CLIMATE CHANGE, SCIENTIFIC UNCERTAINTY AND INTERNATIONAL LAW*

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This article examines the scientific uncertainties surrounding the issue of climate change in the context of the international legal process. It includes a summary of the state of the science of climate change, identifying both the certainties as well as the uncertainties in the available data. It then analyzes and proposes modes by which the international community can resolve these uncertainties. The article ends by asserting the necessity of instituting measures to respond to the problem without ignoring the existing uncertainties. A flexible regulatory regime characterized by aggregate and partial solutions is recommended as a starting point for responding to the threat that climate change brings to the world community.

I. THE PHENOMENON OF CLIMATE CHANGE

The concept of climate change as a result of global warming goes back more than 200 years. Jean-Baptiste Fourier (1768-1830) was the first scientist to formally propose that gases in the atmosphere could absorb some of the heat radiation constantly emitted by the Earth's surface. Fourier theorized that the Earth is kept warm by this process in the same way that the glass of a greenhouse keeps the interior warm on a cold day, and he called this phenomenon *l'effet de verre* (the glass effect), hence the term "greenhouse effect".[1]

The Earth's surface is kept warm enough to prevent the oceans from freezing and to permit the evolution of life by the presence of a few trace gases in the atmosphere. These gases, which scientists call greenhouse

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[1] W. W. Kellogg, *Theory of Climate: Transition from Academic Challenge to Global Imperative*, in GREENHOUSE GLASNOST 94, 95 (1990).

gases (GHGs), retain some of the outgoing infra-red radiation that would otherwise escape to space.[2] Today, human activity adds more of these greenhouse gases to the atmosphere, thus disrupting the natural dynamics of the climate system by increasing average temperatures.

The Enhanced Greenhouse Effect

Greenhouse gases have been present in trace quantities in the atmosphere for the great majority of the Earth's history. They are added into the atmosphere by natural processes and by human activity. Water vapour, because of its abundance, is the most significant natural greenhouse gas. Carbon dioxide (CO_2), the second most important greenhouse gas, has been added naturally by volcanoes throughout history and cycled into and out of the atmosphere through a number of natural phenomena.[3] Without this gas, the temperature of the Earth's surface would be about 33^0C lower than it is today, a temperature insufficient to support life. But CO_2 is also introduced into the atmosphere by human activity. Hence, it is essential to distinguish between the natural greenhouse effect and the greenhouse effect caused by human activity.[4]

While natural GHGs keep the Earth warm enough to be habitable, increasing their concentrations through human activity may result in raising global temperature. This is an enhanced greenhouse effect, with GHG concentrations[5] above those produced by natural processes. Hence, "climate change" has been defined as a

> change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.[6]

It was the Swedish chemist Svante Arrhenius who, in 1896, conceived the notion that human activities might disrupt the delicate

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[2] *Id.*

[3] J. Leggett, *Global Warming: The Scientific Evidence and Its Implications*, 2 TRANSNAT'L L. & CONTEMP. PROBS. 1, 3 (1992).

[4] *Id.*

[5] WMO/UNEP, CLIMATE CHANGE: THE IPCC SCIENTIFIC ASSESSMENT xiv (J.T. Houghton *et al.* eds., 1990), hereinafter referred to as IPCC 1990 SCIENTIFIC ASSESSMENT.

[6] *Framework Convention on Climate Change*, May 9, 1992, Article 1 (2), 31 I.L.M. 849 (1992).

balance in the atmosphere.[7] Arrhenius proposed that the rapid increase in the use of coal in Europe since the industrial revolution would increase carbon dioxide concentrations and gradually raise global temperatures. This theory stirred little interest for decades since no one was certain whether carbon dioxide concentrations were actually increasing.[8]

While the writings of Arrhenius were not entirely forgotten, they had little impact on scientific thinking for a long time. On the whole, except for a few concerned individuals, the scientific community and the public were unaware of or indifferent to the possibility that human activity could amplify the greenhouse effect and thus result in climate change.[9] The situation changed in the 1960s with the pioneering work of scientists like Roger Revelle.[10]

New technology such as satellite reconnaissance and more sophisticated computer models broadened understanding of the complex forces at work in the planet's climate. Powerful computers enabled scientists to develop models that simulate the phenomena that make up the global climate.[11] The use of computer models had, by the early 1980s, helped establish a consensus on the amount of warming that could be expected if carbon dioxide build-up continues for the next hundred years.[12]

Rising Temperatures

Over the last 100 years, as a result mainly of human activity, the average annual surface temperature on this planet has increased by 0.3-.6°C, or approximately half a degree Celsius.[13] After the unusually warm 1980s,

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[7]C. FLAVIN, SLOWING GLOBAL WARMING: A WORLDWIDE STRATEGY 10-11 (1989).

[8]*Id.*

[9]*See* Kellogg, *supra* note 1, at 98. *See* also F. LYMAN, THE GREENHOUSE TRAP 9 (1990).

[10]Revelle is recognized as the father of modern greenhouse science. In the 1950s, he pioneered the study and measurement of atmospheric carbon dioxide. *See* R.T. Revelle and H. E. Suess, *Carbon Dioxide Exchange Between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 during the Past Decades,* TELLUS 9 (1957).

[11]Climate models, known technically as General Circulation Models (GCM), are mathematical formulations of atmosphere, ocean and land surface processes that are based on physics. These models allow scientists to examine the nature of both past and possible future climates under a variety of conditions. *See* IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 99.

[12]FLAVIN, *supra* note 7, at 12.

[13]IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 243.

the planet warmed by a total of 0.7°C. This rate of temperature change was unknown in this planet's recorded history. Global temperatures are now about 0.6 °C warmer than they were a century ago. While there is yet no conclusive proof linking this recent heating to the greenhouse effect, circumstantial evidence has convinced many scientists that this indeed is the cause.

Scientists are more disturbed, however, about the much more rapid warming that is predicted by a half dozen computer models — reaching a rate of 2.5-5.5°C late in the 21st century.[14] The science group of the Intergovernmental Panel on Climate Change[15] (IPCC), the international body tasked with studying the greenhouse effect, has concluded, in its 1990 and 1992 reports, that if business and industry continue operating as usual, global temperatures would increase by 0.3°C per decade -- an increase greater than that seen over the past 10,000 years -- "within an uncertainty range of 0.2-0.4°C".[16]

This is the so-called Business-As-Usual (BAU) scenario of the IPCC. The result is a likely increase in the global mean temperature of about 1°C above the present value by the year 2025 and 3°C before the end of the next century. The rise, however, will not be steady because of the influence of other factors.[17]

The rise in global temperature from pre-industrial times to the year 2070 is estimated to be between 2.2°C and 4.8°C, with the best estimate

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[14] *Id.*, at 243.

