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Energy, Climate Change and Sustainable Development

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Climate change from global warming is a sustainable development problem because rapid climate change will adversely effect all major ecosystems that support human beings and all major economic activities that promote human welfare. Use of fossil fuels, such as coal, oil and natural gas, increases atmospheric concentrations of greenhouse gases, which in turn warm the world and change climate systems. Scientific research has discerned a human fingerprint on the global warming the world has experienced since the Industrial Revolution. An international legal regime is nearly in place to allow the global use of market-based mechanisms to reduce global emissions of greenhouse gases and to increase sinks (storage of greenhouse gases). These mechanisms will promote sustainable development by allowing economic development that is significantly more energy efficient that at present. The major obstacle to adoption of this legal regime and to the institution of the market-based approach is the US refusal to participate.

1 Introduction

Beginning with the discovery of fire, the history of the improvement of human welfare is the story of the human ability to harness energy. Yet there is increasingly compelling evidence that the current rate of consumption of fossil fuels, e.g., coal, oil, natural gas (methane) – sources of energy derived from natural processes of decay and compression of once living plants and animals[1] – while improving the quality of life, is causing a significant warming of the temperature at the surface of the earth, which itself is causing a significant and potentially disastrous change in the planet's climate. If sustainable development is to be achieved, humanity's need for energy will have to accommodate the fact that the earth's atmosphere cannot absorb unlimited amounts of the by-products of fossil fuel consumption without creating problematic climate changes. This chapter will outline the scientific understanding of the relationship between human activity and climate change and the range of consequences climate change will impose on human society and the world's ecosystems, and will describe emerging efforts to create an international law regime to regulate the emission of the harmful GHG products of energy consumption.

The essence of the global warming problem is that the current rate of burning fossil fuels releases into the atmosphere with relative suddenness[2] the carbon the earth removed from the atmosphere over millions of years and stored underground as the remains of ancient plants and animals that have been buried under conditions of enormous pressure over such long periods that the carbon comprising their structures is converted into coal, oil, or natural gas.[3] The beneficial effects of the efficiency gained by exploiting the earth's storehouses of fossil fuel have been dramatic:

> "Simply harnessing oxen, for example, multiplied the power available to a human being by a factor of 10. The invention of the vertical water wheel increased productivity by a factor of 6; the

1 Coal, petroleum and natural gas (methane or CH_4) are commonly referred to as fossil fuels because they are made by the same geological process as fossils – sedimentary pressure over millions of years. Methane, although located in large underground deposits generally associated with oil and coal, can also be naturally created over short time-frames by bacteria acting on organic material such as garbage in dumps, bacteria in the stomachs of ruminants such as cows, and other anaerobic decomposition of organic matter such as in rice paddies, swamps, and even mulch piles. However, the gigantic underground pools of natural gas were created over millions of years in geological formations that trapped the methane.

2 For instance, the USA annually burns about a billion short tons of coal, or about 2030 Tg CO_2 Eq., to make electricity, about 2390 Tg CO_2 Eq. of petroleum for transportation, heating, and industry, and 1200 Tg CO_2 Eq of natural gas. US EPA, *Inventory of US Greenhouse gases and Sinks: 1990–2000* (2002) 2–3 to 2–4, Figure 2–2. *Tg CO_2 Eq.* (teragrams – trillion grams – carbon dioxide equivalent) is the international standard established by the Intergovernmental Panel on Climate Change (IPCC) for reporting fossil fuel use and greenhouse gas emissions. *Id.* at 1–10, 21. *See also* IPCC, Revised 1996 *IPCC Guidelines for National Greenhouse Gas Inventories*, IPCC/UNEP/OECD/IEA (1997).

3 Humans also consume other carbon-based sources of energy, especially wood. Large portions of developing countries rely on wood for fuel, either directly, or after converted into charcoal. In those regions, so much wood is used so inefficiently as fuel that demand for wood far exceeds the rate that forests can be regenerated. However, compared to fossil fuels, forest can be regrown in a relatively short time (decades to a century for forests compared to tens of millions of years for fossil fuels). United Nations Development Programme, *World Energy Assessment: Energy and the Challenge of Sustainability* (2000) 65–68, 370 (hereinafter *World Energy Assessment*).

> steam engine increased it by another order of magnitude. The use of motor vehicles greatly reduced journey times and expanded human ability to transport goods to markets.
>
> Today the ready availability of plentiful, affordable energy allows many people to enjoy unprecedented comfort, mobility, and productivity. In industrialized countries, people use more than 100 times as much energy, on a per capita basis, as humans did before they learned to exploit the energy potential of fire."[4]

Today, the world each year burns about 3.4 billion tons of oil, 4.5 billion tons of coal (2.22 billion tons of oil equivalent), natural gas in an amount equivalent to 2.02 billion tons of oil; and wood and other forms of traditional biomass at a rate equivalent to 0.9 billion tons of oil; taken all together, the burning of these forms of collected, mostly ancient, sources of energy accounts for more than 89% of all human energy use[5] and releases about 6.3 ± 0.4 billion tons of carbon dioxide into the atmosphere annually;[6] carbon dioxide "is the dominant human-influenced greenhouse gas" and accounts for about 60% of the atmosphere's increased heat trapping over the past 150 years.[7]

Although this consumption of our energy capital (fossil fuels) has allowed society to prosper,[8] burning fossil fuels is not a harmless, cost-free activity.[9] Some of the pollutants created by burning fossil fuels are inherently harmful and impose external costs on society.[10] Other emissions, such as carbon dioxide (CO_2), are inherently benign.[11] In the atmosphere, CO_2, together with water vapour,[12] methane,[13] nitrous oxide[14]

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4 *World Energy Assessment* 3.

5 *World Energy Assessment*, Table 1, p6 and 34–35. Large hydro supplies about 2.2%, renewables (wind, geothermal, small hydroelectric dams, photovoltaic, modern biomass, etc), supplies about 2.2%, and the remaining major source of energy is from nuclear power plants, which supply about 6.5% of our primary energy consumption.

6 *IPCC Climate Change 2001: The Scientific Basis*, (J. Houghton *et al*., eds., Cambridge University Press, 2001) Table 2 at 39.

7 *Id.*

8 From a business perspective this consumption of capital is problematic, particularly if we do not invest adequate portions of the wealth generated by this capital consumption in the development of replacement technologies for the future. In terms of sustainable development, wealth should be the result of living off the income earned from the investment of capital (human or natural) so that past and present consumption of capital does not prejudice future generations.

9 Nor is burning wood or charcoal harmless. The indoor pollution from using wood for heating and cooking and the increasing shortage of locally available wood increases poverty and diminishes public health: *World Energy Assessment 69.*

10 Sulphur in fossil fuels, when burned, is emitted as SO2 (sulphur dioxide), which causes adverse respiratory effects and can be converted into acidic compounds that fall to the earth as acid precipitation. High temperature combustion results in the creation of nitrogen oxides (NOx), which can be noxious in their own right, and when combined with volatile organic compounds, humidity, and sunlight can result in ground level (tropospheric) ozone (Oz), the major component of smog, with its adverse health effects. Burning fossil fuels can also release soot and fine particulates, which pose a health risk to people with asthma, and which can carry heavy metals, SO_2, mercury and carcinogens into human lungs. These pollutants also have adverse effects on the health and viability of ecosystems worldwide.

Each of these pollutants has a different mechanism, range and scale of action. For instance, some pollutants, such as mercury and other heavy metals, are directly toxic and long lasting. Other pollutants, such as tropospheric ozone and acid precipitation, result from the interaction of fossil fuel emissions with other atmospheric influences and chemicals to produce adverse regional effects, which may last only hours, days or months until the emissions or atmospheric conditions abate. *See*, *Id.* at 63–85, 63–85, and R. Ottinger *et al*., *Environmental Costs of Electricity* (Oceana Pub. 1989) and *World Energy Assessment* 63–85.

11 The carbon cycle and CO_2 are central components in the web of life. In very simplistic terms, CO_2 is released when we metabolize our food to obtain the energy to live. Green plants use CO_2 in photosynthesis to create, carbohydrates, cellulose and other woody or fibrous structures and release oxygen, which animals and plants use to convert food into energy. Some of the carbon is absorbed by the oceans, and some is stored in soil. The remainder, about half of the original emissions, remains in the atmosphere for up to 200 years. The carbon cycle, in its rich complexity, is described in I. Prentice, *et al., The Carbon Cycle and Atmospheric Carbon Dioxide, IPCC Climate Change 2001: The Scientific Basis*, (J. Houghton *et al*., eds., Cambridge University Press, 2001) 185–213.

12 Water vapour is the largest natural contributor to the greenhouse effect, but the amount of water vapour in the atmosphere is not directly affected by anthropogenic emissions of water vapour. However, human activity can increase atmospheric water vapour concentration indirectly by the emission of other greenhouse gases, such as carbon dioxide, that warm the atmosphere, thereby increasing the rate of evaporation; this increased evaporation increases water vapour, which further accelerates global warming: *World Energy Assessment* 86.

13 Methane (CH_4), the major component of natural gas, is anthropogenically released into the atmosphere from coal mining, leaking natural gas pipelines, ruminant livestock such as cows, rice paddies, and solid waste facilities.

