HOW GLOBAL IS GLOBAL AND HOW WARM IS WARMING?

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TATA ENERGY RESEARCH INSTITUTE

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Tata Energy Research Institute
New Delhi

Tata Energy Research Institute, New Delhi

Printed in India

ISBN 81-85419-19-1

Published by Tata Energy Research Institute, Darbari Seth Block, Habitat Place, Lodhi Road, New Delhi - 110 003 and Printed by Multiplexus (India), Delhi - 110 054

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Preface

The earth's capacity for absorbing and assimilating most human generated pollutants is large, but limited. As pollution rates rise due to increased human activity, the natural processes that absorb and assimilate pollutants are eventually overwhelmed, leading to rising concentrations. In some cases, this can lead to imbalances in the global environment. In November 1995, the IPCC (Intergovernmental Panel on Climate Change), an official scientific group set up by WMO (World Meteorological Organisation) and UNEP (United Nations Environment Programme), concluded that *the balance of evidence suggests a discernible human influence on global climate*. Average global surface temperature has increased by about 0.3 °C to 0.6 °C over the last century and the recent years have been the warmest since 1860. Global sea level has risen by 100–125 mm over the past 100 years and much of this could be attributed to temperature increases. Temperatures will rise substantially in the future. If policies to reduce CO_2 emissions from current levels are not implemented, the IPCC estimates that the average global surface temperature would rise by 2 °C between 1990 and 2100—an average rate of warming greater than any seen in the last 10 000 years.

Such changes in the earth's climate would have far reaching impacts. A warmer future would lead to very high sea level rise (estimated at an average of 500 mm by 2100). Warmer temperatures will also result in a more vigorous hydrological cycle implying more evaporation and more precipitation resulting in more severe floods and droughts in places. There would be an increase in rainstorms, tropical cyclones, and other catastrophic events.

To understand the nature and the extent of economic impacts of climate change better, TERI (Tata Energy Research Institute) undertook a project titled *India country study on global warming impacts,* sponsored by the Ford Foundation. In addition to studying the impact of climate change, the study was expected to collect, compile, and disseminate data and information related to global warming in order to create an understanding, spread awareness, and sensitize people to the risks of climate change.

The publications in the series are:

- *How global is global and how warm is warming?* Introduces the problem of global warming and climate change, underlines the issues and challenges involved, highlights the projections of rising temperatures and effective responses from the international community.
- *Changing coastlines: effects of climate change*. Gives an overview of the issue of sea level rise and its impacts on coastal zones.
- *CO_2 mitigation and the Indian transport sector*. Deals with the growing demand for transportation, and the contribution of motorized road transport to climate change. It highlights the nature and magnitude of transport-related greenhouse gas emissions in India, and identifies possible approaches to mitigate them.

TERI would like to thank the Ford Foundation for providing the financial support that enabled the publication of this series of 'popular publications'. Thanks and appreciation go to Ms Preety Bhandari and Ms Sharmila Barathan for their contribution towards *How global is global and how warm is warming?* Dr Maria Ligia Noronha for *Changing coastlines: effects of climate change*, and Dr Ranjan K Bose for *CO_2 mitigation and the Indian transport sector*. Special thanks go to Dr Chandrasekhar Sinha for his comments and guidance, to Ms Preeti Soni for coordinating this endeavour, and to Ms Beena Menon for the production of this series.

R K Pachauri

Introduction

There has been a real, but irregular, increase in global surface temperature since the late nineteenth century, even as over the same period there has been a marked, but irregular, recession of the majority of mountain glaciers. Several other forms of scientific evidence confirm the general belief that progressive warming is caused by increasing GHGs (greenhouse gases) concentrations in the atmosphere. However, there is considerable uncertainty regarding the extent of temperature rise, scale, timing, regional distribution, and related issues.

Climate System

The climate system consists of five components: atmosphere, ocean, cryosphere (ice), biosphere, and geosphere. The fundamental processes driving the global climate system are heating by incoming short-wave solar radiation and cooling by long wave radiation into space. If the earth had no atmosphere, the average temperature at the surface would be well below freezing.

An important difference

Earth's climate has changed many times in the last two billion years. But there is an important difference on this occasion. Sudan experienced two extremely dry years followed by a year's rainfall in three days in August 1988. In Bangladesh, the *once-in-a-century* typhoon surged out of the Bay of Bengal twice in 20 years. Something significant has disturbed the South Pacific seabed in a manner that there are large masses of dying coral. (Mintzer M I)

What is the greenhouse effect?