[15] The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization and the United Nations Environmental Programme in 1988. It was charged with (1) assessing the scientific information that is related to the various components of the climate change issue, such as emissions of major greenhouse gases and modification of the Earth's radiation balance resulting therefrom, and that needed to enable the environmental and socio-economic consequences of climate change to be evaluated; (2) formulating response strategies for the management of the climate change issue. *See id.*, at iii.

[16] *See id.*, at xi. *See* also WMO\UNEP, 1992 IPCC SUPPLEMENT, reprinted in 9 ARIZ. J. INT'L & COMP. L. 9-10 (1992), hereinafter referred to as IPCC 1992 SUPPLEMENT, which concluded that "(f)indings of scientific research since 1990 do not affect our fundamental understanding of the science of the greenhouse effect and either confirm or do not justify alteration of the major conclusions of the first IPCC Scientific Assessment."

[17] Under the other IPCC emission scenarios which assume progressively increasing levels of controls, the rates of increase in global mean temperature are about 0.2°C per decade (Scenario B), just above 0.1°C per decade (Scenario C), or about 0.1°C per decade (Scenario D). See IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xi.

being 3.3°C. This corresponds to a predicted rise from 1990 of 1.6°C to 3.5°C, with the best estimate being 2.4°C.[18]

According to the IPCC, the magnitude of the warming experienced by the Earth is "broadly consistent with the theoretical predictions of climate models, but it remains to be established that the observed warming (or part of it) can be attributed to the enhanced greenhouse effect."[19] Global temperature alone is not a sufficient indicator of GHG-induced climate change. According to the IPCC,

> Identifying the causes of any global mean temperature requires examination of other aspects of the changing climate, particularly its spatial and temporal characteristics. Currently, there is only limited agreement between model predictions and observations. Reasons for this include the fact that climate models are still in an early stage of development, our inadequate knowledge of natural variability and other possible anthropogenic effects on climate, and the scarcity of suitable observational data, particularly long, reliable time series. An equally important problem is that the appropriate experiments, in which a realistic model of the global climate system is forced with the known past history of GHG concentration changes, have not yet been performed.[20]

Whether a warming is detectable now is arguable; what is certain is that the 1980s was the warmest decade of the past century.[21] According to Leggett, the fact that global warming may have begun is indicated by the following:

> (1) The seven hottest years since temperature records began (more than a century ago) have all been in the last decade;
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> (2) 1990 was the hottest year since records began;
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> (3) 1991 temperatures, despite the cooling effect of copious sulphate aerosol emissions from the eruption of Mt. Pinatubo, was the second highest since records began;
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> (4) March 1990 was the warmest month since records began;

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[18]*Id.*, at 177.
[19]*Id.*, at 243.
[20]*Id.*
[21]WORLD RESOURCES INSTITUTE, WORLD RESOURCES 1990-91: A GUIDE TO THE GLOBAL ENVIRONMENT 3-4 (1990), hereinafter referred to as WORLD RESOURCES.

> (5) The decade of the 1980s is 0.2°C warmer than any other decade since records began;
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> (6) In the late winter and spring of 1990, there was less snow cover in the northern hemisphere than at any time since satellite temperature records began (in 1970);
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> (7) In the late winter and spring of 1990, there was a temperature differential of 1°C in the northern hemisphere over the temperature average from 1959-1970. In March 1990, temperatures were as much as 2.2°C warmer than the 1959-1970 average.[22]

If current trends persist, greenhouse gases will, within 40 years, attain the equivalent of twice the pre-industrial levels of carbon dioxide, and will double again before the end of the next century. According to current models of the Earth's climate system, even one doubling will raise global temperatures by a few degrees centigrade.[23] Most predictions, including the IPCC's,[24] have concluded that the chance of a warming of several degrees Celsius by the middle of the next century is three out of five, and that a warming of three degrees Celsius is possible by the end of the next century.[25]

The prospective change in temperatures may seem insignificant, but it is analogous to the shift between the extreme climate of the last ice age 18,000 years ago, and today's climate. It is sufficient to significantly alter rainfall patterns and temperature regimes in much of the world, affecting agriculture, forestry, and virtually all living things. Even an increase of two degrees would make temperatures higher than human societies have ever experienced.[26] The Stockholm Environmental Institute has suggested that allowing temperatures to rise more than 2°C above pre-industrial levels is to run the risk of traversing a threshold beyond which "risks of grave

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[22]Leggett, *supra* note 3, at 17.

[23]*Id.*, at 3.

[24]The IPCC Business-As-Usual (BAU) scenario, where GHG emissions remain constant at present levels, predicts a rate of increase of global mean temperature during the next century of about 0.3C per decade (with an uncertainty range of 0.2°C to 0.5°C per decade). It projects an increase in global mean temperature of about 1°C above the present value by the year 2025 and 3°C before the end of the next century. See IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xi.

[25]S. Schneider, *The Global Warming Debate: Are We Ready for International Action*, 2 TRANSNAT'L L. & CONTEMP. PROBS. 61, 66 (1992).

[26]*Id.*

damage to ecosystems, and of non-linear responses, are expected to rise rapidly".[27]

II. THE GREENHOUSE GASES

Water vapour, as mentioned earlier, is the most abundant greenhouse gas. Unlike other greenhouse gases which are produced by human activity, the amount of water vapour is determined by natural processes within the climate system. Hence, international concern to combat climate change has discounted water vapour and emphasized other GHGs instead. These gases are principally carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O), ground level (tropospheric) ozone (O_3), and aerosol particles.

The major contributor to increases in global warming or the radiative forcing of climate as a result of increased GHG concentrations, is carbon dioxide.[28] The increase in carbon dioxide is calculated to have contributed approximately 61% of the increased forcing for the last 200 years.[29] Methane is next in significance, adding about 17%.[30] CFCs contribute about 12%, nitrous oxide 4%, and stratospheric vapours, which are expected to follow from methane emissions, 6%.[31] The contribution from changes in tropospheric and stratospheric ozone is difficult to measure. According to the IPCC, increased levels of tropospheric ozone may have caused 10% of the total forcing since pre-industrial times, while decreases in lower stratospheric ozone may have decreased radiative forcing in recent decades.[32]

Although carbon dioxide is the major human-caused greenhouse gas, the other GHGs are said to be more effective in trapping heat. A molecule of methane, for example, traps about 21 times more heat than one molecule of

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[27] *See* STOCKHOLM ENVIRONMENTAL INSTITUTE, RESPONDING TO CLIMATE CHANGE: TOOLS FOR POLICY DEVELOPMENT (1990).

[28] In 1988 alone, some 5.66 billion tons of carbon were produced by the combustion of fossil fuels -- more than a ton for each human being. Another 1 to 2 billion tons were released by the felling and burning of forests mainly in tropical areas. Each ton of carbon emitted into the air produces 3.7 tons of carbon dioxide. Thus, at least 24 billion tons of carbon dioxide entered the atmosphere from these processes in 1988 alone. *See* FLAVIN, *supra* note 7, at 23.

