IMPACT OF INCREASE IN GREENHOUSE GASES ON GLOBAL WARMING AND ITS REMEDIES

Manmatha K. Roul[1], Rasbihari Mishra[2], Atmabhu Das[3]
[1,2,3]Gandhi Institute for Technological Advancement (GITA), Bhubaneswar, India

Abstract: Sustainable energy is the golden thread that connects economic growth, social equity, and a climate and environment that enables the world to thrive. Deep reductions in emissions are possible without undermining the global economy through rapid and significant advancement and deployment in climate-friendly technologies such as renewable energy and emerging technologies such as carbon capture and storage. Such technologies will expand the options for reducing greenhouse gas emissions, and thus for international cooperation. Progress at the global level must be coupled by action on the ground. Steps should be taken to stabilize the concentrations of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Key-words: greenhouse gas, global warming, climate change, greenhouse effect, Ozone layer depletion.

1. Introduction:

According to the National Academy of Sciences, the Earth's surface temperature has risen by about 1-degree Fahrenheit in the past century, with accelerated warming during the past two decades. There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities. Human activities have altered the chemical composition of the atmosphere through the buildup of greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide. The heat-trapping property of these gases is undisputed although uncertainties exist about exactly how earth’s climate responds to them. Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth’s atmosphere. Sulfate aerosols, a common air pollutant, cool the atmosphere by reflecting light back into space; however, sulfates are short-lived in the atmosphere and vary regionally.

Scientists generally believe that the combustion of fossil fuels and other human activities are the primary reason for the increased concentration of carbon dioxide. Plant respiration and the decomposition of organic matter release more than 10 times the CO_2 released by human activities; but these releases have generally been in balance during the centuries leading up to the industrial revolution with carbon dioxide absorbed by terrestrial vegetation and the oceans. What has changed in the last few hundred years is the additional release of carbon dioxide by human activities. Fossil fuels burned to run cars and trucks, heat homes and businesses, and power factories are responsible for about 98% of U.S. carbon dioxide emissions, 24% of methane emissions, and 18% of nitrous oxide emissions. Increased agriculture, deforestation, landfills, industrial production, and mining also contribute a significant share of emissions. In 1997, the United States emitted about one-fifth of total global greenhouse gases.

Global mean surface temperatures have increased 0.5-1.0°F since the late 19th century. The 20th century's 10 warmest years all occurred in the last 15 years of the century. Of these, 1998 was the warmest year on record. The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased. Globally, sea level has risen 4-8 inches over the past century. Worldwide precipitation over land has increased by about one percent. The frequency of extreme rainfall events has increased throughout much of the United States.

Increasing concentrations of greenhouse gases are likely to accelerate the rate of climate change. Scientists expect that the average global surface temperature could rise 1-4.5°F (0.6-2.5°C) in the next fifty years, and 2.2-10°F (1.4-5.8°C) in the next century, with significant regional variation. Evaporation will increase as the climate warms, which will increase average global precipitation. Soil moisture is likely to decline in many regions, and intense rainstorms are likely to become more frequent. Sea level is likely to rise two feet along most of the U.S. coast. Calculations of climate change for specific areas are much less reliable than global ones, and it is unclear whether regional climate will become more variable uncertainties

2. Greenhouse effect:

The greenhouse effect is the rise in temperature that the Earth experiences because certain gases in the atmosphere (water vapor, carbon dioxide, nitrous oxide, and methane, CFCs etc) trap energy from the sun. These gases allow the smaller wavelength solar radiations to pass through them but they are opaque to the larger wave-length earth radiations. Without these gases, heat would escape back into space and Earth’s average temperature would be about-18^{0}C rather than the comfortable 15^{0}C found today. Because of how they warm our world, these gases are referred to as greenhouse gases.

Greenhouses, which look like small glass houses are used to grow plants, especially in the winter. Greenhouses work by trapping heat from the sun. The glass panels of the greenhouse let in light but keep heat from escaping. This causes the greenhouse to heat up, much like the inside of a car parked in sunlight, and keeps the plants warm enough to live in the winter. The Earth’s atmosphere is all around us. It is the air that we breathe. Greenhouse gases in the atmosphere behave much like the glass panes in a greenhouse. Sunlight enters the Earth's atmosphere, passing through the blanket of greenhouse gases. As it reaches the Earth's surface, land, water, and biosphere absorb the sunlight’s energy. Once absorbed, this energy is sent back into the atmosphere. Some of the energy passes back into space, but much of it remains trapped in the atmosphere by the greenhouse gases, causing our world to heat up.