14 Nitrous oxide, N_2O, is produced both naturally in soil and water, and by human activity in agriculture, energy industrial and waste management activities. According to US EPA, "agricultural soil management accounted for 70% of US N_2O emissions" in 2000 and "[f]rom 1990 to 2000, emissions from this source increased 11% as fertilizer consumption, manure production, and crop production rose." N_2O is also produced when fuels are burned at high temperatures, in the manufacture of adipic and nitric acid, and in the context of management of human and animal wastes. N_2O accounts for 6.1% of US emissions. Globally, "the atmospheric concentration of nitrous oxide has increased by 16% since 1750, from a pre-industrial value of about 270 ppb to 314 ppb in 1998, a concentration that has not been exceeded during the last thousand years. US EPA, *Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2000* (2002) ES 21–22, 1–5.

and other trace gases,[15] have the ability to trap heat in the atmosphere. For over a century scientists have known that the gases that trap infrared radiation (heat) in the atmosphere make life on earth possible. Although without these greenhouse gases, the earth would be a frigid rock, much like the moon or Mars, with excessive amounts of heat-trapping gases in the atmosphere, the earth would be an inferno, like Venus. The greater the concentration of greenhouse gases in the atmosphere, the more heat is trapped, and the warmer the earth becomes.[16]

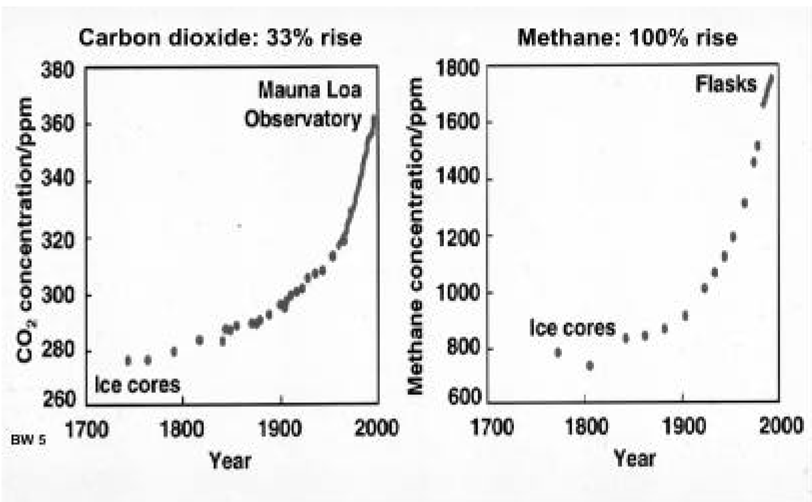
The rate at which society consumes fossil fuels far outstrips the time it took for fossil fuels to be created. Over the last century or two, by burning fossil fuels, we have released carbon into the atmosphere that had been slowly removed by nature over tens to hundreds of millions of years.[17] The atmosphere (with its abundant oxygen) we thrive in today was created by that process of removing carbon from the atmosphere.[18] While the presence of greenhouse gases in the atmosphere is necessary, the rapid increase in their concentration since the Industrial Revolution will change global climate, and if the rate and amplitude of change is too great, catastrophic consequences may ensue.

Analysis of the climate change problem requires consideration of several threshold questions: Are atmospheric GHG concentrations increasing? If so, what portion of the increase is from human activities? If human activity is the principal force behind these increases, what level of increase will cause "dangerous…interference with the climate system?"

2 Atmospheric concentrations of GHGs are increasing

Over the past 50 years, scientists in Hawaii have been recording the atmospheric concentrations of both carbon dioxide and methane. Those records, combined with measurements of the concentration of those gases in bubbles trapped in cores of ancient ice demonstrate that since the beginning of the Industrial Revolution the

Fig. 1 Concentrations of carbon dioxide and methane have risen greatly since pre-industrial times



Source: *IPCC Climate Change 2001: The Scientific Basis.*

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15 Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). HFCs are non-ozone depleting chemicals that are used as a replacement for stratospheric ozone depleting chemicals know as halocarbons (CFCs, HCFCs, methyl chloroform, carbon tetrachloride, bromine halons, methyl bromine and hydrobromofluorocarbons) that are regulated under the Montreal Protocol on Substances that Deplete the Stratospheric Ozone Layer and its Amendments. *See* 26 *ILM* 1550 (1987), UNEP/Oz.L.Pro.2/3 (Annexes I, II, III), and 32 *ILM* 874 (1993). PFCs and SF_6 are emitted by aluminium smelting, semiconductor manufacturing, electric power transmission and magnesium casting. Taken together HFCs, PFCs, and SF_6, are trace gases that only contribute a very small portion of global warming; however, these powerful greenhouse gases have extremely long lifetimes in the atmosphere and are being emitted in growing quantities. *Id.* 1–5 to 1–6.

16 *IPCC Climate Change 2001: The Scientific Basis,* (J. T. Houghton *et al*., eds., Cambridge University Press, 2001) 87–90.

17 Since 1950, the nations of the world have emitted some 720 billion tons of carbon dioxide, of this amount the USA has contributed 186 billion tons and Europe 265. World Resources Institute, Earth Trends: The Environmental Information Portal, available at http://earthtrends.wri.org/datatables (visited 4 November, 2002).

18 *IPCC Climate Change 2001: The Scientific Basis,* (J Houghton *et al*., eds., Cambridge University Press, 2001) 201.

atmospheric concentrations of greenhouse gases and other industrial emissions have increased dramatically.[19] Fig. 1 illustrates this remarkable trend.

Fig. 1 shows that the atmospheric concentration of CO_2 has increased by 31% from the stable pre-industrial level (around 1750) of about 280ppm to 367ppm in 1999. This present CO_2 concentration has not been exceeded during the past 420,000 years and likely not during the past 20 million years. Moreover, the current rate of increase is unprecedented during at least the past 20,000 years.[20] IPCC also reports that about ¾ of the anthropogenic emissions of CO_2 during the past 20 years are from fossil fuel burning; the rest is predominately due to land-use changes, especially deforestation. As a result, during the past 20 years, CO_2 concentration has increased on average about 1.5 parts per million (ppm). Currently the ocean and land together remove about half of the annual anthropogenic CO_2 emissions from the atmosphere. [21]

Atmospheric methane (CH_4) concentration has increased since 1750 by about 151%, from about 690 ppb to about 1,750 ppb, and continues to increase at an annual rate of about 7 ppb. As with CO_2, these increases are greater than anything experienced in the past 420,000 years. The primary anthropogenic sources of methane emissions are the use of fossil fuels, cattle, rice agriculture and landfills; carbon monoxide (CO) emissions from use of fossil fuels also contribute to methane concentrations.[22]

The third major greenhouse gas, nitrous oxide (N_2O), also has dramatically increased in the atmosphere over the last century. From a stable concentration of about 270 ppb from 1000 to around 1800, it has risen to about 310 ppb by 2000. These data are summarised:[23]

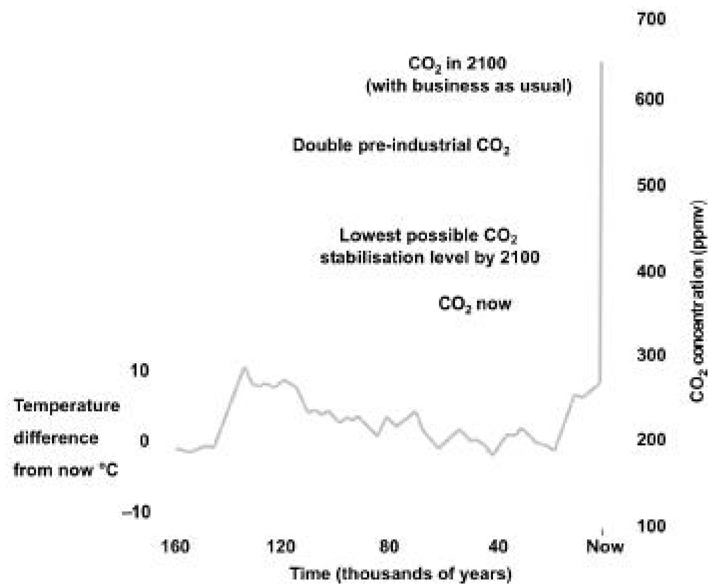
	CO_2	CH_4	N_2O
Pre-industrial atmospheric concentration (ppm)	278	0.7	0.27
Atmospheric concentration (1998) (ppm)	365	1.745	0.314
Rate of concentration change (1990–1999) (ppm/year)	1.5	0.007	0.0008
Atmospheric Lifetime (years)	5–200[a]	12[b]	114[b]

[a] No single lifetime can be defined for CO_2 because of the different rates of uptake by different removal processes.
[b] These lifetimes take into account the indirect effect of the gas on its own residence time.

In terms of radiative forcing[24] since the year 1000, that is, how much additional heat these increased GHGs are trapping now as compared the year with 1000, CO_2 has increased 150%, CH_4 about 50%, and N_20 about 14%. Virtually all of the increased radiative forcing has occurred since 1900, primarily as a result of carbon dioxide emissions. The rate of increase of forcing accelerates in response to the rate of increase of GHG concentrations. See Fig. 2.

19 The data is based both on ice core and other data from Antarctica and Greenland, and on direct samples of the atmosphere since the 1950s. These greenhouse gases are both rapidly and thoroughly mixed around the earth after they are emitted, so measurements of concentrations at remote locations are representative of global concentrations. *IPCC Climate Change 2001: The Scientific Basis* 6.
20 *IPCC Climate Change 2001: The Scientific Basis,* (J. Houghton *et al*., eds., Cambridge University Press, 2001) 185.
21 *Id.* at 7.
22 *Id.* at 6.
23 *Source*: IPCC (2001) at 38 and EPA Inventory (2002).
24 This heat trapping capacity is generally expressed in terms of “radiative forcing,” which measures “the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system, and is an index of the importance of the factor as a potential climate change reaction.” Radiative forcing is calculated in terms of watts of solar energy per m^2. A positive forcing, such as that produced by increasing concentrations of greenhouse gases, such as carbon dioxide, methane and nitrous oxide, tends to warm the earth’s surface. A negative forcing, which can arise from an increase in aerosols such as sulphur dioxide that reflect light from the sun back out into space, or soot or carbon black that block sunlight, tends to cool the earth. IPCC (Science) at 90–91, 353.