[29] IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 45.

[30] *Id.*

[31] *Id.*

[32] *Id.*

carbon dioxide.[33] Other gases are even more effective: nitrous oxide is more effective by 150 times, ozone by 2,000 times, and CFCs by 10,000 times.[34] The effectiveness of a greenhouse gas, *i.e.*, its Global Warming Potential,[35] is an important element to consider in deciding what strategies to adopt in responding to climate change.

Carbon dioxide will remain in the atmosphere, for 50-200 years. Methane, lasts for about 10 years, CFCs for 70-110 years, and nitrous oxide for 170 years. Ozone and aerosol particles last only a few weeks.[36]

The atmospheric lifetimes of GHGs are determined by their sources and sinks in the oceans, atmosphere and biosphere. Carbon dioxide, CFCs and nitrous oxide are removed slowly from the atmosphere. Thus, a reduction in emissions today will not result in an immediate reduction in the atmospheric concentrations of GHGs. In fact, it will take from decades to centuries before corresponding reductions in atmospheric concentrations will be realized.[37] The IPCC points out that even if all human-caused carbon dioxide emissions were halted in 1990, about half of the increase in carbon dioxide concentration caused by human activity would still be evident by the year 2100.[38] This is in contrast to some of the CFC substitutes and methane which have relatively short atmospheric lifetimes such that their atmospheric concentrations will correspond fully to changes in emissions within a few decades.[39]

The long atmospheric lifetimes of these GHGs is significant, from a policy point of view, because it means that whatever measures are taken to reduce their emissions will not reduce concentrations of greenhouse gases in the atmosphere for several decades. Maintaining concentrations of greenhouse gases in the atmosphere at current levels would, according to the

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[33]R.Churchill, *Controlling Emissions of Greenhouse Gases*, in INTERNATIONAL LAW AND GLOBAL CLIMATE CHANGE 148 (1991).

[34]*Id.*

[35]The concept of Global Warming Potential was developed to take into account the different lifetimes of the various greenhouse gases. It refers to the relative radiative effect (i.e. potential climate effect) of equal emissions of each of the GHGs. *See* IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xix.

[36]*Id.*, at 5-6.

[37]*Id.*, at xvii.

[38]*Id.*

[39]*Id.*

IPCC, require immediate reductions in the emissions of the longer-lasting gases of over 60 percent.[40]

Carbon Dioxide

Carbon dioxide, the most crucial of man-made greenhouse gases related to global warming, is produced by the burning of fossil fuels, the manufacture of cement, and changes in land use through large-scale deforestation, including burning and clearing land for agricultural purposes.

A large quantity of carbon dioxide has been released through human activities since the industrial revolution.[41] Worldwide consumption of fossil fuels from 1860 to 1949 has released 51 billion metric tons of carbon into the atmosphere. Moreover, the use of fossil fuel has accelerated to such an extent in the past four decades that carbon dioxide emissions from fossil fuel consumption between 1950 and 1987 totalled an additional 130 billion metric tons.[42] Land use changes, on the other hand, released another 60 billion metric tons of carbon dioxide since 1860.[43] Thus, in the period 1860-1987, the release of carbon dioxide resulting from human activity has amounted to an estimated 241 billion metric tons of carbon.[44]

Given the above picture, it can be concluded that the world energy system is responsible for more than half of the greenhouse effect, releasing annually into the atmosphere not only 21 billion tons of carbon dioxide but also substantial quantities of two other important greenhouse gases, methane and nitrous oxide.[45] Since carbon-containing fossil fuels provide almost four-fifths of the world's energy, and their use continues to grow by 3 percent annually, there is a clear demand to reverse this trend and gradually move the world away from its dependence on fossil fuels.[46]

Deforestation is likewise responsible for the global warming crisis. For example, it has been estimated that if deforestation were reduced to half its present rate in just four countries -- Brazil, Indonesia, Colombia, and

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[40] *Id.*

[41] According to the IPCC, the atmospheric CO_2 concentration, at 353 ppmv (parts per million by volume) in 1990, is now 25% greater than the pre-industrial (1775-1800) value of about 280 ppmv, and higher than at any time in at least the last 160,000 years. *See id.*, at 5.

[42] WORLD RESOURCES, *supra* note 21, at 13-14.

[43] *Id.*

[44] *Id.*

[45] *Id.*, at 7.

[46] *Id.*

Cote d'Ivoire, the total net carbon emissions from tropical forests would drop by more than 20 percent.[47] Indeed, it has been noted that preventing deforestation within their borders is by far the largest contribution that many developing countries can make to global climate stabilization, as well as to their own economic futures.[48]

These trends would be alarming enough if emission levels were holding steady, but they are growing exponentially as well -- at 3 percent annually in the case of carbon. Carbon dioxide is presently rising at about 1.8 parts per million by volume (ppmv) or 0.5% per year due to man-made emissions.[49] While it took 10 years for carbon emissions to increase from 2 to 3 billion tons, it took just six years for it to grow from 3 to 4 billion tons.[50] This growth in emissions has of course been fueled by other exponential growth rates, namely, those of population and economic output.

According to the IPCC, stabilizing concentrations at current levels would require an immediate reduction in global human-caused carbon emissions by 60-80 percent.[51]

Chlorofluorocarbons (CFCs)

The IPCC has estimated that the current atmospheric concentrations of man-made chlorofluorocarbons are about 280 parts per trillion by volume (pptv) for CCl_3F(CFC-11), 484 pptv for CCl_2F_2 (CFC-12), 60 pptv for $C_2Cl_3F_3$ (CFC-113) and 146 pptv for carbon tetrachloride (CCl_4).[52] In the recent past, the atmospheric concentrations of these halocarbons, except for CCl_4, have grown at annual rates of at least 4 percent, increasing more rapidly (on a percentage basis) than the other GHGs.[53]

Future emissions, however, will probably be negligible or eliminated altogether because of the steps that the international community has taken to contain CFC emissions in response to the problem of ozone depletion.[54] Still, because of their long atmospheric lifetimes, the

[47] *Id.*, at 58-59.
[48] *Id.*
[49] IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 5.
[50] WORLD RESOURCES, *supra* note 21, at 23.
[51] IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5 at 5.
[52] *Id.*
[53] *Id.*
[54] under an international agreement, production of chlorofluorocarbons, halons and most other substances that destroy the ozone shield is to be phased out by 1996 . See *Montreal*

atmospheric concentrations of some of the CFCs will continue to have an impact for at least the next century.[55] Moreover, some chemicals proposed as substitutes for CFCs could instead add to the danger of global warming for tens of thousands of years to come. Among possible alternatives to CFCs are fluorocarbons, which lack the chlorine atoms responsible for ozone destruction. But scientists warn that fluorocarbons may remain in the atmosphere for up to 50,000 years.[56]