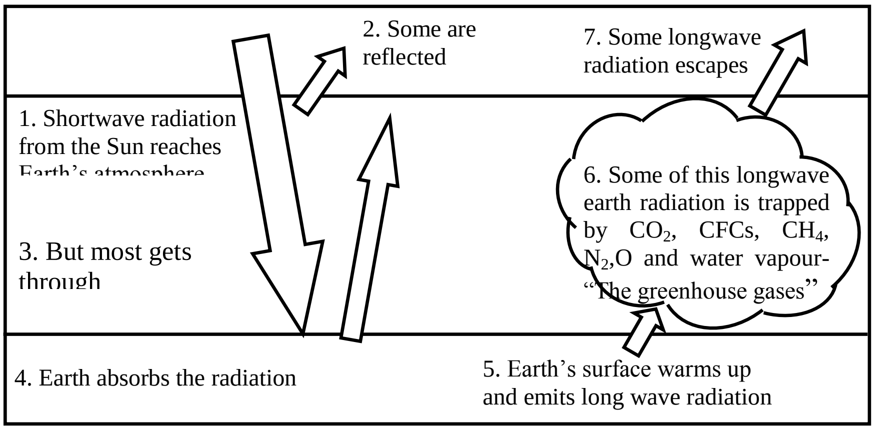

Figure 1: The Green House Effect

The greenhouse effect is important. Without the greenhouse effect, the Earth would not be warm enough for humans to live. But if the greenhouse effect becomes stronger, it could make the Earth warmer than usual. Even a little extra warming may cause problems for humans, plants, and animals.

2.1 Enhanced greenhouse effect:

Since the industrial revolution and expansion of agriculture around 200 years ago, we have been raising the concentration of carbon dioxide gas in the global atmosphere. Levels of other greenhouse gases have also increased because of human activities. Higher concentrations of greenhouse gases in the Earth's atmosphere will lead to increased trapping of infrared radiation. The lower atmosphere is likely to warm, changing weather and climate. Thus, the enhanced greenhouse effect is additional to the natural greenhouse effect and is due to human activity changing the make-up of the atmosphere. The enhanced greenhouse effect is often referred to as global warming.

2.2 Greenhouse gases:

Atmospheric trace gases that keep the Earth's surface warm are known as greenhouse gases. About three-quarters of the natural greenhouse effect is due to water vapour. The next most significant greenhouse gas is carbon dioxide. Methane, nitrous oxide, ozone in the lower atmosphere, and CFCs are also greenhouse gases.

Most of the increase in carbon dioxide comes from burning of fossil fuels such as oil, coal and natural gas for energy, and from deforestation. Cows, sheep and other ruminant animals 'burp' methane into the air. Rice paddies also generate methane. Other sources of methane are landfills, burning vegetation, coal-mines and natural gas fields. Nitrous oxide concentrations are increasing because of changes to the way in which we use land, from fertilizer use, from some industrial processes, and from burning vegetation. Ozone is a component of photochemical smog, which, in turn, is the result of emissions of hydrocarbons and nitrogen oxides from motor vehicles and industry.

Gas	Conc. (ppm)	Average residence time(yrs)	Sources	Reason for Increase
CO_2	360	100	Combustion of fossil fuels Respiration	a) Growing world energy demand leading to increased fossil fuel combustion b) Destruction of vegetation-e.g, rain forests- leading to i) decline in global photosynthesis ii) increased CO_2 in atmosphere due toburning of cleared vegetation
CH_4	1.7	10	a) Anaerobic bacteria in marshes and in guts of ruminants b) Decomposition of organic material c) Leakage from gas pipes and coal mines	a) Increase in ruminant population b) Increase in area given over to landfill c) Increase in area given over to rice paddy
N_2O	0.3	130	a) Combustion of fossil fuels b) Denitrifying bacteria acting on nitrates and nitrites	a) Increased use of fossil fuels b) Increased use of nitrate fertilizers c) Increased cultivation of soil
O_3	0.01-0.05	(variable)	Reaction product of car exhaust pollutants (nitrous oxides, hydrocarbons) and sunlight	Increased use of fossil fuels for transport
CFCs	0.003	55-116	Coolants, propellants and expanders	Increased use of aerosols, refrigerators etc. (although following the Montreal Protocol, CFCs are now banned in developed countries)

CFCs were made in the past for refrigerants, spray pack propellants, producing foam plastics and as solvents for electronic components. All developed countries, including Australia, have stopped producing CFCs. Carbon dioxide persists for more than a century in the air. Methane's average lifetime is about 11 years. Nitrous oxide and some of the CFCs stay in the air for more than a century. Greenhouse gases differ in their ability to trap heat. A kilogram of methane released into the air today, for example, will lead to about 20 times more atmospheric warming over the next century than a kilogram of carbon dioxide. Molecule for molecule, methane, CFCs and nitrous oxide are more potent greenhouse gases than carbon dioxide.