Fig. 2 The last 160,000 years (from ice cores) and the next 100 years



Source: IPCC

Once a greenhouse gas is emitted, it rapidly mixes with the atmosphere and immediately begins trapping infrared radiation (heat) and will continue to do so for as long as it remains in the atmosphere.[25] It is irrelevant, in terms of global radiative forcing effects, where that gas was emitted or who emitted it. All that is relevant for global warming is how much heat that particular type of greenhouse gas can trap (i.e., how much radiative forcing a given amount of GHG will contribute) and how long the gas will remain in the atmosphere contributing its radiative forcing effect. It is therefore possible to develop a common frame of reference to evaluate the comparable effects of emitting different greenhouse gases, as well as the comparable benefits of reducing emissions or removing the gas from the atmosphere (or, in the IPCC nomenclature, creating a sink).[26]

To enable comparisons between gases and policy choices, and to allow credits and trading in GHG emissions reductions and sink enhancements, the IPCC has rated each greenhouse gas's "global warming potential" (GWP),[27] with CO_2 being set at 1 on the scale. Thus, CO_2 has a GWP of 1, for the next 20, 100, and 500 years. Methane, which remains in the atmosphere about 8.4 years before breaking down into CO_2 and water has a GWP of 62 for 20 years, 23 for 100 years and 7 for 500 years. By comparison, N_2O, which has an atmospheric lifetime of about 120 years, has a GWP of 275 for 20 years, 296 for 100 years and 156 for 500 years.[28]

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25 *See* Table 1 for the atmospheric lifetimes of these GHGs.

26 IPCC defines *sink* as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere." IPCC (Science) at 791. When the ocean or a tree absorbs carbon dioxide it acts as a sink, or a reservoir. If a sink's activity could be enhanced, then it may be able to absorb more carbon dioxide, or absorb carbon dioxide at a greater rate, thereby reducing carbon dioxide in the atmosphere. However, if a sink capacity to absorb carbon dioxide were to diminish, as might happen as a forest matures or oceans reach their saturation level and slow down their absorption of carbon dioxide, then less carbon dioxide would be removed from the atmosphere annually, and concentrations would increase faster than at present for the same level of emissions. For details on sinks *see* I. Prentice *et al.*, *The Carbon Cycle and Atmospheric Carbon Dioxide*, IPCC (Science) 185–224, and J. Samiento and N. Gruber, Sinks for Anthropogenic Carbon, *Physics Today* (August 2002) available at http://www.aip.org/pt/vol-55/iss-8/current.html

27 The IPCC defines *global warming potential* as "an index, describing the radiative characteristics of well mixed greenhouse gases, that represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing infrared radiation. This index approximates the time-integrated warming effect of a unit mass of a given greenhouse gas in today's atmosphere, relative to that of carbon dioxide." IPCC (Science) App. 1, 791.

28 *Id.* at 47, 244, 388.

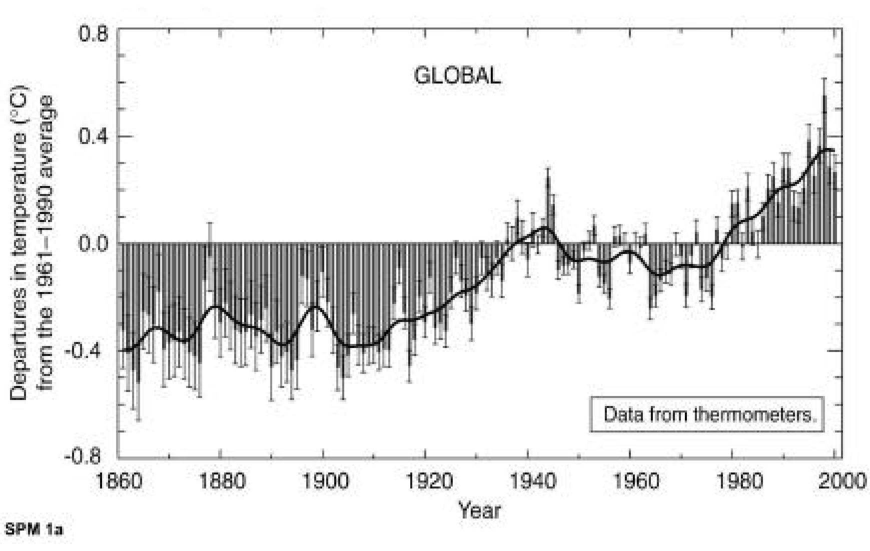
Table 1. Direct Global Warming Potentials (mass based) relative to carbon dioxide

Greenhouse gas	Lifetime (years)	Global Warming Potential – 20 years	Global Warming Potential – 100 years	Global Warming Potential – 500 years
Carbon dioxide (CO_2)	5–200	1	1	1
Methane (CH_4)	12*	62	23	7
Nitrous oxide (N_2O)	114*	275	296	156

*Lifetime estimates for CH_4 and N_2O are *adjustment times* that include feedback effects of the GHG emission on its atmospheric lifetime
Source: (IPCC 2001) 388.

In contrast to the major GHGs, which can remain in the atmosphere for up to two centuries, several other short-lived emissions are also emitted into the atmosphere. Sulphate aerosols, produced from chemical reactions in the atmosphere with the gaseous precursors, primarily sulphur dioxide (SO_2) from burning coal and oil containing sulphur, have grown enormously over the last hundred years from their pre-industrial levels.[29] Sulphates tend to create haze that reflect light and reduce visibility. In this sense they reduce radiation reaching the earth and contribute, indirectly, a small cooling effect. However, sulphates have a short residence time in the atmosphere, and tend to be concentrated regionally instead of being well mixed throughout the atmosphere. With the implementation of the acid precipitation programme in the USA under the 1990 Amendments to the Clean Air Act and sulphur dioxide emission reductions in other coal burning regions of the world, sulphate concentrations have dropped, and will continue to decline. Ironically, to the extent past sulphur emissions have offset the radiative forcing from the major GHGs, the cooling effect from these short-lived aerosols will rapidly disappear as pollution control programmes are implemented. The radiative forcing effects of other aerosols, referred to informally as soot, have also been evaluated by the IPCC: carbon black, organic carbon from burning fossil fuels and mineral dust aerosols. Because some of the aerosols cool and some warm the effect of sulphates, carbon black and organic carbon aerosols on future climate will vary depending on the impact of pollution laws that regulate these short-lived pollutants. Overall the IPCC estimates the effects "to be substantially smaller … than that of CO_2."[30]

Fig. 3 Variations of the Earth's surface temperature for the past 140 years



Source: IPCC (2001).

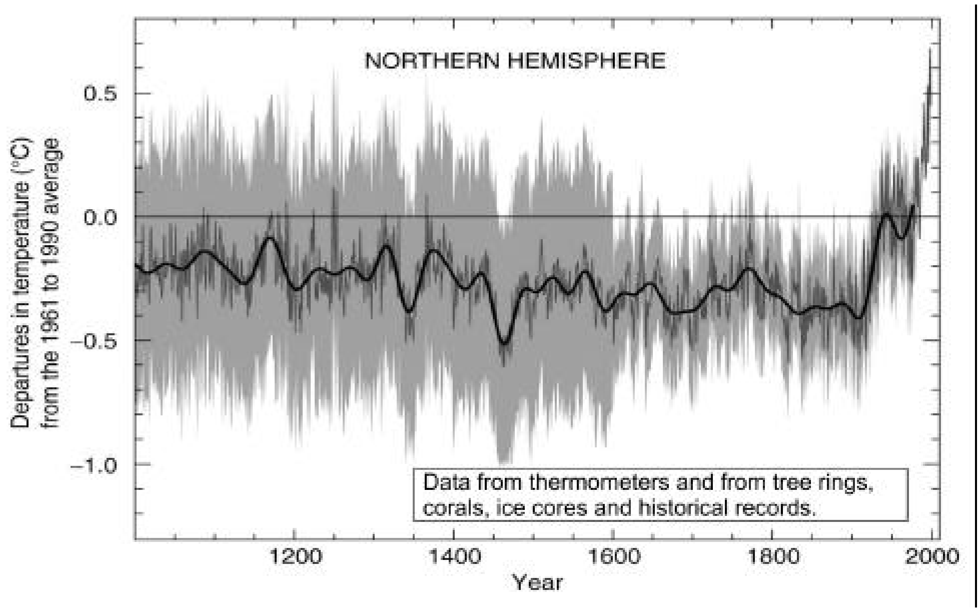
29 Greenland ice cores reveal that with the exception of short-lived spikes (which are statistically insignificant within the context of "a robust running median") due to major volcanic eruptions, there was a long period of stable levels of sulphates prior to about 1900, which quadrupled by the late 1990s. Levels reached their peak between 1991 and 1993, as a result of the Mt. Pinatubo eruption. *Id.* at 36, 307, 351.

30 *Id.* at 351–2.

3 Is the earth warming?

A large and rapidly growing storehouse of data collectively paints a "picture of a warming world."[31] This picture is best seen with the aid of a few graphic depictions of the data. Fig. 3 depicts changes in global temperature from 1860 to 2000, based on accumulated data from thermometer readings around the world. As can be seen, over the last 140 years the surface temperature of the earth has increased by about 0.6º C plus or minus 0.2º C.[32] Combining the 140 year thermometer data with proxy data that represents temperature, such as tree rings, coral reefs, ice cores and historical records, scientists have been able to depict temperature changes for the northern hemisphere over the last 1000 years (see Fig. 4). Mindful of the uncertainties associated with reconstructing temperature from these proxies, the IPCC is confident that the 20th century has been the warmest century over the last 1000 years, and that the 1990s was the warmest decade, with 1998 being the warmest year over the past 100 years in the northern hemisphere.

Fig. 4 Variations of the Earth's surface temperature for the past 1,000 years



Source: IPCC (Science) 2001, based on Fig. 2.20.

The IPCC reports that evidence of warming is now widespread and striking:

- Global average surface temperature has increased 0.6° ±0.2°C since the late 19th century. See Fig. 3.
- Global ocean heat content has increased significantly since the late 1950s.
- It is likely that the rate and duration of the warming in the 20th century is larger than any time during the last 1,000 years. The 1990s are likely to have been the warmest decade of the millennium in the Northern Hemisphere, and 1998 is likely to have been the warmest year.
- Annual land precipitation continue[s] to increase in the middle and high latitudes of the Northern Hemisphere (very likely to be 000.5 to 1%/decade), except over East Asia…. It is likely that total atmospheric water vapour has increased several percent per decade over many regions of the Northern Hemisphere… Changes in total cloud amounts over Northern Hemisphere mid- and high-continental regions indicate a likely increase in cloud cover of about 2% since the beginning of the 20th century, which has been shown to be positively correlated with decreases in the diurnal temperature range.