In recent months, new findings about CFCs and their relation to ozone depletion have put into question their effectivity as greenhouse gases. In studies focusing on the indirect reactive effects of CFC emissions, scientists have found that CFCs deplete ozone in the lower and upper stratosphere. They have also found that lower stratosphere ozone reductions have a significant cooling effect that roughly offsets the warming effect from CFC radiative forcing. According to the IPCC, the depletion of ozone in the lower stratosphere in the middle and high latitudes causes a decrease in radiative forcing believed to be comparable in magnitude to the radiative forcing contribution of CFCs over the last decade or so.[57] This new finding suggests that CFCs in the aggregate may have no net Global Warming Potential.[58]

Methane

The current concentration of methane (CH_4) in the atmosphere is more than double its pre-industrial level.[59] Moreover, it is increasing at a rate of 0.015 ppmv, or 0.9% per year.[60] Methane has a Global Warming Potential of about 60 over a 20-year time frame. This means that within that period, one kilogram of methane will have about 60 times the global warming effect of one kilogram of carbon dioxide.[61]

Protocol on Substances that Deplete the Ozone Layer (as amended), September 16, 1987, 26 I.L.M. 1541 (entered into force January 1, 1989), hereinafter referred to as MONTREAL PROTOCOL.

[55]IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 5.

[56]W. K. Stevens, *Protecting Ozone Shield Called a Warming Risk*, New York Times, January 12, 1993, at C2.

[57]IPCC 1992 SUPPLEMENT, *supra* note 16, at 10.

[58]R.B. Stewart and J. Wiener, *The Comprehensive Approach to Global Climate Policy: Issues of Design and Practicality*, 9 ARIZ. J. INT'L & COMP. L. 83, 87 (1992).

[59]Current levels are at 1.72 ppmv compared to its pre-industrial value of 0.8 ppmv. See IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 5.

[60]*Id.*

[61]Leggett, *supra* note 3, at 45-46.

Rice paddies produce approximately 60 million tons of methane per year. This is about 16% of the total man-made emission of methane. Given that methane production from rice paddies is heavily dependent on temperature and soil moisture, and that increases generate large fluxes, a potentially large increase in methane emissions resulting from global warming is a serious problem. The problem is compounded by a scarcity of precise data on the rice paddies of the world as well as significant variations in the available data.[62]

The IPCC does not state conclusively whether net fluxes will increase or decrease in a warming world. Lashof projects that, on the basis of available data, methane emissions from rice fields will increase by more than 30 million tons per year.[63] However, the 1992 IPCC report indicates that while the rates of increase in the atmospheric concentrations of many greenhouse gases either continue to grow or remain steady, those of methane and some halogen compounds have slowed down. Some data also indicate that global emissions of methane from rice paddies may amount to less than previously estimated.[64]

Without mitigation measures, methane emissions are expected to increase from each source as increases in animal products and rice are required in order to feed the world population. Contemporary emissions from animals, rice, and animal waste could grow by about 40-60%, 50-60% and 30-40% respectively by the year 2025.[65] In order to stabilize concentrations at existing levels, an immediate reduction in human-caused emissions by 15-20 percent would be mandatory.[66]

Nitrous Oxide, Ozone and Aerosol Particles

The current concentration of nitrous oxide (N_2O) in the atmosphere, is 310 parts per billion by volume (ppbv), approximately 8 percent greater than in the pre-industrial period. It is increasing at an annual rate of 0.8 ppbv, or 0.25%. In order to stabilize concentrations at current levels,

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[62] *Id.*

[63] *See* D. A. Lashof, *The Dynamic Greenhouse: Feedback Processes That May Influence Future Concentrations of Atmospheric Trace Gases and Climactic Change*, 14 CLIMACTIC CHANGE 213 (1989).

[64] IPCC 1992 SUPPLEMENT, *supra* note 16, at 10.

[65] *Id.*, at 30.

[66] IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 5.

emissions must be reduced immediately by an amount equal to 70 - 80% of the increase since the pre-industrial period.[67]

It is more difficult to account for the contemporary increase in the atmospheric concentration of nitrous oxide than it is to account for the increases in carbon dioxide, CFCs and methane. It is believed, however, to be due to human activity. Agricultural practices are said to stimulate emissions of nitrous oxide from the soil. Combustion and biomass burning are also sources of emissions, but recent data suggest that the total annual flux from these sources is much less than previously thought.[68]

The atmospheric concentrations of ozone and aerosol particles cannot be measured with certainty. Because of their short lifetimes (a few weeks at the most), they are present in the atmosphere in highly variable concentrations.[69] At present, therefore, little effort has been made to include the control of ozone and aerosol particles in a comprehensive international strategy to deal with climate change. Most efforts have emphasized reductions in emissions of carbon dioxide and methane.[70]

III. UNCERTAINTIES IN THE SCIENCE OF CLIMATE CHANGE

It would seem that there is no reason for the world community to hesitate before taking immediate action to limit or reduce GHG emissions. The problem often cited by those who would oppose a comprehensive international response to global warming is that there continues to be great uncertainty, associated with current models and data, within the scientific community. There is much debate on the extent and impact of the warming. There is also uncertainty about the global and regional distribution of climate change resulting from global warming.

Criticism of Global Warming Scenarios

Most critics of immediate action on climate change emphasize the uncertainties of the climate models on which projections are based, and

[67]*Id.*

[68]*Id.*

[69]*Id.*, at 6.

[70]In the case of CFCs, the regulatory regime established by the Montreal Protocol is deemed sufficient to take care of ensuring that CFC emissions are reduced or eliminated altogether. *See* Montreal Protocol, *supra* note 54.

conclude that global warming is likely to have been over-estimated.[71] Suggesting that the rise in temperature over the past century has been relatively insignificant and within the natural range of the climate system, some critics conclude that radiative forcing due to the increase in atmospheric concentrations of GHGs is minor.[72] In fact, one skeptic claims that the temperature trend is towards cooling rather than warming .[73]

Some authors have pointed out the compensatory effects of other man-made emissions, observing that human activities not only enhance the greenhouse effect but also produce substances that can serve to counter or compensate for that effect.[74] For example, the cooling effect of aerosols from sulphur emissions may have offset a significant part of the greenhouse warming in the Northern Hemisphere during the past several decades.[75]

Others attack the conclusions of the IPCC from an energy use perspective. Professor Tor Ragnar Gerholm, Professor of Physics at the University of Stockholm in Sweden and a familiar figure in the ranks of global warming skeptics, chooses to attack the assumptions underlying projections for energy demand.[76] Gerholm argues that the assumed emissions scenarios are chosen on the basis of an energy demand and supply forecast that is grossly erroneous. In particular, he asserts that the projected increases of carbon emissions by industrialized countries under the Business-As-Usual Scenario are exaggerated.[77] At the very least, future patterns of energy use and other factors that determine GHG levels are characterized by great uncertainty. Projecting these factors over decades, which is required

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[71]*See* R. S. Lindzen, *Some Coolness Concerning Global warming*, 71 BULL. AM. METER. SOC. 288 and MARSHALL INSTITUTE, SCIENTIFIC PERSPECTIVES ON THE GREENHOUSE PROBLEM (1989); See also P. MICHAELS, SOUND AND FURY: THE SCIENCE AND POLITICS OF GLOBAL WARMING (1992).