A greenhouse gets heated due to the optical characteristics of the glass, or the plastic sheets used. The glass lets through up to 90% of the radiation striking it, which warms the air, the soil and the plants inside the greenhouse. Parallel to this process, a cooling mechanism comes into play, involving the radiation of energy from the interior of the greenhouse, to the atmosphere and then into space. The warming and cooling processes stabilize the temperature inside a greenhouse at a level which is higher than the air outside.

A mechanism akin to the above, aids in maintaining the earth's temperature. The glass in this case is the atmosphere surrounding the earth whose surface (soil, ocean, and ice) absorbs solar radiation and emits it back at much longer wave lengths. Most of the radiation emitted back, is absorbed by the atmosphere which in turn reemits it to space. This dynamic interchange of radiation is controlled by gases in the atmosphere that absorb this radiation, just as glass does in a greenhouse. It is this **natural greenhouse effect** which has made the earth habitable. Figure 1

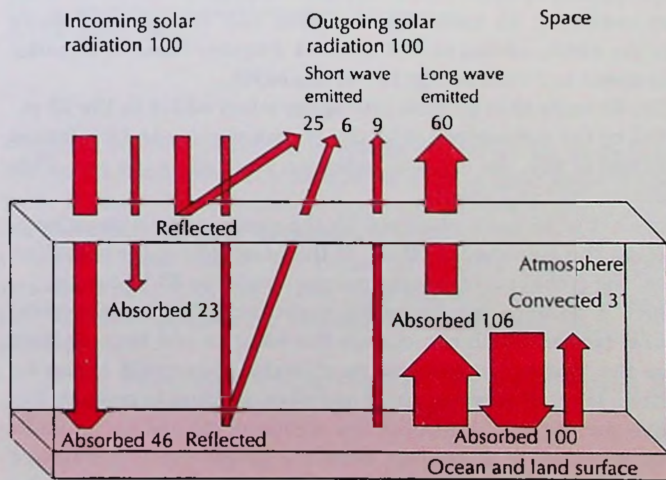

Figure 1. The Earth's heat balance is maintained through complex interactions with the atmosphere. Radiation that is absorbed at the Earth's surface is reemitted as infrared radiation at much longer wavelengths. Most of this is then absorbed in the atmosphere which, in its turn, emits infrared radiation to space.
Source. UNEP/GEMS (1987)

presents the above mentioned interactions between the earth and the atmosphere surrounding it.

In mathematical terms, let us assume that on an average over a year, the earth receives 100 units of solar radiation. Of this 25 units are immediately reflected back into the space by air and clouds, and 23 are absorbed by the atmosphere. The balance, 52 units, strike the surface of the earth. All hot bodies emit radiation and so does the earth's surface (six units). The remaining 46 units are absorbed. In addition to this, as the atmosphere heats up, it radiates 100 units of infrared energy to the earth, leading to a total of 146. The surface in turn convects up 31 units in the form of warm air and transmits another 9 to the space. The balance 106 (146 – 31 – 9) are reflected and absorbed by the atmosphere.

Now the atmosphere has 23 units originally absorbed from solar radiation, 31 units of convection and 106 infrared units from the earth, adding to 160 units. It disposes these by sending 60 to space and redirecting 100 to the earth.

The 60 units that go back into space when added to the 25 reflected by the atmosphere, 6 by the earth's surface and 9 infrared units add to 100, the original radiation emitted by the sun. This is summarized in Table 1.

The net of 46 units absorbed by the gases in the atmosphere, explains the greenhouse effect. If the atmosphere contained no gases, the global surface temperature would be 33 °C cooler.

Such a balance can be easily disturbed. There are several natural factors which can change the balance and these factors cause the **radiative forcing** on climate. This could either be positive, leading to warming or negative, leading to cooling. Radiative forcing only indicates the warming caused by an additional quantity of a gas, but does not reveal the true relative impact of gaseous emissions, primarily because different gases have different atmospheric lifetimes. However, human activities termed **anthropogenic** can also lead to a change in the balance and this is referred to as **enhanced greenhouse effect**, more commonly known as **global warming**. This is ascribed to an imbalance caused by higher levels of certain gases in the atmosphere. The presence of an increased quantity of these gases may lead to higher absorption of radiation and consequent warming of the atmosphere. If the atmosphere is warmed to higher than normal levels, it will radiate more energy to the earth's surface and as the surface gets heated, it emits not only more radiation but more water evaporates. Higher evaporation results in increased moisture and cloud cover, which blocks the incoming solar radiation, thus relieving somewhat the enhanced greenhouse effect. The net result is a combination of higher temperature, a drier soil and a wet atmosphere. It is this scenario which has caught the attention of a wide section of society ranging from the common man and scientists to international organizations.