31 *Id.* at 2.

32 This estimate represents a 95% confidence level given data uncertainties such as random instrument error, ocean surface temperature data, adjustments for urban heat island effects, and ocean data gaps.

- Diurnal temperature range is decreasing very widely, but not everywhere.
- Satellite data show that there are very likely to have been decreases of about 10% in the extent of snow cover since the late 1960s. There is a highly significant correlation between increases in Northern Hemisphere land temperatures and the decreases. There is now ample evidence to support a major retreat of alpine and continental glaciers in response to 20th century warming. … Over the past 100 to 150 years, ground-based observations show that there is very likely to have been a reduction of about two weeks in the annual duration of lake and river ice in the mid- to high latitudes.
- A retreat of sea-ice extent in the Arctic spring and summer of 10 to 15% since the 1950s is consistent with an increase in spring temperatures and, to a lesser extent, summer temperatures in the high latitudes.
- There likely has been an approximately 40% decline in Arctic sea-ice thickness in late summer to early fall between…1958 and the mid 1990s.
- Based on tide gauge data, the rate of global mean sea level rise during the 20th century is in the range 1.0 to 2.0 mm/yr.
- The behavior of ENSO (El Niño – Southern Oscillation) has been unusual since the mid-1970s compared with the previous 100 years, with warm phase [El Niño] episodes being relatively more frequent, persistent, and intense than the opposite cool phase.
- In regions where total precipitation has increased, it is very likely that there have been even more pronounced increases in heavy precipitation events. The converse is also true.
- Taken together, these trends illustrate a collective picture of a warming world.[33]

Other evidence of warming keeps appearing. The year 2001 was the second hottest year on record, nine of the ten warmest years since 1860 have occurred since 1990, global temperatures are now rising three times as fast as they were in 1900, and the year 2001 will be the 23rd consecutive year with the global mean surface temperature above the 1961–1990 average.[34] Warmer weather in Alaska has allowed beetle growth rates to soar, so that vast stretches of Alaska spruce forest have been destroyed.[35] Arctic permafrost is retreating as warming is increasing. Tropical mosquitoes are moving to higher latitudes. Worldwide precipitation has increased over the last century as warmer air simultaneously increases evaporation from the earth's sources of water and also enhances the air's capacity to hold moisture. 100 year extreme weather events, and the catastrophic costs associated with them, are no longer the rarity that by definition they should be, such as the simultaneous 100 year drought in the eastern United States and the August flooding in Europe (the worst in 150 years) during the summer of 2002.[36]

The detection of climate changes, large and small, appears to be consistent with the notion of increased heat being trapped in the atmosphere. However, climate changes can result from many factors natural variation and cycles, as well as changes in atmosphere's ability to trap heat, both natural and human caused. Thus, the next question is whether the observed warming and related climate changes are associated with increased anthropogenic emissions of greenhouse gases, or with some other (human or natural) climate influence.

4 Is global warming the result of human activity?

It is established that GHG concentrations in the atmosphere have increased dramatically, and that a variety of significant climate change phenomena have been observed that are consistent with warming of the atmosphere. However, if this warming were primarily due to natural causes, such as climate cycles of hundreds of thousands of years, changes in the sun's intensity from sun spot cycles, or natural emissions of greenhouse gases, then there is little human society can do to alter the climate trends that are afoot. On the other hand, if the increases of GHGs are primarily anthropogenic, and if the warming is due primarily to these increases, then today's societies, by changing emission patterns, can reduce the damage that rapid climate change will inflict on present and future generations.

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33 *Id.* at 26–34.

34 World Meteorological Organization, *WMO Statement on the Status of the Global Climate in 2001* (2001) available at http://www.wmo.ch/web/Press/Press670.html

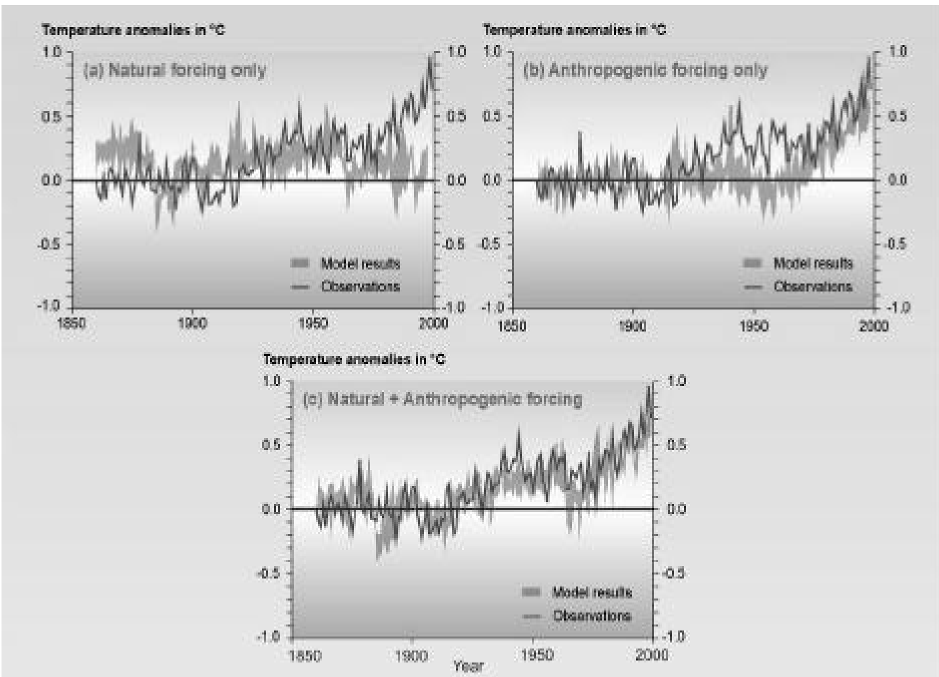
35 IPCC, *Climate Change 2001: Impacts, Adaptations, and Vulnerability* (2001) (IPCC (Impacts 2001)) 824–826.

36 UN Environment Programme, *2002: Natural Disasters Set to Cost Over $70 Billion* (Oct 29, 2002) available at www.enn.com/extras/; *see also*, WMO, *WMO Statement on the Status of the Global Climate in 2001* (2001) available at http://www.wmo.ch/web/Press/Press670.html (reporting on record floods and other natural weather related disasters in 2001).

To tease out whether the observed global warming is driven by natural cycles or by society's release of GHGs, the scientific community has turned to computer models of the climate under various conditions. Over the past decade both the models and the computers that run them have become increasingly sophisticated and capable. Over 30 different models are being continually run and improved at about 15 different public and private scientific centres around the world.[37] These models, when coupled,[38] "provide credible simulations of both the present annual mean climate and the climatological cycle over broad continental scales for most variables of interest for climate change."[39] Not only are the models assessed for how accurately they render present climate, but they are also evaluated as to how accurately they can reconstruct the climate over the past century, and for selected times in the distant past (paleoclimates). The models' improvements in accuracy and detail have been dramatic. In 1996, the IPCC noted that "current atmospheric models generally provide a realistic portrayal of the phase and amplitude of the seasonal march of the large-scale distribution of temperature, pressure and circulation. … [C]urrent models are now able to simulate many aspects of the observed climate with a useful level of skill…at large space scales (e.g., hemispheric or continental); at regional scales skill is lower."[40] By 2001, the IPCC's confidence in the models' ability "to project future climates [has been] increased by the ability of several models to reproduce the warming trend in the 20th century surface air temperature when driven by radiative forcing due to increasing greenhouse gases and sulphate aerosols."[41] Moreover, "climate models now have some skill in simulating changes in climate since 1850," and "all atmospheric models are able to simulate several large-scale features of the Holocene climate [about 6,000 years ago]."[42]

The IPCC has compared three different coupled model scenarios with actual temperature data since 1850.[43] First, the IPCC compared actual temperatures with those predicted if it were assumed that all of the radiative forcing were due to solar and volcanic forcing only. Then, the coupled model simulated the climate using "anthropogenic forcing including well mixed greenhouse gases, changes in stratospheric and tropospheric

Fig. 5 Comparison between models and observations of temperature rise since the year 1860



Source: IPCC (2001).

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37 *Id.* at 478.

38 The IPCC term, *coupled models* or *coupled atmosphere-ocean general circulation models*, refers to "the most complex climate models … involving coupling comprehensive three-dimensional atmospheric general circulation models, with ocean general circulation models, with sea-ice models, and with models of land-surface processes." IPCC at 48–49, 475.

39 *Id.* at 473.

40 *Id.* at 474.

41 *Id.* at 473. For an extensive evaluation of the climate models, with detailed technical references, see IPCC Ch. 8, 472–523.

42 *Id.* at 496.

