dirty energy)
- Ban inefficient products.
- Create reforms in energy sector
- Better urban planning.
- Stop deforestation.
- Ban halocarbons.

Graham Dawson [ ] in his research paper titled, "Free Markets, Property Rights and Climate Change: How to Privatize Climate Policy?" has dealt with the subject more like a commercial type rather than



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SINKS	
Atmosphere	3.2 billion tons
Ocean Diffusion	2.0 billion tons
Residual Sink	1.9 billion tons
Total:-	7.1 billion tons
Note:- The actual carbon budget varies from Year to year	

scientific. According to him, the Anthropogenic Global Warming (AGW) requires government intervention along with safeguarding the rights of citizens. The author has specifically considered the Austrian economics to the problem. According to the current policy of the government, taxation related to climate policy should be withdrawn. Government policy should be to protect rights of people by curtailing carbon emissions. The author ascertains that climate policy instruments, taxes and emission trading should be abandoned. The Austrian way of thinking is that the climate change is taken as a putative inter-personal conflict rather than market failure. Emphasizing global warming on the basis of AGW might bring legal problems. The author

in his paper has considered various issues under the following heads.

- Economic approaches to environmental issues.
- The liberal foundations of economics analysis.
- New classical environmental economic analysis
- Coasean economic analysis.
- Austrian environmental economics.
- Neoclassical and Coasean approaches to climate change policy
- Environmental taxes
- Emission trading
- The insecure knowledge foundations of climate policy
- The IPCC and Climate Science
- Measuring the economic impacts of climate change
- Modeling the monetary value of climate change impacts
- The choice of discount rate
- Failure emission scenarios
- Policy implications
- An Austrian and free market perspective climate policy.

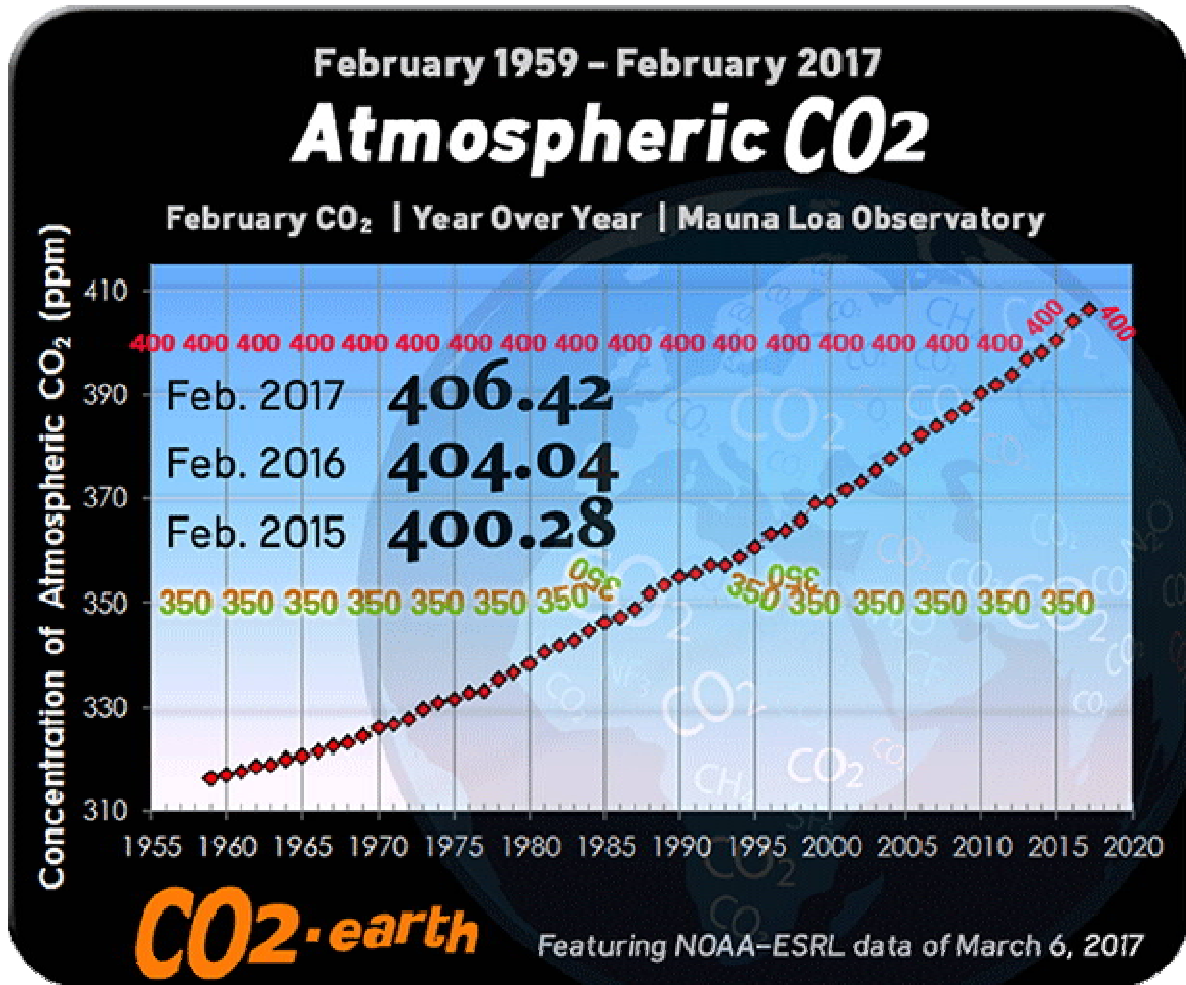
In addition, the author has replied to some 6 putative objections made to the Austro-Libertarian Strategy.