Table 1. The Earth's Radiation Budget

Ia.	Incoming solar radiation	100
b.	Reflected	25
c.	Absorbed by the atmosphere	23
d.	Heating earth surface	52
e.	Of which reflected into space	6
f.	Absorption by Earth Surface	46 (52-6)
II	Atmosphere's radiation to earth	100
IIIa.	Earth's radiation	146
	into space	9
	convected to atmosphere	31
	absorbed by atmosphere	106
IV	Atmosphere budget	
a.	Receives from earth	106
b.	Reflects into space	60
c.	Absorbs	46 < This is absorbed by gases and is responsible for the Natural Greenhouse Effect

Heat Balance

Outgoing radiation into space	=	Ib + Ie + IIIa + IVb
	=	25 + 6 + 9 + 60
	=	100
Incoming solar radiation	=	Ia
	=	100

What are the GHGs, and how and why are they increasing?

The main GHGs are water vapour, CO_2 (carbon-dioxide), CH_4 (methane), N_2O (nitrous oxide), and CFCs (chlorofluorocarbons). With the exception of water vapour, all other gases have anthropogenic sources. A wide range of natural and human activities release GHGs into the atmosphere and are termed sources of GHGs. Similarly, a wide range of natural and human activities result in the absorption of the GHGs and are termed sinks. In the atmosphere large natural exchange influx occurs between the atmosphere and the terrestrial biota and between the atmosphere and the surface of ocean waters. Even though the net contribution from anthropogenic activities is relatively small, it is enough to significantly modify the natural balance.

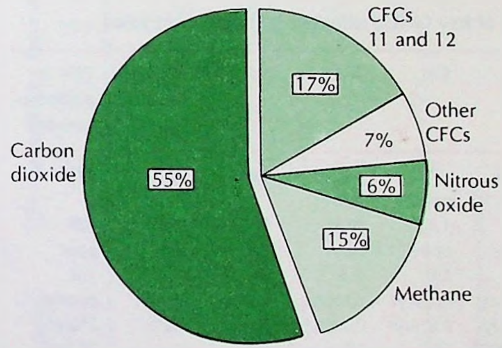

Figure 2. The contribution from each of the human-made greenhouse gases to the change in radiative forcing from 1980 to 1990. The contribution from ozone may also be significant, but cannot be quantified at present.
Source. (IPCC, 1990).

Climatic impact of Mt Pinatubo

The eruption of Mt Pinatubo in Philippines in June 1991 stands out from a climatic point of view as probably the most important eruption of this century. This produced a large, transient increase of stratospheric aerosols which resulted in a surface cooling over a period of two years, estimated from observations to be about 0.4 °C, consistent with model simulations which predicted a global mean cooling of 0.4 to 0.6 °C. Some volcanic eruptions such as the above result in short-lived negative radiative forcing of climate (IPCC, 1995).

As is evident from Figure 2, among the anthropogenic GHGs emissions, CO_2 is the largest contributor to the total increase in **climate forcing**, followed by CFCs, CH_4 and N_2O. Water vapour in the troposphere is the single most important GHG. However, its atmospheric concentration is not significantly influenced by direct anthropogenic emissions. Also, while the contribution from tropospheric ozone may be important, the available data is inadequate to accurately quantify the changes in its concentrations, or its effect on the climate. Though the role of CO_2 in global warming is substantial, other GHGs are relatively more effective, and are consequently dangerous even at their present trace level concentrations. A concept known as the GWP (global warming potential) has been developed to evaluate the relative radiative effect (and hence, the potential climate effect) of equal emissions of each of the GHGs. This has been developed taking into account the differing **residence times** of the gases in the atmosphere.

Table 2 furnishes a comparison between pre-industrial and current concentration levels of these gases.