43 IPCC (Science) at 58.

ozone and the direct and indirect effects of sulphate aerosols." Finally, the models compared actual temperature results with those predicted if the models assumed that the earth was influenced by both natural and human radiative forcings. The results, shown in Fig. 5, demonstrate that the combined predicted temperature effects of human and natural sources of GHGs most closely fit with the actual global temperature over the last 150 years.[44] To the IPCC, and all other scientists examining this data, this last graph is the metaphoric human fingerprint on global warming: "[I]n the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations."[45]

With the benefit of computer modelling, the international scientific community could by 1995 conclude that, "the balance of evidence suggests a discernible human influence [from greenhouse gas emissions] on global climate."[46] Six years later scientific understanding had improved to the point that the IPCC Third Assessment Report not only confirmed that "emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate," but also definitively concluded "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."[47]

Based on close scrutiny of the data of increasing temperatures and upon climate data for the past 1,000 years, scientists agree that the warming over the past 100 years is very unusual and unlikely to be due primarily to natural causes; neither solar flares and storms nor volcanic activity explain the warming during the last 50 years.[48] Moreover, "it is very likely (90–99% chance) that the 20th century warming has contributed significantly to the observed sea level rise, through thermal expansion of sea water and widespread loss of land ice."[49]

5 How much will the earth warm and what will be the consequences of that warming?

Unfortunately, there are large uncertainties in predicting regional effects of climate change, which depend on understanding how regional ecosystems will react to climate changes, and on whether climate changes will be linear or erratically variable. It appears that the amount and rate of global warming is generally dependent on the rate at which society emits GHGs into the atmosphere: the higher the concentration of GHGs when GHGs concentrations eventually stabilize in the atmosphere, the greater the warming. The IPCC has projected warming over the next century using various emission scenarios, ranging from so-called business as usual, with carbon dioxide rising by the year 2100 to 970 ppm (250% above the 280 ppm concentration in 1750), to an aggressive international regime which might result by 2100 in a concentration of 540 ppm (90% above the concentration in 1750).[50] The computer models predict that "the globally averaged surface temperature is projected to increase by 1.4 to 5.8ºC from 1990 to 2100"[51] (see Figs. 6–9 and Table 2). However, if the oceans, which currently absorb about 50% of our annual emissions, become saturated catastrophic warming could result.[52]

The warming projections vary by scenario. The IPCC modelled four different scenarios, each based on its own "storyline." Scenario A1 assumes a "future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies."[53] Scenario A2 envisions "a very heterogeneous world" which has regionally oriented economic

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44 IPCC (Science) 728. The IPCC also found that natural forcing alone was unlikely to account for the warming, but "anthropogenic greenhouse gases are likely to have made a significant and substantial contribution to the warming observed over the second half of the 20th century, possibly larger than the observed warming."

45 IPCC (Science) 60, 728 ("Results from optimal fingerprint methods indicate a discernible human influence on climate in temperature observations at the surface and aloft and over a range of applications.")

46 *Intergovernmental Panel on Climate Change, 1995: The Science of Climate Change* (J. Houghton *et al.*, eds., Cambridge University Press, 1995) 3–5.

47 IPCC, *Climate Change 2001: The Scientific Basis*, (J. Houghton et al, eds., Cambridge University Press, 2001) 5.

48 *Id.* at 10.

49 *Id.*

50 IPCC (Science) 63. IPCC also factored in uncertainties about land and ocean feedback loops by causing scenario to actually range from a low of 490 ppm (75% above 1750 levels) to 1260 (350% above 1750 levels).

51 IPCC (Science) 69.

52 *See*, National Academy of Sciences, Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises* (National Academy Press 2002); IPCC (Science) 444–5, 536.

53 IPCC (Science) 63, 532. A1 is subdivided into three groups: A1FI (fossil intensive), A1T (non-fossil energy source), and A1B (balanced across all energy sources and end use technologies).

Fig. 6 Projected temperatures during the 21st century are significantly higher than at any time during the last 1,000 years

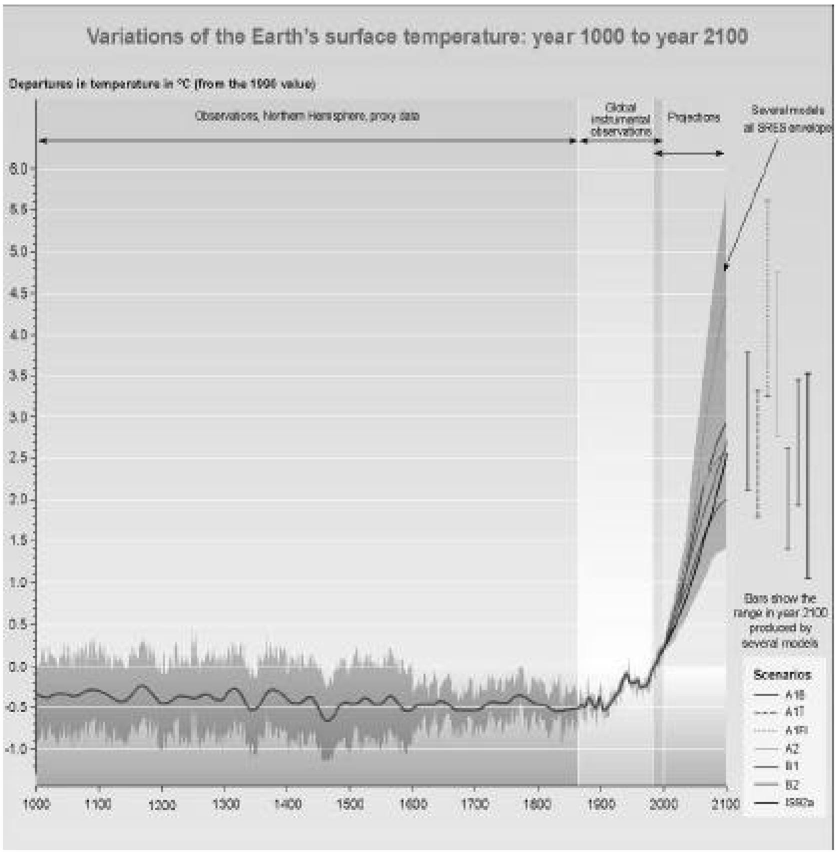


Fig. 7 Projected concentrations of CO_2 during the 21st century are two to four times the pre-industrial level

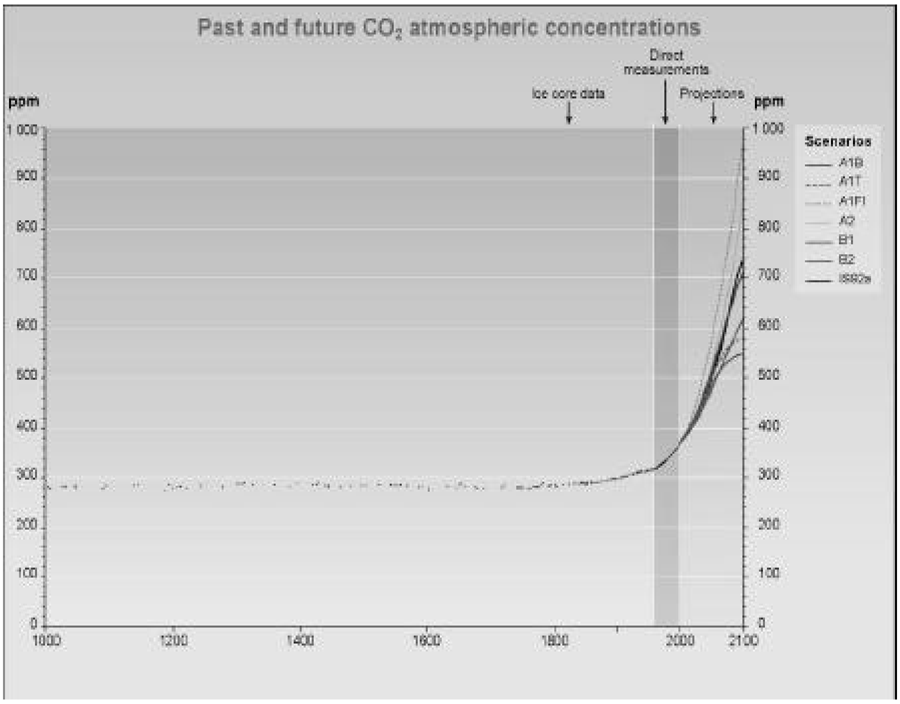


Fig. 8 Constant emissions of CO_2 do not lead to stabilization of atmospheric concentrations

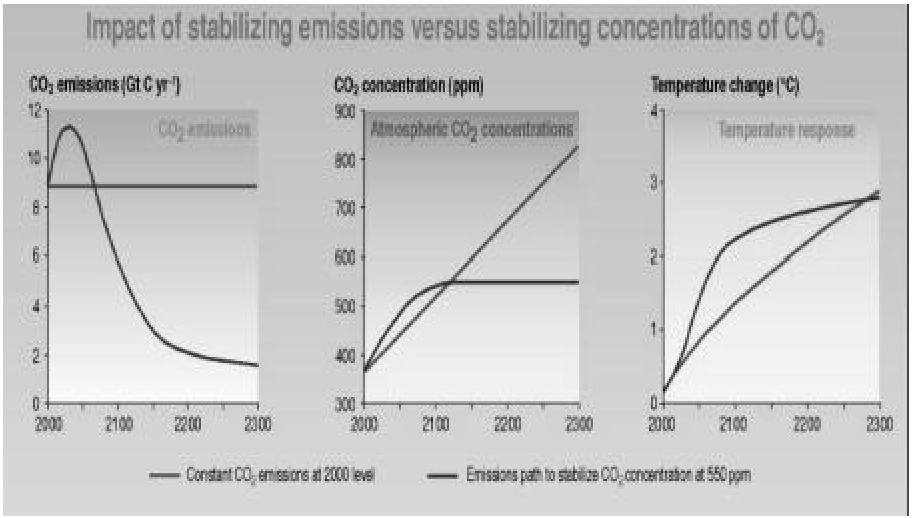
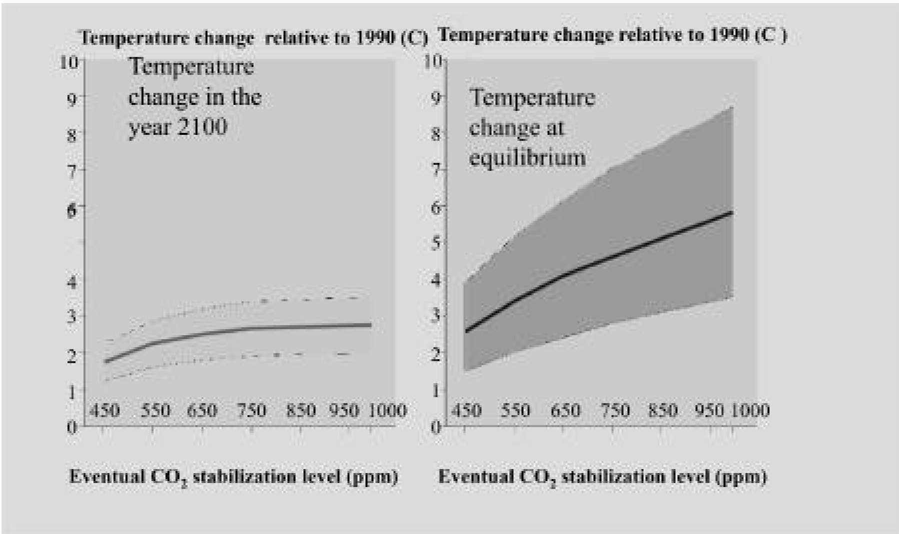


Fig. 9 There is a wide band of uncertainty in the amount of warming that would result from any stabilized concentration of greenhouse gases



growth and continuously increasing population. Scenario B2 assumes a world similar to A1, "but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives." Finally, B2 assumes a world similar to A2, but with a lower rate of increasing population and less rapid and more diverse technological change; B2 focuses on local and regional responses to environmental protection and equity. A1FI (fossil intensive) results in the most warming by the year 2100 (about 3.5 to 6.7ºC) while A1T (non-fossil) warms less (about 1.7 to 3.3ºC).[54] Thus, by choosing a development scenario, the world will be choosing a warming track, with all the impacts associated with that amount of warming.