2.3 Increase in the concentrations of greenhouse gases:

According to recent survey, greenhouse gases will increase anywhere between 25 to 90 per cent in 2030 from 1990 levels. The concentration of carbon dioxide is approximately 30 per cent greater than it was in the 18th century, before the industrial revolution. It has increased from around 280 parts per million (ppm) to approximately 360 ppm today. Although carbon dioxide comprises only 0.036 per cent of the air, its warming effect is significant.

Methane levels have risen from a pre-industrial concentration of about 700 parts per billion (ppb) to 1700 ppb. However, the rapid growth of methane has slowed considerably since the 1980s. Nitrous oxide concentrations have increased from approximately 275 ppb to 315 ppb. There is strong evidence that ozone concentrations in the lower atmosphere are greater than in pre-industrial times, especially in the northern hemisphere. CFCs didn't exist 200 years ago. However, the concentrations of many of them are now starting to fall, thanks to international agreements to protect the ozone layer.

Human activities do not directly change atmospheric water vapour concentrations. However, changes to water vapour concentrations may occur in response to increases in concentrations of carbon dioxide and other greenhouse gases.

3. Impacts:

Rising global temperatures are expected to raise sea level, and change precipitation and other local climate conditions. Changing regional climate could alter forests, crop yields, and water supplies. It could also affect human health, animals, and many types of ecosystems. Deserts may expand into existing rangelands, and features of some of our National Parks may be permanently altered.

Most of the United States is expected to warm, although sulfates may limit warming in some areas. Scientists currently are unable to determine which parts of the United States will become wetter or drier, but there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils. Unfortunately, many of the potentially most important impacts depend upon whether rainfall increases or decreases, which cannot be reliably projected for specific areas.

3.1 Past climate and sea level:

The average surface temperature of the world is now 0.4 to 0.8^0C higher than it was late in the 19th century. Most of the warming occurred over two periods in the 20th century: from 1910 to 1945 and from 1976 to 2002. Evidence for global warming is multi-faceted. In addition to the global average surface warming of about 0.6^0C since 1900, there has been an increase in heat waves, fewer frosts, warming of the lower atmosphere and deep oceans, retreat of glaciers and sea-ice, a rise in sea-level of 10-20 cm and increased heavy rainfall in many regions. Many species of plants and animals have changed their location or the timing of their seasonal responses in ways that provide indirect evidence of global warming. The latest research by Mann and Jones in 2003 confirms that the 20th century Northern Hemisphere warming is greater than any time in the past 1800 years.

Both air over land and over the oceans has warmed. The most recent period of warming has been almost global, although the largest temperature increases have occurred over northern hemisphere continents in the mid- to high- latitudes. Parts of the north-western North Atlantic and the central North Pacific Oceans have cooled in recent decades. 1998 was the warmest year and the 1990s the warmest decade globally since the record began in 1861. Nine out of the ten warmest years on record occurred in the 1990s and 2000s. A recent study by Vinnikov and Grody found good agreement between the satellite and surface data from 1978-2002, with a satellite-based warming of 0.24^0C per decade compared with 0.17^0C per decade from surface data. Another study by Mears et al (2003) found a satellite-based warming of 0.10^0C per decade. Santer and others have concluded that apparent inconsistencies between surface and satellite results may be an artefact of satellite data uncertainties. The satellite record is too short to be certain. The longer record of temperature measurements from weather balloons shows that the lower atmosphere has warmed by about 0.10^0C per decade from 1958 to 2000, a similar rate to the surface warming.

In addition, both weather balloons and satellites show that the stratosphere (the layer of the atmosphere from about 12 to 50 kilometres above the ground) is cooling. This is a change that scientists expect to happen as levels of greenhouse gases increase and the ozone layer thins.