[72]Michael B. McElroy, *Changes in Climates of the Past: Lessons for the Future* in CONFRONTING CLIMATE CHANGE 65, 79 (Irving M. Mintzer ed., 1992).

[73]According to atmospheric scientist, Jonathan Kahl, the Arctic is one place where the temperature should increase the most and soonest if the Earth were truly warming up. But his analysis of 27,000 temperature readings shows a statistically significant temperature trend toward cooling. *Scientist Counters Greenhouse Effect*, UPI, November 23, 1992, available in LEXIS, Nexis Library, UPI File.

[74]Patrick J. Michaels and David E. Stooksbury, *The Failure of the Popular Vision of Global Warming*, 9 ARIZ. J. INT'L & COMP. L. 53, 69 (1992).

[75]This phenomenon was recognized in the 1990 IPCC report and some progress has been made in quantifying its effects. *See* IPCC 1992 SUPPLEMENT, *supra* note 16, at 10.

[76]See *Global Warming: Opec's Counter-attack*, Energy Economist, July, 1992, available in LEXIS, Nexis Library, Energy Economist File.

[77]*Id.*

for policy prescription, will probably be as difficult and as uncertain as attempting to predict climate as a function of increases in GHG atmospheric concentrations.[78]

Identifying the Certainties and the Uncertainties

Notwithstanding the uncertainties, there are some generally accepted facts about climate change and global warming. First, although there is much argument about the exact climatic effects of the rapid release of greenhouse gases into the atmosphere, there is no dispute that the greenhouse phenomenon itself -- the trapping of heat by atmospheric gases -- is a reality.[79] Second, the atmospheric concentrations of greenhouse gases are rising at unprecedented rates which, in many cases, show signs of accelerating. No scientist disagrees that we are altering our atmosphere very rapidly. Historically, changes in greenhouse gas concentrations are closely related with changes in the Earth's surface temperature.[80] The IPCC states:

> We are certain of the following: (1) there is a natural greenhouse effect which already keeps the Earth warmer than it would otherwise be; (2) emissions resulting from human activities are substantially increasing the atmospheric concentrations of the GHGs . . . These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. The main GHG, water vapour, will increase in response to global warming and further enhance it.[81]

The uncertainty is in the magnitude of change as a function of the level, and the rate of increase, of GHGs.[82] While the increase in atmospheric greenhouse gases is probably the principal external factor, this still leaves alternative explanations of the recent global warming. Hence,

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[78]George W. Rathjens, *Energy and Climate Change*, in PRESERVING THE GLOBAL ENVIRONMENT 154, 163 (Jessica Tuchman Mathews ed., 1991).

[79]The greenhouse effect is undisputed. It is well understood and based on established scientific principles. As the IPCC explains: "We know that the greenhouse effect works in practice for several reasons:Firstly, the mean temperature of the Earth's surface is already warmer by about 33°C than it would be if the natural greenhouse gases were not present . . . Secondly, we know [that] the composition of the atmospheres of Venus, Earth and Mars are very different, and their surface temperatures are in general agreement with [the] greenhouse theory. Thirdly, measurements from ice cores going back 160,000 years show that the Earth's temperature closely paralleled the amount of carbon dioxide and methane in the atmosphere." *See* IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xiv.

[80]WORLD RESOURCES, *supra* note 21, at 19-20.

[81]IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xi.

[82]Rathjens, *supra* note 78, at 163.

all that can be concluded about the observed temperature increases is that it is qualitatively consistent with the greenhouse hypothesis. On the basis of rising temperatures alone, scientists are unable to either prove or disprove the hypothesis.[83] Rathjens explains why:

> Although substantial efforts have been made to model climate, the problems are formidable, and the results so far are anything but definitive. There are many nonlinear processes, competing effects, and feedback loops involved, so that great uncertainty attaches to attempts to estimate the magnitude of effects and, in some instances, even the sign.
>
> "The problem is particularly complicated because so much of the earth's surface is covered by water and because, at the temperatures that obtain on the earth, water is present in significant quantities in all three phases: gas, liquid, and solid. The formation, dissipation, and characteristics of clouds are consequently important determinants of climate and so, too, is the transfer of heat and CO_2 within the oceans, and between the oceans and the atmosphere. Unfortunately, some of the processes are poorly understood.[84]

The IPCC Scientific Working Group admits that there are many uncertainties in its predictions particularly with regard to

> the timing, magnitude and regional patterns of climate change, due to our incomplete understanding of: (1) sources and sinks of greenhouse gases, which affect predictions of future concentrations; (2) clouds, which strongly influence the magnitude of climate change; (3) oceans, which influence the timing and patterns of climate change; and (d) polar ice sheets which affect predictions of sea level rise.[85]

The IPCC noted that while these processes are already partially understood, "the complexity of the system means that we cannot rule out surprises."[86] IPCC confidence in its regional estimates, for example, is low.[87] Indeed, the Framework Convention on Climate Change recognizes these many uncertainties in predictions of climate change, particularly with regard to timing, magnitude and regional patterns.[88]

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[83]Tom Wigley et. al., *Indices and Indicators of Climate Change*, in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 85, 92.

[84]Rathjens, *supra* note 78, at 159-160.

[85]IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xii.

[86]*Id.*

[87]*Id.*, at xxiii.

[88]*See* Preamble, *Framework Convention on Climate Change*, *supra* note 6.

Among the scientific uncertainties surrounding the climate change issue, three problems particularly stand out. These are (1) the role of feedback mechanisms in the climate system; (2) the issue of whether the rise in global temperatures can now be attributed to the enhanced greenhouse effect; and (3) the limits of the climate models used to predict future climatic changes.

The Role of Feedback Mechanisms

The uncertainties in the science of climate change are primarily due to feedback in the climate system. Feedback mechanisms are crucial to understanding the climate models on which projections of future climate rely. They are critical in assessing the risks associated with climate change.

A feedback mechanism is "a process in which a force that affects a system is itself made stronger or weaker by the reaction of that system".[89] Positive feedback[90] acts to amplify the initial warming while negative feedback reduces it. Negative feedback can reduce the warming but cannot produce a global cooling.[91]

Clouds are an example of a feedback mechanism. Changes in cloud cover and their climatic consequences are probably the largest uncertainty in predicting the magnitude of global warming. Through changes in such characteristics as to their amount, altitude and water content, clouds can act as both positive and negative feedback.[92] Thus, high clouds, which are cooler, can enhance the greenhouse effect since they trap upward-going thermal radiation from the warmer earth surface and lower atmosphere, while emitting less energy to space. The opposite is true for low clouds.[93]

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[89]Paul J. Crutzen and Georgii S. Golitsyn, *Linkages Between Global Warming, Ozone Depletion, Acid Deposition and Other Aspects of Global Environmental Change* in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 15, 18.