The IPCC also ran warming projections based on the assumption that climate was stabilized at 450, 650 or 1,000ppm of carbon dioxide. At 450 ppm, the earth would warm about 1.7ºC by 2100 (and peak at 2ºC by about 2300); in contrast, at 1,000 ppm the earth would heat up about 2.8ºC by 2100 (and by 2300 it would rise

54 IPCC (Science) 64–5, 554–7.

to about 4.7ºC and would continue rising for at least another century thereafter).[55] To stabilize at 450 ppm would require anthropogenic emissions to drop below 1990 global levels within the next few decades; 650 ppm requires reaching sub-1990 levels within a century, and 1,000 ppm requires sub-1990 levels in about two centuries. Each level would require steady decreases in GHG emissions thereafter.[56]

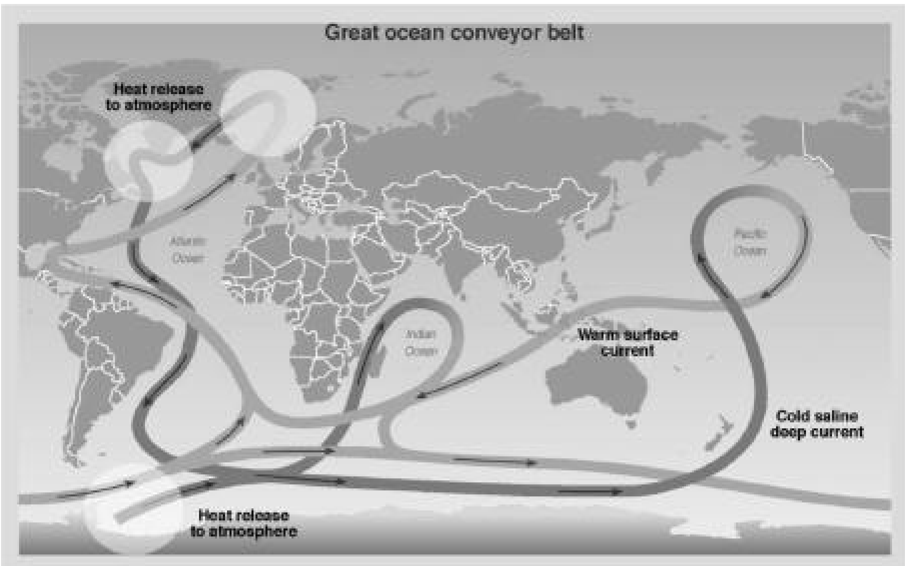
Table 2 Stabilization of atmospheric concentrations of CO_2 will require emissions reductions globally

Stabilization level (ppm)	Date for global emissions to peak	Date for global emissions to fall below current levels
450	2005–2015	2000–2040
550	2020–2030	2030–2100
650	2030–2045	2055–2145
750	2050–2060	2080–2180
1000	2065–2090	2135–2270

These dates are associated with CO_2 stabilization alone – stabilization of CO_2 equivalent concentrations need to occur even earlier because of the contribution of the non-CO_2 greenhouse gases.

The adverse consequences of the climate change driven by this warming could be dramatic, depending on the sensitivity, adaptability and vulnerability of ecosystems as well as the magnitude and the rate of climate

Fig. 10 The thermohaline circulation could be disrupted by climate change



change affecting the systems. The IPCC predicts that, on average, evaporation, water vapour and precipitation will increase, although some regions of the world will be wetter and some drier.[57] Thermal expansion of the oceans and melting of ice and permafrost will cause global mean sea levels to rise between 13 and 94cm by 2100. Sea level rise will inundate coastal areas, harming many highly populated and fertile regions of the world, such as the Nile Delta, Bangladesh, and the Gulf of Mexico coast of the US, disrupting fisheries, agriculture, ecosystems and human settlements. As temperature warms, many forests will shrink. Temperature changes will have variable effects on the production of food around the world. Arctic ice is already more than a metre thinner than it was several decades ago, and the thinning will continue.[58]

55 IPCC (Science) 76.
56 IPCC (Science) 75.
57 IPCC (Science) 71.
58 According to UNEP this trend is confirmed by data going back to 1693 which shows the shifting of the date when winter ice begins to break up on the Tornio River, Finland to earlier in the year. http://www.grida.no/climate/vital/31.htm

With respect to extreme weather, it is:

- very likely that most land areas will experience:
  - higher maximum temperatures and more hot days
  - higher minimum temperatures and fewer cold days and frosts
  - increased days with high heat indexes (a measure of heat and humidity effects on people)
  - more intense precipitation events;
- likely that most areas will experience increased summer continental drying and risk of drought;
- likely that some areas will experience:
  - increased tropical storm wind intensity;
  - increased tropical storm mean and peak precipitation intensities.[59]

Global warming could also result in nonlinear responses or what the IPCC terms *large-scale singularities*, in which a series of feedback loops trigger major regional or global impacts. For example warming and freshwater melting from Greenland could shut down the Northern Hemisphere Thermohaline Circulation (the Gulf Stream), which warms the northern Atlantic Ocean and Western Europe.[60] IPCC models also predict that global ocean circulation will also weaken and possibly collapse as a result of the warming.[61] Weaker global ocean circulation could significantly reduce the ocean's ability to absorb carbon dioxide, cause a shutdown of ocean circulation in the North Atlantic, Labrador and Greenland Seas, and could shut down the formation of Antarctic bottom water. The impact on marine ecosystems and fisheries could be severe because the shutdown would lead to a stagnant deep ocean, reducing deepwater oxygen levels and carbon uptake, would severely reduce the warmth that Europe now enjoys, and could cause dramatic changes in global wind and weather patterns. The IPCC concerns are sobering:

> "Neither the probability and timing of a major ocean circulation change nor its impacts can be predicted with confidence yet, but such an event presents a plausible, non-negligible risk. The change would be largely irreversible on a time scale of centuries, the onset could be relatively sudden, and the damage potential could be very high."[62]

Other large-scale singularities the IPCC has evaluated are the disintegration of the West Antarctic Ice Sheet, which could raise the sea level 4–6m (the irreversible process of disintegration could begin in the 21st century); runaway warming if the oceans and biosphere became less able to absorb carbon dioxide or if vast gas hydrate reservoirs were released; major intensification of continental monsoons; even El Niño becoming a permanent condition; major die-back of forests, and major "destabilization of international order by environmental refugees and emergence of conflict as a result of multiple climate change impacts."[63]

Human health will be adversely affected[64] as summer heat puts more stress on fragile members of society and as warming expands the range (both latitude and altitude) of many disease carrying vectors, such as dengue fever and malaria. Hotter days and heat waves will increase mortality and morbidity in the elderly, weak and sick in urban areas, damage crops, and place heat stress on livestock. Fewer cold days and frost will benefit those who suffer from cold weather, but will also extend the range and seasons of pests and diseases.

Ecosystems will be adversely affected.[65] Lack of frost can adversely affect some trees that need a frost for their seeds to grow. Increased precipitation can lead to floods, land slides and mud slides; more intense winds in tropical storms will increase their potential to inflict great human and property loss. Plant and animal species will become endangered and extinct. Rangeland wildfires and forest fires may increase. Heat sensitive crops will wither. Small island nations may be flooded or even disappear under rising seas. Irrigation and drinking water systems will be threatened; saltwater will intrude into coastal aquifers, freshwater wetlands may become brackish or saline, and coral bleaching will continue, especially at the Great Barrier Reef.

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59 IPCC (Science) 72.
60 National Academy of Sciences, Committee on Abrupt Climate Change, Abrupt Climate Change: *Inevitable Surprises* 108 –117.
61 IPCC (Science) 562–3.
62 IPCC (Impacts) 950–951.
63 IPCC (Impacts) 949–950.
64 IPCC (Impacts) 12, 451–478, 570.
65 IPCC (Impacts) 7–17, 28–61.