F. Chevallier, et al [3] and other 32 authors) in their paper titled “Global CO<sub>2</sub> fluxes inferred from surface air-sample measurements and from TCCON retrievals of the CO<sub>2</sub> total column” have presented the first estimate of the global distribution of CO<sub>2</sub> surface fluxes from 14 stations of the Total Carbon Column Observing Network (TCCON). The authors have evaluated this inversion based on

- Classical inversion of surface air-sample measurements
- CO<sub>2</sub> mixing ratios calculated with aircraft measurements carried out in 2009 and 2010. The test carried out in 2009 shows similar seasonal cycles in the northern hemisphere. The

test carried out in 2010 showed that the TCCON inversion has improved quality. Both the tests confirm the usefulness of space-borne monitoring of the CO<sub>2</sub> column. The inversion scheme is that which implements minimization of cost function. The inversion system computes the Best Linear Unbiased Estimate designated as (BLUE) of the CO<sub>2</sub> surface fluxes. The measurements of the CO<sub>2</sub> total column constrain the mass and distribution of carbon in the atmosphere. TCCON provides the first experimental opportunity to verify this concept. TCCON inverted fluxes improve the fit to independent air-sample measurements made at a series of surface stations over the globe or made from aircraft by about a few tenths of a ppm (rms).





**Fig.10. The variation of Atmospheric CO<sub>2</sub> versus years from 1950 to 2020**

The variation of atmospheric CO<sub>2</sub> versus years (known as the Keeling Curve named after Charles Keeling who took observations for the first time in 1958 at the Mauna Loa Observatory, Hawaii in the US) from 1950 to 2020 featuring most recent data of 6 March 2017 is shown in Fig.10.

Arthur B. Robinson. et.al [16] have discussed the increased levels of atmospheric carbon dioxide during the 20<sup>th</sup> and 21<sup>st</sup> century and they opine that it has not produced any deleterious effects on the Earth's weather and climate. In fact, it has increased plant growth. They have also discussed the environmental effects of nuclear and hydrocarbon energies. The authors say that the average temperature of the Earth has varied within a range of about 3°C during the past 3000 years.

The variation of atmospheric CO<sub>2</sub> and the world hydrocarbon use from 1850 to 2000 plus is shown in Fig.11. The magnitude of the atmospheric increase is currently about 4 Giga tons of carbon per year. The authors at some point in their paper makes a highly meaningful statement,