CO_2

Since the beginning of the nineteenth century, the increase in CO_2 emissions has been the result of a variety of world wide human activities. It is claimed that until 1950, the oxidation of organic matter exposed by tilling of agricultural soils, was the chief

Table 2. A summary of key GHGs affected by human activities

	CO_2	CH_4	N_2O	CFC-11	HCFC-22 (a CFC substitute)	CF4 (a perfluoro-carbon)
Pre-industrial concentration	~280 ppmv*	~700 ppbv**	~275 ppbv	zero	zero	zero
Concentration in 1994	358 ppmv	1,720 ppbv	312§ ppbv	268§ pptv†	110 pptv	72§ pptv
Rate of concentration change	1.5 ppmv/yr 0.4%/yr	10 ppbv/yr 0.6%/yr	0.8 ppbv/yr 0.25%/yr	0 pptv/yr 0%/yr	5 pptv/yr 5%/yr	1.2 pptv/yr 2%/yr
Atmospheric lifetime (years)	50–200‡	12·	120	50	12	50,000

*1 ppmv = 1 part per million by volume.
**1 ppbv = 1 part per billion by volume
†1 pptv = 1 part per trillion by volume.
‡No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes.
·This has been defined as an adjustment time which takes into account the indirect effect of methane on its own lifetime.
§Estimated from 1992–93 data.
Source: (IPCC, 1994).

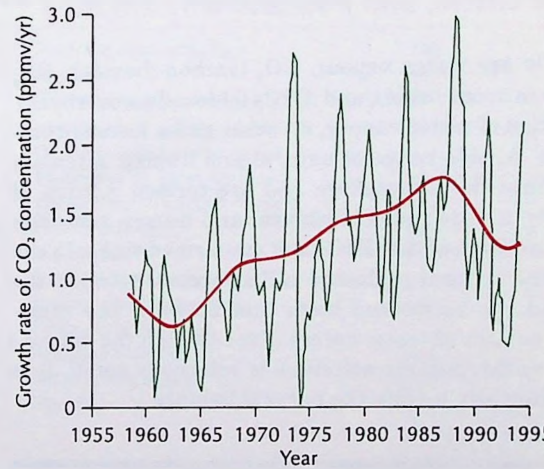

Figure 3. Growth rate of CO_2 concentration since 1958 in ppmv/yr at the Mauna Loa station showing the high growth rates of the late 1980s, the decrease in growth rates of the early 1990s, and the recent increase. The smooth curve shows the same data but filtered to suppress any variations on time-scales less than approximately 10 years.
Source. (IPCC, 1995).

source. The main anthropogenic sources of CO_2 are the burning of fossil fuels (with additions from cement production) and land-use changes. While there is uncertainty over changes in CO_2 levels at the present pace, it is well known that for approximately the last 18 000 years, CO_2 concentrations in the atmosphere have fluctuated around 280 ppmv. Figure 3 presents the growth rate in CO_2 concentrations during the last 40 years.

The single largest anthropogenic source of radiative forcing is energy production and use. Fossil fuels are currently the dominant global source of CO_2 emissions, and generally accepted to account for at least half of the warming that has occurred in the past, and that which is likely to occur.

The atmosphere, the ocean and the land (with its plants and animals), comprise the world's three major carbon sinks. The only sink whose carbon content is known with any certainty is the atmosphere.

CH_4

The natural sources of CH_4 include natural wetlands and fermentation in the guts of ruminants, especially cattle, releases from termite mounds, and biomass decay. Anthropogenic sources include coal mining, leaks in natural gas distribution systems,

Analysis of ice cores

The most reliable information on past atmospheric CO_2 concentrations is obtained by the analysis of polar ice cores. The process of air occlusion lasts from about 10 years to 1000 years, depending on local conditions, so that an air sample in old ice reflects the atmospheric composition averaged over a corresponding time interval.

Measurements on samples representing the last glacial period (18 000 years before the present) from the ice cores of Greenland and Antarctica showed CO_2 concentrations of 180–200 ppmv, i.e., about 70% of the pre-industrial value (IPCC, 1995).

rice cropping and biomass (wood, wastes, etc.) burning. The concentrations of methane show a steady increase since 1965. Although recent trends show an acceleration of about 1.1% annually, it must be noted that it was not till the late 1960s that concentrations of this gas were measured. Longer term trends have been determined by analyzing air trapped in ice cores. Results derived from the ice core record at Vostok, Antarctica are presented in Figure 4.

The major sink for anthropogenic methane is the troposphere—its reaction with OH in the troposphere and the OH concentration being controlled by a complex set of reactions. Soils also act as a sink for CH_4.

N_2O

There are many small sources of N_2O, both natural and anthropogenic, which are difficult to quantify. The main anthropogenic sources are from agriculture (especially the development of pasture in tropical regions), biomass burning, and a number of industrial processes (e.g., nitric acid production). Natural sources are probably twice as large as anthropogenic ones.