6 The international legal response

In response to the evidence that greenhouse gas concentrations are increasing and threaten to change the earth's climate, the UN Framework Convention on Climate Change was created to:

> [a]chieve…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.[66]

7 The international treaty framework

On May 29, 1992, at Rio, the leaders of all the nations of the world, being both "concerned that human activities…enhance the natural greenhouse effect and that this will result…in additional warming of the earth's surface and atmosphere and may adversely affect natural ecosystems and humankind" and "determined to protect the climate system for present and future generations," signed the UN Framework Convention on Climate Change (FCCC) to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system;" the FCCC entered into force on 29 May 1994.[67] When the treaty was negotiated and signed, the science of global warming was less certain, and the fear of possible significant economic consequences of creating new, binding legal obligations confined international consensus to recognition that a global threat existed, that more research and information was needed, and that only general, substantive goals could be declared. Thus, instead of committing to binding targets for GHG emissions or atmospheric concentrations, the industrial nations agreed to "tak[e] the lead in modifying long-term trends in anthropogenic emissions" by taking steps to reduce GHGs "with the aim of returning…to their 1990 levels of …anthropogenic emissions of carbon dioxide and other greenhouse gases" by the year 2000.[68] In response to the FCCC's principle of "common but differentiated responsibilities," the industrialized nations (designated as Annex 1 countries) agreed to take the lead in reducing emissions, assist in technology transfer, and follow the "additionality" concept with respect to developing nations.[69]

The FCCC, being a framework convention, envisioned the need for protocols to establish future targets, timetables, commitments and rules, and so set up the procedural mechanisms for a continuing international effort to address climate change.[70] In particular, the Conference of the Parties (COP) was created as the institutional entity that would conduct future negotiations at regular meetings; the efforts of the COP and FCCC would be supported by a secretariat, headquartered in Geneva, and other subsidiary bodies assigned particular topics by the COP.[71]

Parallel to the FCCC and COP process, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to review, assess and report on the current state of knowledge concerning climate change issues.[72] The IPCC is divided into three working groups. Working Group I's mandate was to prepare a "comprehensive and up-to-date scientific assessment of past, present and future climate change" that will be "the standard scientific reference for all those concerned with climate change and its consequences" from scientists to policy-makers in government and industry.[73] Working Group II's report is a comprehensive analysis of the

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66 UN Framework Convention on Climate Change, Act 2 (concluded at Rio de Janeiro, May 29, 1992, entered into force, March 21, 1994), 31 I.L.M. 849 (1992).

67 UN Framework Convention on Climate Change, 1771 UNTS 108, *reprinted in* 31 I.L.M. 849 (1992)), Art. 2.

68 *Id.*, Art. 4, ¶ 2(a) and (b).

69 *Id.*, Art. 4, ¶ 3 ("Additionality" is expressed as an obligation of the industrialized world to "provide new and additional financial resources" to developing countries to meet their "full incremental costs of implementing" measures under the FCCC.)

70 *Id.*, Art. 12–18.

71 The Secretariat internet web site is http://www.fccc.int

72 The WMO and the UNEP established the IPCC in 1988. It is open to all member nations of the UNEP and WMO. The IPCC is "to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. It does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature." The IPCC web site is http://www.ipcc.ch

73 IPCC, Working Group I, *Climate Change 2001: The Scientific Basis.* (J. Houghton *et al.*, eds., Cambridge University Press, 2001) (cover page). In addition to the hard copy version published by Cambridge University Press, the reports are also available in pdf on the IPCC website at http: www.ipcc.ch.pub

potential consequences of, and adaptation responses to, climate change.[74] Working Group III's report is a scientific, technical and economic assessment of climate change mitigation options.[75] Each report also contains a definitive Summary for Policymakers, which were each fully reviewed and approved by IPCC member governments.[76] The most recent IPCC report, commonly referred it as its Third Assessment Report, was issued in 2001.[77]

The COP, at its first meeting (COP-1 in 1995), concluded that the FCCC's non-binding approach was not going to achieve GHG reductions, and began years of intense negotiations that led to the drafting of the Kyoto Protocol to the FCCC, at COP-3 in Kyoto in 1997.[78] The key element of the Kyoto Protocol was the creation of binding national targets for Annex 1 nations (developed countries and countries in transition to a market economy) to reduce their overall emissions of greenhouse gases at least 5% below 1990 levels[79] by 2008–2012, the first commitment period.[80] To achieve total reduction of 5%, each Annex 1 nation agreed to reduce its own "aggregate anthropogenic carbon dioxide equivalent emissions of greenhouse gases listed in Annex A,"[81] a schedule of GHG reductions indexed to achieving a GHG emissions levels some 6–8% below that country's level in 1990.[82] These emission reductions could be achieved directly or by earning credits for verifiably creating carbon sinks that remove and store carbon from the atmosphere.[83] Each nation, or the European Union as a group, would be allowed to develop its own mix of implementation policies, which could range from command and control to market-based options or taxes, so long as the target was met within the commitment period 2008–2012. However, to promote economic efficiency, the Kyoto Protocol, at the insistence of the USA, established a variety of flexible, international, market-based mechanisms to promote reductions: emissions trading,[84] joint implementation of GHG emission reductions between Annex 1 nations,[85] and a Clean Development Mechanism, which would allow Annex 1 nations to invest in a fund that would finance emission reduction projects in developing nations and receive a credit for the certified emission reductions accruing from the project.[86]

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74 IPCC, Working Group II, *Climate Change 2001: Impacts, Adaptations and Vulnerabilities* (J. McCarthy *et al*., eds., Cambridge University Press 2001).

75 IPCC, Working Group III, *Climate Change 2001: Mitigation* (B. Metz *et al.*, eds., Cambridge University Press 2001).

76 The Working Group I (Science) Summary for Policymakers was prepared by 122 lead authors, 515 contributing authors, 21 review editors, and 420 expert reviewers, and was formally accepted by the 99 IPCC member countries at the 8th session of Working Group I in Shanghai January 17–20, 2001. Working Group II's (Adaptation) Summary for Policymakers was "approved in detail at the 6th Session of IPCC Working Group II in Geneva, February 13–16, 2001. The Working Group III (Mitigation) Summary for Policymakers was approved in detail at the 6th Session of IPCC Working Group III in Accra, Ghana, 28 February–3 March, 2001.

77 In July 2002, the IPCC agreed to start the process of preparing its fourth assessment, which it plans to release in 2007.

78 As of 16 October, 2002, 96 nations have ratified the Protocol, and the ratifications represent 37.4% of Annex 1 1990 emissions of carbon dioxide. Thus, the Kyoto Protocol will enter into force when Annex 1 nations representing an additional 17.6% of 1990 emissions ratify. This could happen, even if the USA (36.1%) does not ratify, if Russia (17.4%) and any country or combination of Annex 1 nations accounting for 0.2% such as Canada (3.3%), Poland (3.0%), Australia (2.1%), Switzerland (0.3%), New Zealand (0.2%) ratify the Kyoto Protocol. The status of the Kyoto Protocol can be checked at http://unfccc.int/resource/ kpthermo.html

79 Unfortunately, the goal of the Kyoto Protocol is only to return the industrial world's emissions to about 8% below the 1990 level by 2008–2012 which will only modestly slow the rate of *increase* of GHG concentration in the atmosphere, and will still result in significant additional global warming.

80 Kyoto Protocol to the United Nations Framework Convention on Climate Change, UN Doc. FCCC/CP/1997/7/ADD.2, *reprinted in* 37 *ILM* 22 (1998) (signed Dec. 10, 1997) Art. 3.

81 The Kyoto GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Compliance flexibility was also promoted by the adoptions of a "comprehension" approach to all GHGs of concern. Each GHG's "global warming potential," as determined scientifically by the IPCC, would be scaled to CO_2 as 1, so that all GHG reductions could be calculated and expressed in the common currency of tons of CO_2 equivalent. *Id.,* Art. 5, ¶ 3.

82 Annex B targets, as a percentage of 1990 emissions, are: Australia 108, Austria 92, Belgium 92, Bulgaria 92, Canada 94, Croatia 95, Czech Republic 92, Denmark 92, Estonia 92, European Community 92, Finland 92, France 92, Germany 92, Greece 92, Hungary 94, Iceland 110, Ireland 92, Italy 92, Japan 94, Latvia 92, Liechtenstein 92, Lithuania 92, Luxembourg 92, Monaco 92, Netherlands 92, New Zealand 100, Norway 101, Poland 94, Portugal 92, Romania 92 and the Russian Federation 100.

83 *Id.,* Art. 3, ¶ 3.

84 *Id.*, Art. 6.

85 *Id.*, Art. 4. *Joint implementation (JI)* refers to "a market based implementation mechanism defined in Article 6 of the Kyoto Protocol, allowing Annex I countries or companies to implement projects jointly that limit or reduce emissions, or enhance sinks, and share the emission reduction units. JI activity is also permitted in Article 4.2(a) of the UN FCCC." IPCC (Mitigation 2001) 715. The FCCC also established a pilot phase for *activities jointly implemented* for projects among developed countries (and their companies) and between developed and developing nations (and their companies). At present, these activities do not receive any emission reduction credits, but may in the future, but are encouraged as first steps in creating a market in tradable permits for GHG emission reductions and sink enhancements. *Id.* at 427–29, 708.

86 *Id.,* Art. 12. The Kyoto Protocol also expects Annex 1 nations to "provide new and additional financial resources" to institutions such as the Global Environment Facility to fund the developing countries' cost of implementation of their FCCC obligations, and to cover the incremental costs of technology transferred to developing countries to reduce GHG emissions. Art. 11.

It was left to future COP meetings to establish the specific rules for how emission reductions and carbon sinks will be measured and verified, how the various flexible mechanisms will actually work, and how each country's compliance with its duties will be verified and enforced. The Kyoto Protocol will enter into force when ratified by 55 parties to the FCCC, including a sufficient number of Annex 1 nations to account for 55% of total 1990 carbon dioxide emissions.[87] As of May 2003, 108 parties including Annex I parties accounting for 43.9% of 1990 emissions have ratified the Kyoto Protocol, which leaves only six more Annex I countries: USA (36.1%), Russian Federation (17.4%), Australia (2.1%), Switzerland (0.3%), Monaco (0.0%), and Lichtenstein (0.0%).[88]

The Kyoto Protocol created binding targets and envisioned flexible, market-based implementation. But the operating rules and definitions needed to measure, validate and verify the reduction credits were the subject of contentious and frustrating negotiations that dragged on for years, through many COPs and an almost unending series of international meetings. While progress was modest, emissions were steadily increasing. Ironically, when President George W. Bush rejected the Kyoto Protocol in March 2001,[89] the withdrawal by the USA, the world's greatest GHG emitter, seemed to galvanize the rest of the world. In July 2001, major political and policy issues were resolved at the Bonn COP meeting (the Bonn Agreements),[90] which allowed the Marrakesh COP in November 2001 to craft the detailed rules for emissions trading and control measures (the Marrakesh Accords).[91]

8 The Bonn Agreements and Marrakesh Accords

The Bonn Agreements and Marrakesh Accords comprise hundreds of pages of language that attempt to resolve, first at a political level in the Bonn Agreements, and then at the detailed rule level in the Marrakesh Accords, most of the many contentious issues at stake in the overall climate change negotiations. Generally speaking they establish the operational guidelines for creating a transparent market in credible emission reductions. The Accords address so-called flexibility mechanisms, sinks (also referred to under the awkward title of "Land Use, Land Use Change and Forestry"), monitoring, reporting, review, compliance and enforcement, and funding for developing countries.