[90]Snow and ice are examples of positive feedback. Crutzen and Golitsyn describe how: "Warmer temperatures melt the snow and ice cover, which means that the darker land surface underneath is revealed; this darker surface absorbs more solar energy, causing still further temperature increases. In this example of positive feedback, the warming temperature (reinforces) itself. The temperature change, as a result, will be more dramatic than anyone would ordinarily expect. This is the main reason for the stronger-than-average climate warming at high latitudes. In general, when positive feedback takes place, it exacerbates the effect of the new force, and makes it stronger". *See id.*

[91]*See* IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xxxvii.

[92]Leggett, *supra* note 3, at 35.

[93]Crutzen and Golitsyn, *supra* note 89, at 18-19.

Scientific understanding of the role of clouds in the climate process is unfortunately inadequate. According to Hoffert, this understanding is so incomplete that, "by itself, it produces a factor-of-three uncertainty in future temperature changes."[94] This means that the range of prediction is so uncertain that the top limit is three times the bottom limit. As a result, we can be no more specific than to predict a rise of between 1.5 and 4.5°C for an atmospheric CO_2 doubling.

There are more than 20 known potential feedback mechanisms,[95] all of which are difficult to quantify. In the case of some feedback, scientists cannot even state whether they will be positive or negative. As a result, most feedback are presently omitted from even the most sophisticated climate models.[96] For example, scientists do not know if changes in cloud cover will accelerate or depress global warming. Hence, the rise in projected future temperature depends on how clouds are simulated in the computer models.[97]

Scientific knowledge of many of the feedback mechanisms, while incomplete to allow their quantification in models, is, however, adequate to permit important qualitative conclusions. The most significant of these is that majority of the known climate feedback, at least qualitatively, are recognized to be positive. This is often overlooked by those who hold up the uncertainties of climate change as a reason for delaying policy responses.[98] Indeed, as climate warms, these feedback, according to the IPCC, will lead to an overall increase, rather than decrease, in natural GHG abundances.[99] For this reason, climate change is likely to be greater than the estimates the IPCC has given.

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[94]See Martin I. Hoffert, *Climate Sensitivity, Climate Feedbacks and Policy Implications* in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 33, 34.

[95]*See* Leggett, *supra* note 3, at 3.

[96]In fact, some possible "wild card" feedback have almost certainly been left out simply because no one has thought of them yet. *See* Hoffert, *supra* note 94, at 51.

[97]Leggett, *supra* note 3, at 51.

[98]*Id.*

[99]An illustration of a positive feedback gone wild is the runaway greenhouse of Venus, where vaporized greenhouse gases apparently caused progressively more warming until all surface, including water and carbon dioxide, were driven to the gaseous phase. Such a life-threatening runaway greenhouse effect, caused by anthropogenic greenhouse emissions, is however unlikely on Earth. *See* Hoffert, *supra* note 89, at 39.

The Detection Issue

Global-mean temperature has increased by 0.3-0.6°C over the past 100 years, a rise which concurs with the theoretical projections of climate models. However, it remains to be verified that the observed temperature rise (or part of it) can be ascribed to the enhanced greenhouse effect. A rising global-mean temperature alone is not sufficient to establish GHG-induced climate change. This is the detection issue: "Have we detected changes in climate that can, with high statistical confidence, be attributed to the enhanced greenhouse effect associated with increasing trace gas concentrations?"[100]

A change in climate is also not sufficient to prove that global warming has begun. A climatic change must be both identified and attributed, at least in part, to the enhanced greenhouse effect. Detection demands that the observed changes in climate are consistent with detailed model predictions of the enhanced greenhouse effect, illustrating an understanding of the cause or causes of the changes. While analyses show a statistically significant warming trend over the past 100 years, it is not definite that this warming trend is due to the enhanced greenhouse effect. In fact, there is evidence that changes of similar magnitude and rate have occurred prior to the twentieth century. Since these changes were certainly not attributable to the enhanced greenhouse effect, it is possible that the recent climate changes merely represent a natural, long-time scale fluctuation.[101]

The detection problem has been described in terms of the concepts of "signal" and "noise". The signal is "the predicted time-dependent climate response to the enhanced greenhouse effect", while noise is any change in climate that is not due to the enhanced greenhouse effect. For global warming to be detected, the observed signal must be large relative to the noise. Moreover, the detected signal must be attributed to the enhanced greenhouse effect, *i.e.* it should be one that is specific to this particular cause.[102] However, as a result of the natural variability of climate, there are substantial obstacles to proving whether or not a particular event, or set of events, can be imputed to the enhanced greenhouse effect. The rise in global average temperatures is not a particularly good signal in this sense because there are many possible causes of such warming. Thus, the IPCC concludes that

[100]IPCC 1992 SCIENTIFIC ASSESSMENT, *supra* note 5, at 245.
[101]*Id.*
[102]*Id.*

> despite great limitations in the quantity and quality of the available historical temperature data, the evidence points consistently to a real but irregular warming over the last century. A global warming of larger size has almost certainly occurred at least once since the end of the last glaciation without any appreciable increase in GHGs. Because we do not understand the reasons for these past warming events it is not yet possible to attribute a specific proportion of the recent, smaller warming to an increase of GHGs.[103]

Detecting the enhanced greenhouse effect is critical for validating models of the global climate system. Until GHG-induced changes are identified in the observed climate record with high confidence, reservations about model validity will persist, and doubts will remain about even the most general predictions of future climatic change. However, even when detection has occurred, uncertainties regarding the magnitude and spatial details of future changes will still remain.[104]

In recent years, phenomena predicted to characterize a warming world have been observed. Dr. James Hansen, who suggested the possibility that the 1988 drought was a signal of global warming, testified before the U.S. Congress in 1988 that "we can ascribe with a high degree of confidence a cause and effect relationship between the greenhouse effect and the observed warming of around 0.5°C in mean global temperature this century."[105]

Other scientists have since concurred with Hansen that recent climatic changes are signal, or physical manifestations of global warming. It has been said that "the heat and drought that have afflicted North America and other regions of the Earth in recent years are consistent with the predictions of a global warming trend."[106] They also mention reports of "increasing depth to permafrost in the Alaskan and Canadian Arctic, increase in the average temperature of Canadian lakes, decline in the annual maximum extent of sea ice surrounding Antarctica and the Arctic, and the decline of glaciers in Europe and elsewhere."[107] However, because of the historical variability of climate, this evidence can still be considered as

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[103] *Id.* at 199.

[104] IPCC, Houghton, 245.