N_2O is removed from the atmosphere, mainly by photolysis (breakdown by sunlight) in the stratosphere.

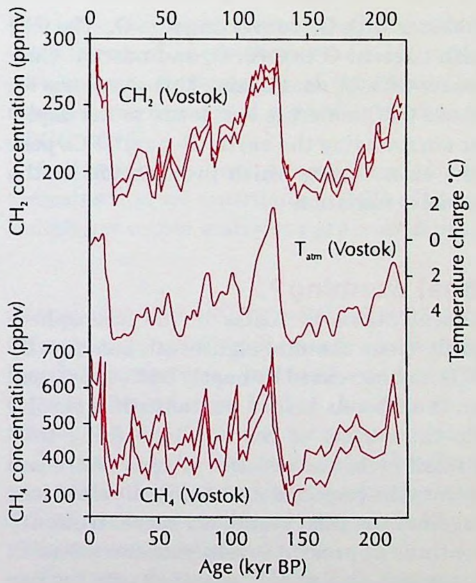

Figure 4. Temperature anomalies and methane and CO_2 concentrations over the past 220 000 years as derived from the ice core record at Vostok, Antarctica. *Source.* (IPCC, 1995).

CFC

CFCs, unlike other greenhouse gases, are not produced naturally. They are a product solely of industrial activity. CFCs are used in refrigeration, in aerosols, as solvents and foam blowing agents. These CFCs have a twin role to play. First, in their capacity to trap the infrared radiation emitted by the Earth, they act as greenhouse gases. Second, they have a high ozone depleting potential. This is because they are relatively stable and pass through the troposphere to reach the stratosphere, where in the presence of strong sunlight they break down, releasing free chlorine. This chlorine combines with O_3, converting it to O_2. The ClO molecule combines with nascent O to form O_2 and nascent chlorine, which in turn reacts with O_3 once again. This continues for the residence time of the CFC molecule and leads to the depletion of the ozone layer surrounding the earth. Hence, CFCs pose a serious threat to the ozone layer, which protects life on the earth from solar ultraviolet radiation.

How warm is global warming?

We do know that concentrations of GHGs in the atmosphere have grown significantly since the mid-eighteenth century. By 1992, CO_2, CH_4 and N_2O had increased by nearly 30%, 145%, and 15% respectively from their levels before the industrial revolution, tending to warm the surface of the earth resulting from changes in the use of fossil fuels, the practice of agriculture and land use. Figure 5 presents the projected anthropogenic emissions (1990–2200) plotted against the final stabilized concentration.

If CO_2 emissions continue at present levels, concentrations in the atmosphere will increase at a nearly constant rate for two centuries. They will reach about 500 parts per million by volume (ppmv), approaching double the pre-industrial level of 280 ppmv by the end of the next century.

Studies indicate that CO_2 can only be stabilized at 450 ppmv in the atmosphere if global anthropogenic emissions decline to 1990 levels in about 40 years time, and thereafter decline substantially. In the event of a decline in emissions to the 1990 levels in 110 years, concentrations could be stabilized at 650 ppmv; if it took 240 years they would only level off at 1000 ppmv—nearly four times of the pre-industrial level. The higher the emissions during the forthcoming years, the lower will they have to be, subsequently.

Stabilizing methane concentrations at today's levels would involve reducing anthropogenic emissions by eight per cent; doing the same for N_2O would mean cutting them by more than half their present emission levels.