The key provisions of the Marrakesh Accords concern the establishment of concrete rules and guidelines to support a market-based approach to GHG emission reductions and sink enhancements.[92] To do this, the Accords create a trading vehicle in the form of the "emission reduction unit," (ERU) which is equal to one ton of carbon dioxide equivalent (calculated using IPCC global warming potentials and can be used to meet emission reduction targets).[93] A supervisory committee of ten members of the Parties to the Kyoto Protocol or independent entities accredited by the supervisory committee must verify all ERUs generated by GHG reduction projects. To participate in a project and be allowed to earn and trade ERUs, a nation must be a Party to the Kyoto Protocol and have in place a national system of GHG emission measurements that meet IPCC best practice guidelines. Projects must first be approved, after undergoing review in a transparent process, that includes establishing baselines for measurement. Once implemented, projects must also be verified by a certified independent entity. The same process must be followed for credits under the Clean Development Mechanism and other flexible mechanisms under Kyoto. All credits will be issued and transferred by the

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87 *Id.*, Art. 25. If, and when, the Kyoto Protocol enters into force, the COP will serve as the meeting of the parties to the Protocol, except that nations that have not ratified the Protocol will not be able to vote when the COP acts as the meeting of the Parties to the Protocol. Art. 13.

88 http://unfccc.int/resource/kpthermo_if.html (visited May 9, 2003) "President Putin has said that Russia intends to ratify the Kyoto Protocol, which would push the emissions to 61.3% and cause the Kyoto Protocol to enter into effect as international law. However, Russia has not yet ratified."

89 The USA, under the Bush Administration, has refused to adhere to its proposed Kyoto reductions. Instead it proposes to slightly increase the efficiency of the US economy so that the emissions per dollar of GDP are reduced by about 1% per year. However, this rate of efficiency occurs naturally in the economy, so the "new" idea is actually a "business as usual" proposal that will only lead to increased levels of GHG emissions.

90 *See*, Bonn Agreements for the Implementation of the Buenos Aires Plan of Action, UN Doc. FCCC/CP/2001/L.7 (2001). COP-4, Buenos Aires 1998, could not reach any substantive agreements on operational details to implement Kyoto, as a default it issued the Buenos Aires Plan of Action, which identified the issues on which rules were needed to implement Kyoto, and self-imposed a deadline of COP-6 for reaching agreement.

91 The Marrakesh Accords, UN Doc. FCCC/CP/2001/13/Add.1–4 (2002).

92 For analysis of the Marrakesh Accords, *see* M. Vespa, Climate Change 2001: Kyoto at Bonn and Marrakesh, 29 *Ecology L.Q.* 395 (2002) D. Wirth, The Sixth Session (Part Two) and Seventh Session of the Conference of the Parties to the Framework Convention on Climate Change, *American J. of International Law* (July 2002).

93 Marrakesh Accords, Add 2 Annex. Related tradable units were also created: "certified emission reduction," and "removal unit" (allowing trading in sink enhancement).

supervisory committee, which will be compensated for its administrative expenses by receiving a share of the project credits. Strong compliance and enforcement provisions were also agreed included in the Accords. It appears that the Accords create all the necessary elements for a global market in GHG emission reduction credits and sink enhancements. Such a system, if implemented could unleash an enormous demand for renewable energy technology and energy efficient supply-side and demand-side technology. Taken together, the texts from the FCCC to the Marrakesh Accords comprise an emerging international legal structure to control GHG emissions. Ultimately, each nation will be responsible for its own reductions. To do that, they will need to adopt some combination of policies described in this book to improve energy efficiency, to shift from fossil fuels to renewable sources of energy (See, e.g., the chapter by Richard L. Ottinger *et al.*, *Legal Measures To Promote Renewable and Energy Efficiency Resources*), and to enhance carbon dioxide sinks. Even with ambitious efforts, GHG concentrations will rise, the earth will warm and society will face expensive imperatives to adapt to the consequences of climate change.

9 Prospects for the new legal regime

President Bush's opposition to Kyoto has been firm since March 2001, although over time his reasons have transmogrified. At first, President Bush questioned the IPCC scientific assessment that global warming was a serious imminent problem and so he asked the US National Academy of Science to evaluate the IPCC Third Assessment Report. Instead of rejecting the IPCC findings, the National Academy of Science "generally agree[d] with the assessment of human caused climate change presented by the IPCC Working Group 1…scientific report"[94] and concluded:

> "GHGs are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperature and subsurface temperatures to rise. Temperatures are, in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes are also a reflection of natural variability. Human-induced warming and associated sea level rises are expected to continue through the 21st century".

Faced with scientific consensus on the seriousness of human induced climate change, Bush's opposition to the Kyoto Protocol shifted to concern that compliance would hurt the US economy and that the Kyoto Protocol does not require developing nations to reduce emissions. Bush's worry is that to reduce USA to 7% below its 1990 levels, its current emissions will have to be lowered by about 25–30%, because its emissions have steadily increased since 1990. Instead of reducing GHG emissions over the next ten years, the Bush administration now proposes to reduce the carbon intensity (not total GHG emissions) of the economy by 18%, even though the economy will, based on historic and present investment patterns, become 17.5% more efficient over the next decade through the unremarkable, ongoing process of capital replacement.[95] However, following the Bush administration's strategy will result (based on the Bush administration's own projections) in the USA in ten years emitting 30% more GHGs per year than it was in 1990; in contrast, the industrialized nations meeting their Kyoto Protocol targets will reduce emissions by about 3% from 1990 levels.[96]

The Bush administration's second objection to the Kyoto Protocol is that it does not mandate targets and timetables for developing countries. Yet, because the USA has the largest historic total of GHG emissions, accounting for the largest share of the past emissions, and is the world's largest emitter of GHG in total quantity and among the highest in per capita GHG emissions,[97] the USA, along with all the industrial nations, bound itself in the FCCC to "tak[e] the lead in modifying long-term trends in anthropogenic emissions." The Kyoto Protocol is only a small first step. In fact, the US share of Kyoto reductions is less than its proportionate share of 1990 emissions. More substantial reductions will need to be established for post 2012 commitment periods, when the obligations of developing countries will most likely engage. By taking the lead, the industrialized countries will assuage some of the developing world's present resistance to reducing GHG

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94 Committee on the Science of Climate Change, National Research Council, Climate Change Science: An Analysis of Some Key Questions 1 (2001).

95 *See* S. Eizenstat, F. Loy and D. Sandalow, *President Bush's Disappointing Climate Proposal*, (2002), and John Podesta, *Do the Math: Under the White House Global Warming Plan, Carbon Dioxide (CO2) Pollution Would Continue Increasing at Same Rate as Past Decade Accounting Tricks Hide Growing Damage Behind Veil of Progress,* (2002).

96 S. Eizenstat, F. Loy and D. Sandalow, *President Bush's Disappointing Climate Proposal*, (2002).

97 *World Energy Assessment* 94 .

emissions growth on the grounds that the problem created by the industrialized world is being unfairly imposed on the developing nations.[98]

The FCCC obligates all parties (including developing nations) to adopt GHG emission programmes and to address GHG emissions within their energy, transportation, industry, agriculture, forest and waste management sectors,[99] and some developing countries, such as China and India, are voluntarily beginning to address climate change. It is well understood by all nations that the greenhouse gas problem cannot be successfully addressed without all nations participating, and that all developing nations will be phased into the legal regime, but on a timetable that reflects their common, but differentiated, obligations.

Perhaps thwarted by the Marrakesh Accords (and the possibly imminent entry of the Kyoto Protocol into force) in its argument that the USA should not be bearing the burden of reducing GHG emissions without participation of developing nations, the Bush administration announced at COP-8 a new spin on the Kyoto Protocol. The USA first opposed the Kyoto Protocol because developing nations refused firm GHG targets and timetables. But at COP-8, the USA agreed with the developing countries' view. According to Paula Dobriansky, US Under Secretary of State for Global Affairs, "[the US] does not see targets and timetables as realistic for developing countries."[100] Therefore, the circular reasoning goes, the USA cannot ratify the Kyoto Protocol because developing countries should not be subject to any hard commitments. This led the USA to announce in Delhi its new approach to global warming: adaptation is as essential to climate change as is prevention, and the key to environmental progress is economic growth. In other words: learn to live with it, the USA can and so should you.[101]

In rejecting Kyoto, Bonn and Marrakesh, the USA is obstructing the emergence of market-based mechanisms that could be financially beneficial to all participants, that would motivate the industrial nations to develop new technology, and that would provide the incentives and open the channels for the flow of investment for energy efficient and renewable technology to developing countries. Without this leadership, China, India and other developing nations will use traditional coal-based and oil technologies to develop. If they do that and approach per capita emission rates anywhere near those of the industrial world, global GHG emissions will soar out of control, and any hope of sustainable development will be lost. The USA will also be excluding itself from these new market opportunities because both the Kyoto Protocol and the Marrakesh Accords exclude non-Parties from participation.

98 India's Prime Minister, Atal Bihari Vajpayee, at COP-8 in Delhi on 31 October, 2002, addressed the differences between developed and developing countries over how to approach global warming. His speech, which expressed the views (even resentments) of developing nations, argued that poor nations should not be expected to spend money preventing global warming because they bear little responsibility for global warming and emit fewer GHGs than developed nations, but suffer more from natural disasters, such as floods and droughts, attributable to global warming. Moreover, poorer nations are already challenged in trying to meeting critical social needs such as health care and education, and so have little money to invest in reducing GHG emissions. A. Waldman, At Climate Meeting, Unlikely Ally for Have-Nots, *New York Times*, 1 Nov., 2002, at A8.

99 FCCC, Art. 4, ¶1 (b), and (c).

100 *Id.*

101 *Id.*