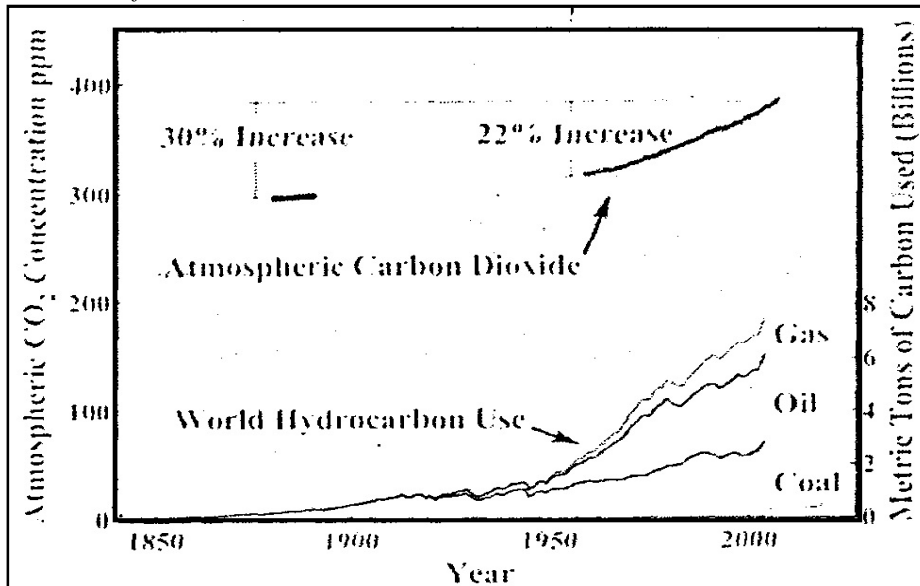
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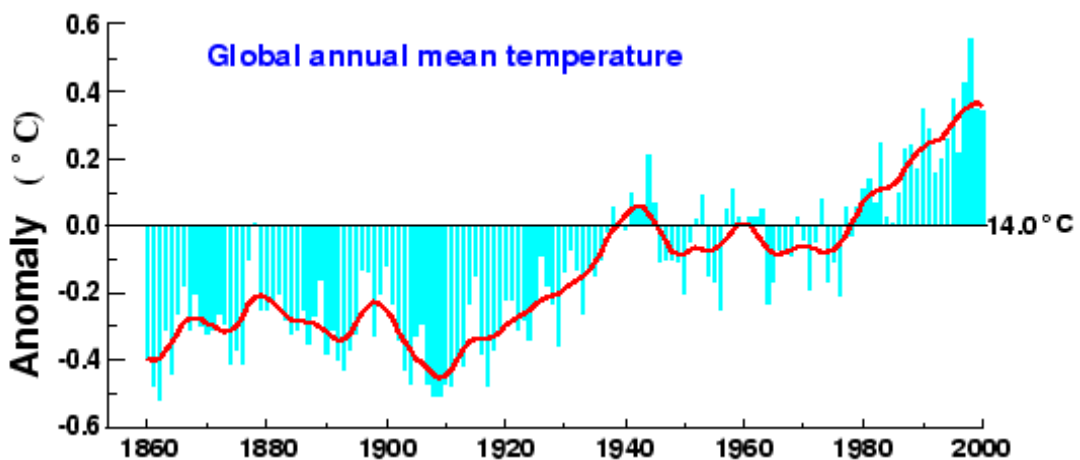
“Energy is the Foundation of Wealth”



**Fig.11 Atmospheric CO<sub>2</sub> concentration versus years** (Credit: [16, p.6])

The authors further stress in the conclusion that one need not worry even if the present warming trend continues. They say that the Earth was warmer in the past without any catastrophic effects.

Different authors vary differently in the temperature anomaly. Trenberth Kevin E [20] of National Center for Atmospheric Research has quoted the IPCC Assessment of Global Warming 2001 as shown Fig.12 where the anomaly is  $\pm 0.6^{\circ}\text{C}$ , keeping the global mean as  $14^{\circ}\text{C}$ .



**Fig.12 Global Annual Mean Temperature from 1860 to 2000** (Credit: Data provided by Hadler Cntr, UKMO and Climate Research Unit, Univ., East Anglia)

David Bernhold, et.al (19 authors) [2] in their invited research paper titled, “The Earth System Grid: Supporting the Next Generations of Climate Modeling Research” stress the point that understanding the climate change and preparing global climate models is really a challenge for the scientific community. Research is carried out using super-computers

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and about 100 TB of simulative data already existing. The challenge of enabling management discovery, access and analysis of those critically important data bases is done through a collaborative interdisciplinary project called the “Earth System Grid” (ESG). It is a grid problem developing an environment that addresses authentication, authorization for data access, data transport and management.