3.2 Future changes to climate and sea level:

Increasing levels of greenhouse gases are likely to produce a warming at the Earth's surface. This warming is likely to lead to world-wide changes in weather and climate. Some places may get more rain and storms while others may get less. Not all changes will be bad for everybody. However, almost everywhere the weather and climate will be different from what it used to be. By the end of the 21st century, according to the Intergovernmental Panel on Climate Change, average world temperatures are likely to be between 1.4°C and 5.8°C higher than they were in the year 1990. This is much larger than the changes observed over the 20th century, and the rate of warming is unprecedented in at least the last 10,000 years. Average rainfall across the globe is likely to increase, particularly during winter in northern mid- to high latitudes. Precipitation events are very likely to be more intense over most areas of the globe, as well as a likely increase in summer risk of drought.

Most climate models indicate that in many places global warming is likely to increase the frequency and duration of extreme events such as heavy rains, droughts and floods. We don't know what impact global warming will have on the frequency and severity of El Niño events. It is these events that are so often responsible for devastating droughts in Australia. By the year 2030, the global average sea level is likely to be between 3 and 17 cm higher than the 1990 level. By 2100, sea level is projected to rise by approximately 9 to 88 cm, compared with 1990. The rate and magnitude of sea-level change will vary from place to place in response to coastline features, changes in ocean currents, differences in tidal patterns and sea-water density, and vertical movements of the land itself. In some areas, sea level may actually fall. For much of the planet though, sea levels are expected to continue rising for hundreds of years even if atmospheric temperatures stabilize.

If the Earth's atmosphere warms, the upper layers of the oceans will also warm. Like most substances, water expands when heated. Expansion will raise sea level. Land-based ice in temperate regions such as South America and North America will melt more rapidly. Glaciers may retreat. Melting also contributes to increased sea level. The net effect on sea level rise from ice changes in Greenland and

Antarctica is likely to be small. Overall, Antarctica is not warming significantly. Only the Antarctic Peninsula is warming throughout the year at a rate that statisticians call 'significant'. Ice shelves, such as those in the Antarctic Peninsula, float and will not change sea level if they disintegrate or melt. Global warming may even lead to increased precipitation over Antarctica, which would lock water away in the ice caps. This may offset some of the sea-level rise caused by thermal expansion of water.

4. The latest research:

Scientists have been regularly measuring the amount of carbon dioxide in air since the late 1950s. The collection, held in stainless steel flasks, dates back to the first samples of pristine "baseline" air collected at the Cape Grim Baseline Air Pollution Station in Tasmania in 1978. To go back further in time, scientists study air trapped within Antarctic ice. Snow falling in polar- regions such as Antarctic continuously traps tiny pockets of air. More snow lands on top and after a while the enclosed air forms a bubble in the ice. In this way, air is preserved for thousands of years. Ice deep below the surface has older air trapped in it than ice at the surface. Thanks to polar ice, scientists can analyze air dating back more than 300,000 years. Haze is caused by fine pollutant particles and droplets suspended in air. The best known impact of these particles, called aerosols, is the white haze of pollution visible over heavily industrialized areas of the northern hemisphere. This haze reflects some sunlight back to space, and can have a small, cooling effect on climate. Aerosols can also make clouds brighter and last longer, causing them to be more reflective than normal. This is also likely to cool the planet in some regions. However, the cooling effect of aerosols is largely restricted to the more polluted regions, whereas greenhouse gases are well mixed throughout the entire atmosphere. Scientists use sophisticated computer models of the world's atmosphere, surface and oceans to examine likely future changes to climate due to global warming.

Climate models are complex, lengthy computer programs based upon the physical laws and equations of motion that govern the Earth's climate system. The models work by mimicking (or reproducing) the way in which the Earth's climate behaves from day to day, and from season to season. They do this for all parts of the globe: the surface, throughout the atmosphere, and for the depths of the oceans. Climate models are good at simulating the broad features of our present climate. Simulated distribution of surface temperatures, winds and precipitation over the seasons are very similar to what is observed. This gives us confidence that the models adequately represent the important physical and dynamic processes of climate.

Using these climate models, scientists can simulate present climatic conditions ('control' runs). They can also simulate anticipated future conditions, such as increased atmospheric concentrations of greenhouse gases, changes to aerosol levels or different ozone levels ('climate prediction' runs). By comparing results from the two (or more) simulations allow scientists to assess likely future climate changes. Scientists also study changes that have happened throughout history on geological timescales when greenhouse gas concentrations were higher than today to learn about what may happen in future.