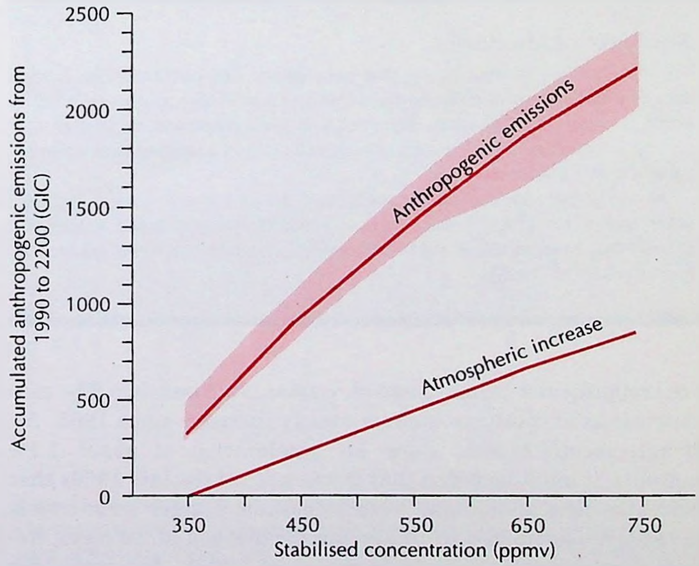

Figure 5. Anthropogenic CO_2 emissions accumulated from 1990 to 2200 plotted against the final stabilized concentration. For example, accumulated emissions of between 1200 and 1600 GtC lead to stabilization at a concentration of 550 ppmv. The figure also shows the amount of CO_2 (in GtC) remaining in the atmosphere at each stabilization level. The difference between accumulated emissions and atmospheric increase represents the accumulated uptake by the ocean and the marine and terrestrial biospheres. The range of results from different models is indicated by the shaded area.
Source: (IPCC, 1995).

The average global surface temperature has increased by about 0.3 to 0.6 °C over the last century, and recent years have been amongst the warmest since 1860. The global sea level has risen by between 100 mm and 125 mm over the past 100 years, and much of this may be related to temperature increase. Night-time temperatures over land have generally increased more than day time ones.

Temperatures will rise substantially in the future. The IPCC (Intergovermental Panel on Climate Change), established in 1988 and sponsored by WMO (World Meterological Organisation) and UNEP (United Nations Environment Programme) estimates, if policies to reduce CO_2 emissions from current levels are not implemented, the average global surface temperature will rise by about 2 °C between 1990 and 2100: its lowest and highest estimates give a range of about 1 °C to about 3.5 °C. In every case the average rate of warming would probably be greater than any seen in the last 10 000 years, but the actual changes over years and decades would include considerable natural variability. Because of the inertia of the oceans, which take time to heat up, temperature will continue to rise beyond the year 2100 even if concentrations of GHGs in the atmosphere have been stabilized by then (Houghton J, 1996).

How global is global warming?

Some regional changes have also become evident. While, for example, the mid-latitude continents have experienced the greatest warming in winter and spring, there have been a few areas of cooling, such as the northAtlantic Ocean. Precipitation has increased over high latitudes in the northern hemisphere, particularly in winter.

There is clear evidence of changes in some extremes of climate in some regions. The proportion of rain falling during heavy storms over the contiguous states of the United States of America has increased, and several large areas of the world now have fewer frosts. While in some areas the weather has become more variable, in others it is less so. There is not enough evidence at present to determine if there have been consistent changes in the variability of the climate, or during extreme weather on a global scale over the 20th century.

Very little can be said about likely local or regional changes partly because we do not yet know enough about the effects of aerosols, and how they may change in the future. The IPCC will encourage more work on this, but some features are predictable. The land will warm more than the sea, in winter. The greatest warming up will be in the northern latitudes in winter, but there will be little warming up of the Arctic in summer. All these changes are associated with identifiable physical mechanisms (IPCC, 1996).

In the global context, a comparison of the CO_2 budget for India indicates that we contribute to 2.2% of the global CO_2 emissions. India's per capita emissions are a sixth of the world average.

What are the likely impacts of climate change?

Climate change will impact agriculture and forestry, natural terrestrial ecosystems, hydrology and water resources, human settlements, energy, human health, air quality, oceans and coastal zones, seasonal snow cover, ice, and permafrost.

Methane emissions from natural wetlands and rice paddies are particularly sensitive to temperature and soil moisture. Emissions are significantly larger at higher temperatures and with increased soil moisture.

The net emissions of CO_2 from terrestrial ecosystems will be elevated if temperature increases the respiration at a faster rate than photosynthesis, or if plant populations, particularly large forests, cannot adjust rapidly enough to changes in climate.

Warmer temperatures will also produce a more vigorous hydrological cycle. This means that there will be more evaporation

Evidence for warming

Long term data extracted from ice cores in Vostock, show a strong correlation between CO_2 concentrations and temperature measurements going back 160 000 years.

Over the last 100 years or so, the global temperature records suggest that a warming of 0.5 °C has occurred, and that the decade of the 1980s was the warmest. This pattern roughly parallels that of fossil fuel use and injection of GHGs into the atmosphere.

and more precipitation. This in turn will lead to more severe floods and droughts in some places, and there may be heavier rain storms. We do not yet know enough to say whether or not tropical cyclones and other severe storms will increase, decrease or change in their geographical distribution.