[105] *See* Greenhouse Effect and Global Climate Change: Hearing Before the Senate Comm. on Energy and Natural Resources, 100th Cong., Ist Sess. 44 (1988), Prepared statement of Dr. James Hansen, Director, NASA Goddard Institute for Space Studies.

[106] *See*, for example, Richard A. Houghton & George M. Woodwell, *Global Climactic Change*, SCI. AM., April 1989 at 36, 38.

[107] Leggett, *supra* note 3, at 16.[]poffvf fdds sehggjygyu6

merely circumstantial rather than firm. The observed climate changes are still within the statistical ranges of natural variability. This means that nothing definitive can yet be proven about future climate change.[108]

One reason why it is extremely difficult to find climate changes which can be attributed to the enhanced greenhouse effect is that these events take place on a regional, or smaller, spatial scale. Usually, "the smaller the scale, the lower the signal-to-noise ratio, and thus the more difficult it is to detect the influence of the greenhouse effect".[109]

An example is the biological indicator that is coral bleaching.[110] This has been attributed by some to an increase in marine temperatures. Even if ocean warming were the cause of coral bleaching, scientists cannot yet conclude that the global-mean observed ocean warming can be ascribed to the greenhouse effect, so that to impute a regional change to this specific cause is impossible.[111]

Detection is not a simple yes-or-no issue. It entails the steady accumulation of evidence supporting model predictions which, coupled with refinements in the models themselves, will boost confidence in them and gradually narrow the scientific uncertainties. The IPCC states:

> detection with high confidence is unlikely to occur before the year 2000 under the BAU scenario when a further 0.5°C warming (or 1°C since the late 19th century), chosen as the threshold for detection, is attained. Detection would be reached sometime between 2002 and 2047. If stringent controls are introduced to reduce future GHG emissions, and if the climate sensitivity is at the low end of the range of model predictions, then it may well be into the 21st century before we can say with high confidence that we have detected the enhanced greenhouse effect.[112]

To conclude, the inability to detect the signs of global warming at present is not a reason for complacency. As the IPCC puts it "The fact that we are unable to reliably detect the predicted signals today does not mean

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108Irving M. Mintzer, *Living In A Warming World* in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 1, 2.

109Wigley *et al*, *supra* note 83, at 95.

110Coral bleaching has been identified as a "biological canary" - - a life form which integrates different effects to serve as an early indicator of larger and more extensive changes, like the canary carried into mines so that it will faint first when air becomes short. Other types of biological canaries may also be identified in the future. *See id.*

111*Id.*

112IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 253.

that the greenhouse theory is wrong, or that it will not be a serious problem for mankind in the decades ahead."[113]

The Limits of Modelling

There are two techniques of predicting future climate: (1) the Analogue Method, which attempts to project future climate change from reconstructions of past climates using paleoclimatic data, and (2) the use of General Circulation Models,[114] which allow scientists to consider simultaneously interacting physical processes making up the climate system. General Circulation Models are powerful tools whose objective numerical solutions enable climatologists to examine the nature of both past and possible future climates under different conditions. Unfortunately, even though this is critical for accuracy in projecting climate change, only a few models linking all the major elements of the climate system in a comprehensive way have been developed.[115]

The climate system, as earlier described, is determined by feedback from processes involving ice, clouds, water vapour, ocean circulation, terrestrial and marine life. It is "a set of closely coupled, non-linear systems whose interactions are very difficult to simulate in detail using mathematical equations."[116] Hence, despite their complexity,[117] climate models are incapable of predicting with confidence the response of climate to increased concentrations of GHGs. Models, like all mathematical representations of complex systems, are not as comprehensive as the world they try to represent. Climate models only give us a rough estimate of the true "signal" of climatic response to GHG forcing. A model should be viewed as a "dirty window" through which we look to try to isolate the signals that we seek in our observations.[118]

Assessing the utility of model predictions requires validating them against the observed climate, past and present.[119] To judge whether the

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[113]*Id.*, at 243.

[114]*Id.*, at 80. *See* also note 17.

[115]*Id.*, at 89.

[116]McElroy, *supra* note 72, at 66.

[117]The most powerful of the models used to simulate the climate system are "as complex as the models used to represent the explosion of nuclear weapons." Moreover, these models are run on the world's largest supercomputers. See Schneider, *supra* note 25 at 69.

[118]Wigley *et al*, *supra* note 83, at 88.

[119]For a full account of how scientists are trying to validate climate models, see IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at 97-130 (Section 4 of the Report).

projections of future global warming may reasonably be trusted, it is necessary to study the climate record since accurate and thorough reconstructions of past climate conditions afford credible estimates of future patterns of climate changes.[120]

While most scientists concur that modelling is the most scientifically acceptable approach to resolving the uncertainties of climate change predictions, such a resolution may be decades away. Hence, studying the paleoclimatic record has become an attractive semi-empirical approach that may provide an alternative path to resolving uncertainties arising from the limits of climate models. Indeed, initial analysis of paleoclimatic data favors the hypothesis that widespread or regional climate change can occur quite rapidly.[121]

In conclusion, it must be said that the unequivocal detection of the enhanced greenhouse effect is not probable for a decade or more.[122] A decade or two is necessary before scientific study will succeed in narrowing the wide range of uncertainty surrounding the climate change issue. Progress will be contingent on several vital experiments, many of which will take about a decade in duration, and the development of new technologies for space-based observation and numerical computation.[123]

IV. DEALING WITH SCIENTIFIC UNCERTAINTY

With significant uncertainties characterizing the science of climate change, the question before the international community is how to respond to the problem. One of the most difficult aspects of this issue is that decisions

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[120]The air trapped within pockets of ice in the coldest places on earth where snow never melts, is a continuous, permanent record of the contents and behavior of the earth's atmosphere. With the development of new analytic methods, this glacial record has become a natural archive, among others, of past climate conditions. In some areas of Greenland and the Antarctic, a continuous period of more than 100,000 years has been recorded, with the longest such record analyzed to date -- a record covering 160,000 years -- taken from ice core samples drawn at Vostok Station, Antarctica. New ice cores are now being drilled in Central Greenland that could result in records as long as 200,000 years. See Hans Oeschger and Irving M. Mintzer, *Lessons from the Ice Cores: Rapid Climate Changes During the Last 160,000 Years* in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 55-56.

[121]*Id.*, at 63.

[122]IPCC 1990 SCIENTIFIC ASSESSMENT, *supra* note 5, at xii.

[123]*Id.*, at 315. The IPCC action plan to reduce these uncertainties is laid out in pp. 311-328 of IPCC 1990 SCIENTIFIC ASSESSMENT. *See* also Articles 5 and 9 of fs]\the Framework Convention on Climate Change which provides the procedures and mechanisms through which the international community can resolve these uncertainties.

must continue to be made and actions taken in the face of great scientific and economic uncertainty.[124] On one hand, the possibility of social, political and environmental damage as a result of climate change argues for measures that would limit the rate of climate change. On the other hand, taking action now in spite of the uncertainties would not only have a considerable impact on the world economy but would also lead to the possibility of establishing inadequate, or worse, incorrect regulatory mechanisms. It is obvious that whether the decision be to wait or to act now, the stakes are high.