The Division studies changes to greenhouse gas concentrations in the atmosphere as well as determining past changes to the make-up of air from bubbles trapped in ice cores. We are also using powerful scientific tools to establish where greenhouse gases are coming from and what happens to them once they reach the atmosphere. Divisional scientists also study the way in which the atmosphere, land surfaces and the oceans interact to determine our climate. The research involves satellite remote sensing and aircraft measurements, theory and numerical models and underpins development of more advanced climate models. We are examining clouds and cloud processes and the interaction of clouds and radiation. For this activity, we use data from satellite and ground-based remote sensing instruments. We have developed powerful computer-based global and regional climate models, linking models of the atmosphere, biosphere, oceans and sea-ice. By evaluating and applying the latest scientific findings and model results, we also produce scenarios and assessments of likely climatic changes and their impacts for various regions in Australia and overseas. Of particular interest are future changes to rainfall, the incidence of droughts and floods, tropical cyclone behavior, evaporation rates and sea level. Research is performed in close collaboration with a number of other CSIRO Divisions, with the Bureau of Meteorology, and with universities.

4.1 International agreements:

Global warming, or global climate change, has been one of the most urgent and controversial environmental issues in the last decade. Two international agreements have been adopted so far. The UN Framework Convention on Climate Change (UNFCCC) adopted in 1992 and entered into force in 1994, urged developed countries as well as countries in transition (former USSR and Center and Eastern European countries) to stabilize emission of green house gases by 2000 at 1990 levels. The Kyoto Protocol adopted in 1997 and yet to be entered into force, has a legally binding emission target for each of those countries above. Countries are now negotiating details for the implementation of the two agreements. The objective of this Convention is to stabilize concentrations of greenhouse gases in the atmosphere at a level that would 'prevent dangerous human interference' with global climate.

The Kyoto Protocol would bind many developed nations to greenhouse gas emission targets. The Protocol aims to cut emissions from developed countries by about 5% from 1990 levels by the year 2012. However, the Kyoto Protocol target will not lead to stabilization of carbon dioxide in the atmosphere. The target represents only the first step towards meeting the objectives of the Framework Convention on Climate Change. The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets. Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities." The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh, Morocco, in 2001, and are referred to as the "Marrakesh Accords." Its first commitment period started in 2008 and ended in 2012.

In Doha, Qatar, on 8 December 2012, the "Doha Amendment to the Kyoto Protocol" was adopted. The amendment includes:

- New commitments for Annex I Parties to the Kyoto Protocol who agreed to take on commitments in a second commitment period from 1 January 2013 to 31 December 2020;
- A revised list of greenhouse gases (GHG) to be reported on by Parties in the second commitment period; and
- Amendments to several articles of the Kyoto Protocol which specifically referenced issues pertaining to the first commitment period and which needed to be updated for the second commitment period.

On 21 December 2012, the amendment was circulated by the Secretary-General of the United Nations, acting in his capacity as Depositary, to all Parties to the Kyoto Protocol in accordance with Articles 20 and 21 of the Protocol. During the first commitment period, 37 industrialized countries and the European Community committed to reduce GHG emissions to an average of five percent against 1990 levels. During the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020; however, the composition of Parties in the second commitment period is different from the first. The Kyoto Protocol is seen as an important first step towards a truly global emission reduction regime that will stabilize GHG emissions, and can provide the architecture for the future international agreement on climate change.

In Durban, the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) was established to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention, applicable to all Parties. The ADP is to complete its work as early as possible, but no later than 2015, in order to adopt this protocol, legal instrument or agreed outcome with legal force at the twenty-first session of the Conference of the Parties and for it to come into effect and be implemented from 2020.

5. Actions:

5.1 Global:

Today, action is occurring at every level to reduce, to avoid, and to better understand the risks associated with climate change. Many cities and states across the country have prepared greenhouse gas inventories; and many are actively pursuing programs and policies that will result in greenhouse gas emission reductions. At the national level, the U.S. Global Change Research Program coordinates the world's most extensive research effort on climate change. In addition, EPA and other federal agencies are actively engaging the private sector, states, and localities in partnerships based on a win-win philosophy and aimed at addressing the challenge of global warming while, at the same time, strengthening the economy.

At the global level, countries around the world have expressed a firm commitment to strengthening international responses to the risks of climate change. The U.S. is working to strengthen international action and broaden participation under the auspices of the United Nations Framework Convention on Climate Change.