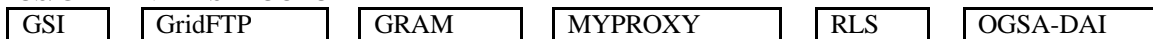
### CLIENT APPLICATIONS



### HIGHER LEVEL/ESG SPECIFIC SERVICES



### GLOBUS/GRID INFRASTRUCTURE



### DATABASE AND APPLICATION SERVERS



**Fig.13. Block diagram of ESG Architecture showing major components (Credit:[2])**

Nomenclature for Fig. 13

- CDAT → Climate Data Analysis Tools
- OPeNDAP-g → Open Source Project for Network Data Access
- SRM → Storage Resource Manager
- THREDDS → Thematic Real time Environmental Data Distributed Services
- METADATA → (Description of Data)
- GSI → Grid Security Infrastructure
- MYPROXY → Service where certificate is stored
- RLS → Replica Location Service
- OGSA-DAI → Open Grid Services Architecture Data Access and Integration
- CPU → Central Processing Unit
- DB → Data Base
- NCAR → National Centre for Atmospheric Research
- NCL → NCAR Graphics Compound Language

Because of several Earth-system components such as the atmosphere, oceans, land, sea-ice and biosphere, the data amounts to petabytes. The goal of the ESG project is to create a link with distributed centers, users, models and data. The participants in ESG include almost all major laboratories in the United States. The authors have described what the ESG project has accomplished during the years 2003, 4 and 5 and its utility in the years to come.

Major components of ESG architecture is shown as a block diagram in Fig. 12. The authors have made satisfactory progress in ESG during the three years of their research.

Jyoti K. Parikh and Kirit Parikh[14] in their research paper titled, “Climate Change : India’s Perception, Position, Policies and Possibilities” have given an exhaustive account of matter related to the title of their paper. They have presented India’s perceptions on the problem of Climate change and sustainable development. According to the authors, India should take care of agriculture, sea-level rise and increased frequency of extreme events. Growth of crops is very sensitive to temperature changes. A rise of 2.5°C to 4.9°C for India will be disastrous from its agriculture point of view.

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Rising of sea level is due to ice melting near the poles. One meter rise in sea level would displace 7 million people in India. Building walls on the sea shore has no meaning in such cases. Examples of extreme events are cyclones and tsunamis.

The authors have considered in their paper the following heads:

(i) The cost of changing Energy Strategy. In order to reduce the carbon emission, India has to re-orient its energy policies.

(ii) Profile of India's emission from an input-output model. The authors have represented India's emissions from the input-output coefficients from the input-output model. This, according to them, has to be updated by the Planning Commission every 10 years.

(iii) What India had done regarding Climate Change?

India has stressed the following points:

- Priority for energy conservation
- Encourage renewable energy sources
- Control air pollution
- More forestation and avoid de-forestation
- Policy regarding fuel substitution

(iv) Issues regarding Climate Change :

- India has to be serious about the warming of 2 to 4.8°C
- Risks are more important than costs
- India should get a major share in the global environmental space.

In the conclusion, the authors say that

- India feels not responsible for the Climate Change
- Climate Change affects the overall progress
- Afforestation and de-forestation have been observed
- Strict control on automobile emission

Spencer and Braswell [19] in their research paper, "On the Misdiagnosis of Surface Temperature Feedbacks from Variations in Earth's Radiant Energy Balance" have referred the NASA's Terra Satellite data which shows that when the climate warms, the Earth's atmosphere is more efficient at releasing energy to space than models used to forecast climate change have been programmed to behave. Dr. Roy Spencer, a principal research scientist in the Earth System Science Centre at the University of Alabama in Huntsville says that climate forecasts that are warming substantially than the atmosphere. It has been a controversy for more than two decades that there are differences between model-based forecasts of rapid global warming and meteorological data showing slower rate of warming. Most of the climate models say what the atmosphere should do rather than what the atmosphere did. Spencer said that according to the satellite observation, much more energy is lost to space during and after warming than what is shown by climate models. The climate models forecast that the climate should continue to absorb solar energy until a warming even peaks. At the peak, according to Spencer, satellites show energy being lost while climate models show energy still being gained.