The most widely discussed global impact of greenhouse warming is the increase in average sea level. It is expected to rise because the oceans expand as they get warmer and because glaciers and ice-sheets will melt. The *best estimate* projects a rise of about 500 mm between now and 2100—the lowest estimate is 150 mm and the highest 950 mm. Sea levels would continue to rise at a similar rate in future centuries even if GHG concentrations were stabilized by the year 2100, and would carry on doing so even after global average temperatures stabilized (IPCC, 1996).

Response strategies

An overview of the response strategies to such a problem has been presented below:

- wait and watch till we are certain of the problem;
- adapt to climate change;
- use countermeasures to offset global warming; and
- limit GHG emissions/concentrations.

The key question here is that what would constitute absolute certainty? While it is believed that the scientific community has reached a consensus about the likely average rate of warming, it is unlikely that estimates at the regional level would be available within a decade. Hence, one could wait and watch till we are certain of the effective measures that need to be taken.

The second response would be to take steps to adapt to climate change. The strategy could include any or more of the following measures: improvement in coastal defences for small islands and low lying regions; water management; change in agricultural practices including greater crop diversity and tolerant strain selection; and enhanced national and international stocks of food and other resources.

Another response option could be to counteract with geo-engineering solutions, those that either block some of the solar radiation that reach the earth or reflect the solar radiation reaching the earth. Very specifically this would involve injecting dust into the atmosphere to absorb some solar radiation there, using small particles to seed more clouds over the oceans so as to reflect more solar radiation, launching dust or small plates outside the atmosphere to block some solar radiation before it reaches the earth. However, there may be several problems with the aforementioned geo-engineering solutions.

Yet another response to the problem of global climate change could be one of limiting greenhouse gas emissions/concentrations. There is no doubt that this option is widely debated and acknowledged as probably one of the best strategies to be followed globally. This option stands out due to the joint benefits (both local and global) that it would have. For e.g., the promotion of efficient use of energy would relieve one to some extent of the energy security problem, local pollution problems, and so on.

Spectre of climate change and emergence of international agreements and institutions

While the 1972 UN Conference on the Human Environment at Stockholm drew attention to the issue of sustainable development, the need to effectively manage global commons, led to the emergence of various conventions and protocols, and the establishment of requisite institutions.

A significant milestone reflecting the growing consciousness about the environment was the June 1992 UNCED (UN Conference on Environment & Development). This conference held at Rio de Janeiro also referred to as the Earth Summit, was attended by numerous heads of State and three major documents were approved.

- A non binding declaration voicing the nexus between environment and development, concerns for environmental degradation and outlining a set of principles regarding the rights and responsibilities of nations toward the environment. This was the Rio Declaration for Environment & Development.

Box 1

UNFCCC

This Convention provides a framework within which the international community could deal with the issue of climate change. It clearly acknowledges that climate change and its impact are a common concern and that anthropogenic activities have resulted in increasing concentrations of GHGs which exacerbate the natural greenhouse effect leading to additional warming and which may adversely impact natural ecosystems and humankind. The Convention, however, also draws attention to the uncertainties attached to predictions regarding climate change. A note is attached on the "largest share of historical and current global emissions of GHGs which has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of global emissions originating in developing countries will grow to meet their social and development needs"

The commitments as listed in this Convention, are based on "common but differentiated responsibilities". Article 4.2 of the UNFCCC clearly demarcates the responsibilities of developing and developed countries. Further it states that the developed countries should provide "new and additional financial resources to meet the agreed full costs incurred by developing country Parties in complying with their obligations——" They shall also provide financial resources as well as transfer technology needed by developing countries to meet the full incremental costs of implementing measures.

The Convention provides for the establishment of a Conference of Parties, as the supreme body of the Convention, to review regularly the implications of the Convention and any legal instruments that may be adopted by the COP. It was also decided that the first session of the COP will take place no later than one year after the date the Convention comes into force. The first COP was held at Berlin in March 1995.

Under Article 21 on interim arrangements for the Convention, the role of the Global Environment Facility was outlined. The GEF was entrusted with the operation of the financial mechanism on an interim basis, and upon it being restructured and its membership being made universal, it was to graduate to the body that would fulfil the requirements of a financial mechanism.

- A statement focussing on principles for sustainable management of forests, which should subserve as the basis for a future international agreement on forestry.
- An action plan to steer nations and the international community toward the goal of sustainable development, called the Agenda 21.

Two international treaties were also signed at UNCED and these are UNFCCC (UN Framework Convention on Climate Change) and UNCBD (UN Convention on Biological Diversity). The main features of the two Conventions are given in Box 1 and Box 2.