5.2 Individual:

What difference can I make? When faced with this question, individuals should recognize that collectively they can make a difference. In some cases, it only takes a little change in lifestyle and behavior to make some big changes in greenhouse gas reductions. For other types of actions, the changes are more significant. When that action is multiplied by the 270 million people in the U.S. or the 6 billion people world wide, the savings are significant. "Individuals Can Make A Difference" identifies actions that many households can take that reduce greenhouse gas emissions in addition to other benefits, including saving you money! The actions range from changes in the house, in the yard, in the car, and in the store. Everyone's contribution counts, so why not do our share?

There is no immediate fix to the problem other than to curtail our use of fossil energy. As individuals we can help in the short term:

- We need to drive smaller vehicles and heat and cool our buildings more moderately.
- Carbon dioxide emissions can be reduced if consumers purchase more energy-efficient appliances, such as new refrigerators.
- Compact fluorescent light bulbs save tremendous amounts of fuel.

But in the long term, we need to extract energy more efficiently from fossil fuels and to develop alternative energy sources that do not lead to the production of greenhouse gases. By doubling the concentration of atmospheric CO_2, we are conducting a planetary wager -- one we can't afford to lose.

Conclusions:

Our problems have solutions and we must work both individually and globally to save our lovely planet. All the developed and developing nations must obey the Kyoto Protocol adopted in 1997 and subsequently amended in 2012. Only international agreements in themselves will not solve the problem unless all the countries work sincerely in this regard.

Deep reductions in emissions are possible without undermining the global economy through rapid and significant advancement and deployment in climate-friendly technologies such as renewable energy and emerging technologies such as carbon capture and storage. Such technologies will expand the options for reducing greenhouse gas emissions, and thus for international cooperation. In the words of Ban Ki-moon, the Secretary-General of United Nations, “Sustainable energy is the golden thread that connects economic growth, social equity, and a climate and environment that enables the world to thrive.”

Progress at the global level must be coupled by action on the ground. Steps should be taken to stabilize the concentrations of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Whatever is to be done, it must be done now because tomorrow it may be too late.

References:

[1] Alcamo, J., Kreileman, G.J.J., Bollen, J.C., van den Born, G.J., Gerlagh, R., Krol, M.S., Toet, A.M.C. and de Vries, H.J.M., 1996. Baseline scenarios of global environmental change. Global Environ. Change, 6: 261-303.

[2] Capros, 1998. Note on the costs for the EU of meeting the Kyoto target, preliminary analysis, NTUA, Athens, April 1998.

[3] COHERENCE, 1998. Economic evaluation of quantitative objectives for climate change. Contribution of non- CO2 greenhouse gases to the EU Kyoto target: evaluation of the reduction potential and costs, draft report prepared for the Commission, October 1998.

[4] Ecofys, 1998. Reduction of the emissions of HFCs, PFCs and SF6 in the EU, draft report prepared for the European Commission, October 1998.

[5] European Commission, 1998. Communication on Climate Change – Towards and EU Post-Kyoto Strategy, COM(98) 353.

[6] Eurostat, 1998. Carbon dioxide emissions from fossil fuels 1985-1996, Commission of the European Communities, Eurostat.

[7] IPCC, 1997. The Regional Impacts of Climate Change, An Assessment of Vulnerability, R.T. Watson, M.C. Zinyowera, R.H. Moss. Cambridge, Cambridge University Press.

[8] Krause, F., Bach, W. and Koomey, J., 1989. Energy Policy in the Greenhouse, Volume 1: From Warming Fate to Warming Limit. Benchmarks for a Global Climate Convention. International Project for Sustainable Energy Paths. El Cerrito, California.

[9] Leemans, R. and Hootsman, R., 1998, Ecosystem vulnerability and climate protection goals, Report no. 481508004, RIVM, the Netherlands.

[10] Martin, P.H., et. al., 1998. A New Estimate of the Carbon Sink Strength of EU Forests integrating Flux Measurements, Field Surveys, and Space Observations, AMBIO, 27 (7), 582–584.

[11] WBGU, 1998. The accounting of biological sources under the Kyoto Protocol – a step forward or backwards for global environmental protection, German Advisory Council on Global Change Special Report, 1998.

[12] Choi, O. and A. Fisher (2003) "The Impacts of Socioeconomic Development and Climate Change on Severe Weather Catastrophe Losses: Mid-Atlantic Region (MAR) and the U.S." Climate Change, vol. 58 pp. 149