When applied to long-term climate change, the climate may be less sensitive to warming due to increased CO<sub>2</sub> concentration in the atmosphere than suggested by climate model specialists. As there are many factors such as flow of clouds, solar radiation, heat rising from the oceans and a myriad of other factors, it is difficult to pin-point the Greenhouse effect from anthropogenic emissions.

An experiment was performed by University of Alabama, Huntsville team by using surface temperature data gathered by the Hadley Climate Research Unit in Great Britain. The radiant energy data was collected by the clouds and Earth's Radiant Energy System (CERES) instruments aboard NASA's Terra satellite.

The United Nation's Intergovernmental Panel on Climate Change (IPCC) chose six climate models out of which the University of Alabama at Huntsville team used three models duly programmed and with great sensitivity to radiative forcing and the remaining with less sensitivity.

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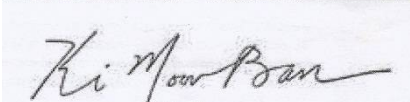
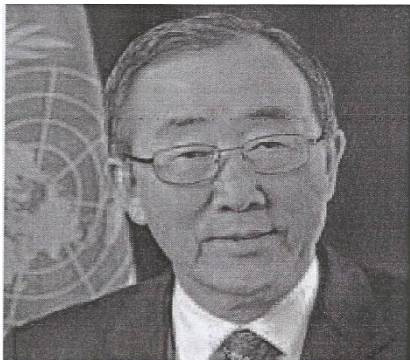
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### V. CONCLUSION

If we apply the 'Cause' and 'Effect' formalism, 'global warming' is the 'cause' and 'Climate change' is the 'effect'. In fact, Anthropogenic Emissions, Enhanced Greenhouse Effect, Global Warming and Climate Change form a dangerous cascade effect on the humans. The conclusion for this chapter can be put in one single statement, "Preserve and maintain what has been given to you by almighty and if you protect the planet Earth, you remain protected." If you add more anthropogenic emissions, you are a trouble-maker and you will be the sufferer along with many innocents. All countries should take a serious note of the climate change factor and device methods and measures to protect the planet. There has to be global need for Climate Audit.

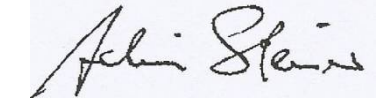
Global Audit for Climate Change – The Need for All Nations :- In the same lines as the Global Nuclear Policy in objecting nations from enriching weapon-grade uranium for development of nuclear bombs, the United Nations have already formed committees. There has to be a quarterly or at least half-yearly audit by UN.

In the <sup>9,12</sup>Science Compendium on Climate Change 2009 in a 68 page booklet have considered the following topics: Earth Systems, Earth's Ice, Earth's Oceans, Earth's Ecosystems and Earth's Management. In the Foreword, the Secretary General of the United Nations, Ban Ki-Moon (Fig.14) has said that climate change is a planetary crisis requiring global attention. He said that the world should realize once and for all, that the time to act is



**Ban Ki-moon**

**Fig. 14 Ban Ki-Moon, UN Secretary General**



**Achim Steiner**

**Fig. 15 Achim Steiner UN Under Secretary General**

now and we must all work together to meet the challenge. In the preface of the Compendium, Achim Steiner (Fig.15) the UN Under-Secretary General and Executive Director, United Nations Environment Programme has stressed the impact on the Earth's multitrillion dollar ecosystems as a key area of concern. Under a high emission scenario, he says, 12 to 39 percent of the planet's terrestrial surface could experience novel climate conditions and 10 to 48 per cent could suffer disappearing climates by 2100.