Box 2

UNCDB

The UNCDB, recognizing the value of biodiversity and various aspects attached to it, including among others ecological, genetic, social and economic, registers concern that it is being reduced significantly as a result of anthropogenic activities. It, however, recognizes the dependence of many indigenous local communities on bioresources and the desirability of sharing equitably benefits arising from the use of traditional knowledge, innovations and practices relevant to conservation of biological diversity and sustainable use of its components. The way in which biodiversity is distributed, namely, in-situ and ex-situ, has influenced the structuring of this Convention.

In addition to a provision for establishing areas for protection of biodiversity, regulation, management and development of such resources both within and outside such areas, in-situ conservation is also provided for. It is envisaged that this will be accomplished through international cooperation including financial support to the developing countries, to the extent of agreed full incremental costs (Articles 8 and 20). Ex-situ measures are meant to complement in-situ - ones, preferably in the country of origin.

The UNCDB, like the UNFCCC, has stipulated separate commitments for developed and developing countries. Further, the developed countries are encouraged to provide and facilitate under fair and favourable terms, access to and transfer of technologies relevant to conservation and sustainable use of biodiversity in developing countries. For technologies under IPR protection, it is hoped that it would be on a basis which *recognize and are consistent with adequate and effective protection.*

This Convention has provided for a COP, and also the use of GEF as an interim financial mechanism.

The following table furnishes the list of ongoing projects in India which are funded by the GEF.

Table 3. Ongoing GEF projects in India

Project	Implementing agency	Executing agency	Duration (years)	Total cost (million $)	GEF share of cost	Co financing
Optimizing development of small hydel resources in hilly regions	UNDP	MNES	5	7.5	7.5	Rs 224.8 m by GoI
Bio-energy from industrial, municipal, and agricultural waste	UNDP	MNES	3	5.5	5.5	Rs 142 m by GoI
Renewable resource management	World Bank	IREDA	7	430	26	IDA: $ 100 m IBRD: $ 75 m SDC: $ 4 m DANIDA: $ 50 m Local: $ 175 m
Greenhouse gas pollution prevention project	USAID	MNES/ NTPC/ IDBI/IREDA	5	19		
Solar thermal power	World Bank	Rajasthan Energy Development Agency (REDA)/ Private Independent Power Producer (IPP)	5	245	49	MNES: $ 10 m; REDA: $ 10 m; Equity from IPP with balance from Kreditansalt fur Wiederaufbau (KfW), Germany

Institutions

The Global Environment Facility (GEF) was established in 1991 as a pilot programme to provide funding to developing countries for activities to protect the global environment. It is jointly managed by UNDP, UNEP and the World Bank. In 1994, negotiations to restructure the Facility and replenish its funds were concluded. The restructuring imperative was in response to the directives in Agenda 21 and the two conventions on climate change and biodiversity which identified GEF as their financial mechanism and called for its restructuring. The focal areas for projects and activities that GEF funds are climate change, biological diversity, international waters and depletion of the ozone layer. Activities dealing with land degradation, particularly desertification and deforestation, in so much as they relate to the focal areas, are also eligible for funding.

The responsibilities of the three managers of GEF are delineated as follows:

- UNDP is responsible for technical assistance and capacity building. It runs a SGP (small grants programme) for NGOs and community groups world over.
- UNEP is responsible for catalysing the development of scientific and technical analysis and advancing environmental management in GEF financed activities. It manages STAP (Scientific and Technical Advisory Panel), an advisory body that provides assistance to GEF.
- World Bank is the repository of the Trust Fund and is responsible for investment projects. It aims to mobilize resources from the private sector in a manner consistent with GEF objectives and national sustainable development strategies.

The GEF's governance structure includes an Assembly, a Council and a Secretariat. The Commission on Sustainable Development (CSD) was set up to monitor the progress in the implementation of Agenda 21 nationally, regionally and globally. Its mandate includes encouraging an integrated approach toward environment and development decisions, and policies.

Conclusions

While several questions are still unanswered and may not be for a few years to come, it is clear that the world is slowly moving toward a negotiated agreement to limit the risks of rapid climate change and minimize unavoidable damages. There is growing concern for the environment, as evinced in deliberations leading up to UNCED and also the conventions and institutions that have come into place after the UNCED. However, the extent and effectiveness of these processes and institutions are largely dependent on the willingness of nation states to initiate actions, as also the ease of availability of appropriate technologies, building capacity to identify and address environmental issues and, lastly but not the least, financial resources.

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