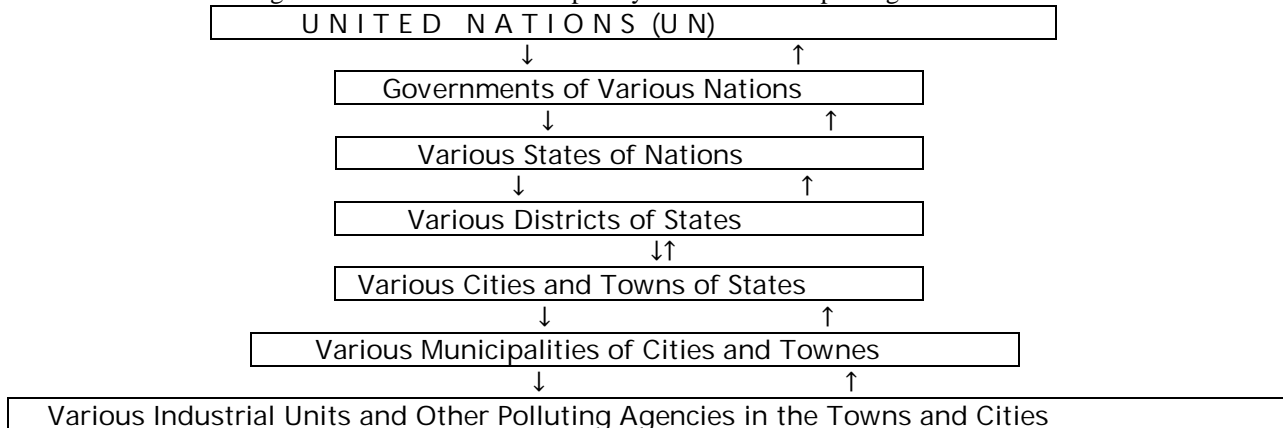
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A flow chart on global Climate Audit developed by author of the Paper is given below:



↓ Arrow of Authority

↑ Arrow of Response and Feedback

Necessary steps for Climate Audit:-

U N to various countries →

- (i) Have you formed a separate ministry for environment?
- (ii) Submit a report regarding steps taken to control Greenhouse gases and Climate Change

Municipalities/Local bodies → To carry out surprise checks and enforce penalty

What is required is,

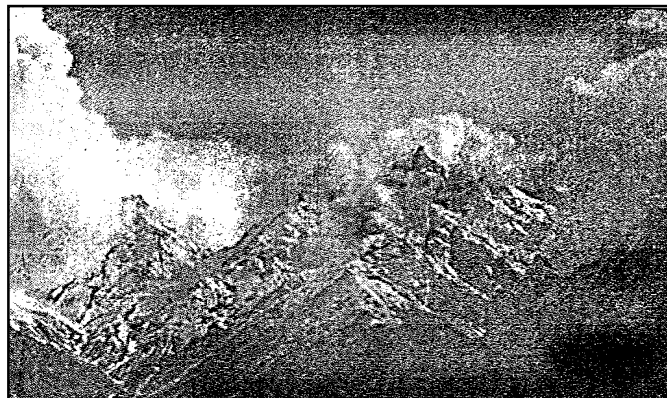
- Stop global warming
- Avoid and get rid of anthropogenic emissions causing enhanced Greenhouse effect and responsible for global warming leading to climate change.
- Create more forestation.
- Enforce strict control on corruption in the system.

About half the reference in the conclusion of this chapter is from the news that appeared in reputed local dailies such as the Times of India, Mumbai Mirror, The Free Press Journal, etc. of the city of Mumbai, India. That indicates the global concern regarding Climate Change. Such most modern research papers which are reported through the press I am giving them in the conclusion because readers getting tired of reading this chapter might need a change.

Stephen Harrison [7], Prof., at UK's University of Exeter published in the Nature Geoscience Journal which appeared in the Times of India, Mumbai dated 17 April 2012, page-17.

As a news item reporting from London with the title, "Warming? Karakoram glaciers are expanding". The Karakoram glaciers of the Himalayan mountain range (Fig.16) bordering India, China and Pakistan according to the author gained some mass between 1999 and 2008.

The research carried out in the University of Grenoble, France indicated that the ice melting of Karakoram glaciers increased the sea level from 0.11 to 0.22 metre during that period. The author



**Fig.16 The Himalayan Karakoram Glacier**

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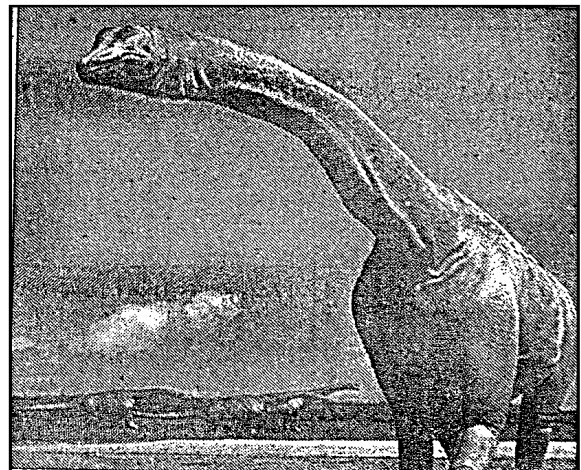
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says that the world's ice cap and ice sheets shed around 4200 cubic km from 2003 To 2010 and it is sufficient to raise The water level by 12 mm. The author further said that this is due to climate change

Andrew E. Dessler [4], a climate researcher at Texas A&M along with Richard S. Lindzen, Prof, of Meteorology at Massachusetts Institute of Technology published a news item in the Times of India, Mumbai dated 6 May 2012, page-15, titled, "Climate Change? The Clouds will save us". They say that whether the Earth is cooling or warming, the clouds will manage to equalize the temperature. The clouds will react to counter the Greenhouse gases and will allow more heat to escape to space, countering the temperature increase. Dessler says that "If you listen to credible climate skeptics, they have really pushed all their chips on to clouds". The authors say that in spite of existing stringent laws in the US and other countries, emissions of Greenhouse gases are soaring.

Prof. Graeme Ruxton [17] of St. Andrews University, Scotland published in the Daily Mail, London which appeared in the Free Press Journal, Mumbai dated 8 May 2012, page-11 titled, "Dinosaurs caused climate change?" The author says that the dinosaurs, specially the 90 ton, 140 feet long argentinosauros (Fig17). emitted the potent global warming Greenhouse gas, methane which could have been factor for their own demise. The giant animals spent 150 years emitting methane, in fact, large plant-eating Sauropods would have been the main culprits due to huge amounts of greens they consumed. According to calculations carried out by the scientists, the animals would have collectively produced more than 520 million tons of methane a year more than all today's present sources put together. The climate change was so catastrophic, that it caused the demise of the dinosaurs. Methane is 20 times more effective in trapping heat in the atmosphere than Carbon dioxide. Cows and other livestock emit only 100 m tons of methane a year which, according to Prof. Ruxton, is only a fifth of what was there during the dinosaurs walked the Earth.



**Fig.17 The 90 ton 140 feet long  
Argentinosauros**

Dr. Harmut Hellmer [8] and his team from the Alfred Wegener Institute for Polar and Marine Research in Germany reported a news item published from London and appeared in the Times of India, Mumbai dated 11 May 2012, page-19 with a title, "Another Antarctic ice shelf under threat". According to their research, the Filchner-Ronne ice shelf fringing the Weddell Sea on the eastern side of Antarctica is under threat of melting which means 450,000 square km ice shelf may disappear in raising water level by 4.4 mm per year. Water level already rose by 1.5 mm a year between 2003 and 2010 due to melting glaciers.

Uttam Babu-Shrestha [21] and Kamaljit Bawa of Bangalore-based Ashoka Trust for Research in Ecology and the Environment (ATREE) in their research paper published from New Delhi and appeared in the Times of India, Mumbai dated 16 May 2012, page-15 with the heading, "Himalayan bloom sign of global warming?". A report published by them on Tuesday the 15 May 2012, says that Himalayas are warming faster than other parts of the world. In a 25 year period (1982-2006) the temperature has risen by 1.5 degree which is three times larger than the average. Due to this the agricultural pattern and vegetation in the region has changed.

Gary Kendrick, Prof, at University of Western Australia and his colleague, Carlos Duarte [10] co-authored research with James Fourqurean of Florida International University, US and the same reported from Sydney with a title, "Sea grass can mitigate Climate Change" and the same appeared in the Free Press Journal, Mumbai dated 24 May 2012,

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page-11. The authors say in their paper that Conserving sea grass meadows may reduce Greenhouse gas emissions and increase carbon stores. Sea grass can store twice as much carbon as the world's temperate and tropical forests. It is calculated that coastal sea grass beds can store up to 83,000 metric tons of carbon per square kilometer, mostly in the soils below them compared to a typical land forest can store only 30,000 metric ton per square kilometre. The authors have estimated that although sea grass meadows occupy less than 0.2 per cent of the world's oceans, they are responsible for more than 10 per cent of all carbon buried annually in the sea.

Liviu Giosan [12], a geologist with Woods Hole Oceanographic Institution in the US in a research paper published from Washington and appeared in the Times of India, Mumbai dated 29 May 2012, page 17 with a title, "Climate killed Harappan civilization" - 'Decline in Monsoon Weakened River Dynamics, Leading to Collapse'.

The author conducted research between 2003 and 2008 and says that climate change may be the main culprit behind the collapse of the Indus Valley Civilization about 4000 years ago. The study claims to have resolved the long-standing debate over the source and fate of Saraswati, a sacred river in Hindu mythology. The decline in monsoon rains led to the weakened river dynamics, and played a critical role both in development and fall of the Harappan culture which relied on river water for their agricultural needs. An international team led by the author published their findings in the Journal Proceedings of National Academy of Sciences, used satellite photos and topographic data to make and analyze digital maps of landforms constructed by the Indus and other neighboring rivers, which were then probed in the field by drilling, coring and even manually dug trenches. Collected samples were used to determine the sediments' origins whether brought in by rivers or wind, and their age, in order to develop a chronology of landscape changes. The study was applied, to The Indus Valley Civilization built about 5200 years ago and which got disintegrated some 3000 to 3900 ago and the only remains of which are Mohenjodaro (Fig. 9.17) now in Pakistan and found that decline in monsoon was the main reason. The author confirmed that the river Sraswati was not fed by glaciers but by monsoon rains.

Rakesh Kumar [15] of National Environment Engineering Research Institute (NEERI), Nagpur recently conducted a study on pollution and the head-line, "Warm gas may rise 300% in 4 decades." appeared in the Times of India, Mumbai dated 5 June 2012, page-7. The author has targeted the year 2051 and worked out the emission levels from Households and Transport in areas of Mumbai, Thane, Navi Mumbai, Kalyan, Dombivli, Ulhasnagar, Ambernath, Pavel, Alibag, Virar, Vasai and Nallasopara. The facts and figures are shown in Fig.18 (a) and (b).

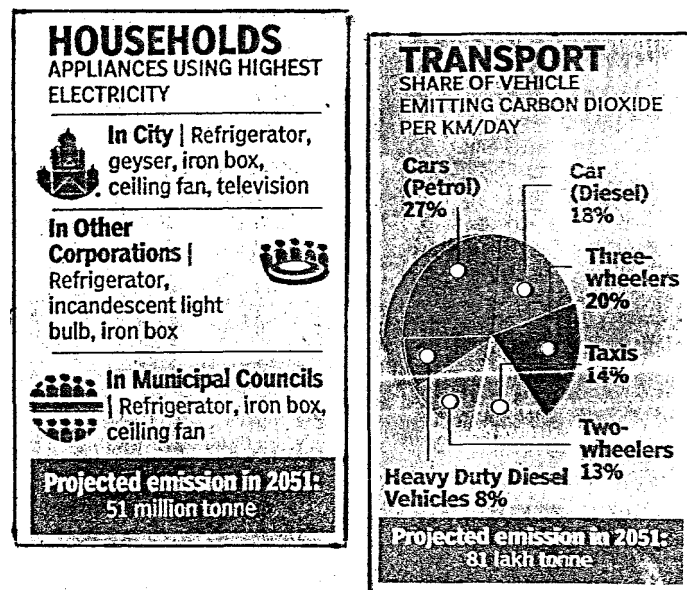


Fig.18 (a) Power Guzzlers in Households and (b) Transport

According to the author, there is going to be an 'Energy Crisis' and emissions leading to climate change. There will be a need to plant 5100 million trees for offsetting carbon dioxide by 2051. The author says that one tree has the capacity to offset an average of about 10 kg carbon dioxide every year. Thus to end the conclusion, I hereby give my quote in a cascade form maintaining the title of this Paper in letter and spirit.



# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 3, March 2017

Anthropogenic emissions → Enhanced Greenhouse Effect → Global Warming → Climate Change →  
→ Health of Humans

It is interesting and worth quoting at this point the conclusive paragraph from one of author's research papers titled, "The Turmoil on Climate Change", International Journal of Engineering Research and Development, Vol.11, Issue 11, Ver.3, Nov.2015, p.59.

*"Health is Wealth" is not a mere slogan. Before we try to be healthy, make the Earth healthy. Stop emitting a anthropogenic emissions Allow Earth to maintain its processes without which life will be miserable. There is no question of any loss or gain. The principle of mass and energy will be maintained. Earth is both a most obedient servant and a best master. Preserve this divine planet by all means."*

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