Deciding whether to act now or to wait until the uncertainties are reduced is a matter of weighing the costs and benefits of either policy. Both policy alternatives are characterized by costs and benefits. If the policy were to wait, all that would need to be done now is to intensify scientific research on climate change, but the cost would be the additional harm that occurs in the meantime. On the other hand, if the international community were to take immediate policy actions to reduce or stabilize GHG emissions, the advantages would be the benefits of earlier implementation but possibly at the price of adopting inappropriate policies.[125]

This is a typical dilemma in environmental policy-making, whether in the domestic or international arenas. Environmental agreements are distinguished from many other types of agreements by the central role of scientific evidence. The importance of scientific evidence imposed conflicting demands on the negotiation process: the parties require sufficient data to comprehend the problem and to develop workable solutions, but they may need to act quickly to prevent the problem from worsening or becoming irreversible. Since scientific evidence is always somewhat uncertain, and because research is expensive and time-consuming, the international community faces a dilemma: to act in the face of uncertainty or not to act at all. Moreover, failure to resolve this dilemma is often equivalent to inaction. Elliott describes the difficulty of resolving the dilemma between acting and waiting:

> Either choice makes us uncomfortable. Acting may be burdensome or threaten powerful interest groups, but waiting to act can also make us uncomfortable. Like many other environmental decisions, decisions to stay our hand to await more information force us to confront the existential terror of an unknown future. We can never be certain whether the new information

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[124]Nancy G. Maynard, *Science: The Basis for Action on Global Change*, 9 ARIZ. J. INT'L & COMP. L. 35 (1992).

[125]E. Donald Elliott, *Global Climate Change and Regulatory Uncertainty*, 9 ARIZ. J. INT'L & COMP. L. 259, 261 (1992).

> that will develop if we wait will outweigh the harm that occurs in the meantime.[126]

In the climate change issue, calculating the costs and benefits of either policy is complicated by the fact that it is impossible to avoid having to balance benefits that are very uncertain against costs that seem so certain.[127]

The problem then is finding the basis for making the decision. This requires (1) comparing and balancing the costs and benefits of acting and waiting as policy options; (2) identifying the corresponding legal principles which are relevant in resolving the dilemma posed by uncertainty; and (3) recognizing the political and institutional process through which the balancing of costs and benefits and the application of legal principles will be pursued.

Acting Versus Waiting: Balancing Costs and Benefits

In dealing with the scientific uncertainties surrounding an environmental issue, the question is always "whether a decision in the future is likely to be better than a decision today by an amount sufficient to compensate for the delay."[128] Deciding to act immediately or to wait should be based on the capacity to anticipate changes in the balance of available information that is likely to affect the decision substantially. Simultaneously, policy-makers must calculate the costs (or benefits foregone) that are unavoidably incurred while waiting.[129] Thus, the appropriate criterion for resolving scientific uncertainty depends on the nature of the problem and the scientific uncertainties surrounding it.

Applied to the climate change issue, the question that needs to be asked is whether the international community can expect "many significant new pieces of information that fundamentally change or challenge prevailing theories."[130] If new data will only confirm what is already known about climate change, a policy of waiting would probably be unjustified as additional data will only duplicate existing knowledge. But if the state of the science of climate change particularly the nature of the

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[126]*Id.*, at 263-264.
[127]Rathjens, *supra* note 78, at 172-173.
[128]Elliott, *supra* note 125, at 263.
[129]*Id.*, at 263-264.
[130]*Id.*

uncertainties surrounding it, is such that it is still undergoing vital modifications, a policy of waiting is probably desirable.[131]

Elliot distinguishes between two kinds of uncertainty in environmental policy-making. He argues that resolving technical uncertainty is only the first step.[132] He says that this refers to "such things as debates among scientists about whether a particular environmental problem is real." The source of substantial uncertainty is the matter of "deciding what our policy response to a problem should be." This Elliot terms "regulatory uncertainty", the resolution of which requires a continuing process of evaluating the probable risks and benefits of immediate action against the probable risks and benefits of waiting while we obtain more information.[133]

Applying the above criterion, Elliott concludes that a policy of waiting is appropriate for the climate change issue. First, the state of the science of climate change is such that "it is still experiencing fundamental changes that would be significant for designing regulatory programs."[134] Second, Elliott warns against the danger of early regulation. He observes

> By regulating too soon we may not only regulate the wrong thing, but we may regulate in the wrong way. To be more precise, it may be that if we had waited a little while, we would have developed regulatory tools and techniques that are better by an amount that more than compensates for the harm that comes about in the meantime.[135]

Others, argue, however, that while climate change is a young science many aspects of which are uncertain, this provides no excuse for years of delay. They point out that if the international community waits until detailed regional climate predictions are possible, it will be too late to avert disaster. The argument is that societies already invest in many areas, such as defense programs, to protect against uncertain but potentially dangerous threats. Investing in strategies to slow down global warming is akin to obtaining insurance against disasters that have far greater odds of

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[131]*Id.*

[132]According to Elliott, In the conventional view, delay in taking regulatory action is justified only until a sufficient 'scientific consensus' about the problem is reached. Once such a consensus is reached, it is thought to be important to 'do something' as quickly as possible to deal with the problem." *See id.*, at 259-260.

[133]*Id.*

[134]*Id.*, at 264.

[135]*Id.*

occurring than most of the events for which insurance policies are usually bought. Indeed, if nations delay actions in an elusive quest for scientific certainty, the risks and costs could rise at an unacceptable rate.

The truth is that scientists can never give the absolute and definitive answers politicians and businessmen want on whether or not to take action on global climate change. Remaining uncertainties on global warming should however render more, rather than less, cause for concern and immediate action. For scientific uncertainty is a double-edged sword: current projections (which predict a few degrees warming by the middle of the next century) might just as well be underestimates as overestimates.[136] At present, it is impossible to know, which, if either, of these scenarios will transpire.

The time lags which characterize the climate change issue -- the fact that it could a decade or more before the scientific uncertainties are resolved, coupled with the long lifetimes of some greenhouse gases -- also militate against a policy of waiting. Because of these time lags, a policy of waiting could mean a commitment to global warming. Effectively then, such a policy may result in consequences that are partially or wholly irreversible with potentially catastrophic consequences. A policy of waiting, in this sense, would appear to be an unpromising regulatory strategy.[137]

Arguing for a policy of immediate action does not mean ignoring or sweeping aside the scientific uncertainties of climate change. It does not imply an acceptance *in toto* of the so-called "doomsday" version of global warming. Rather, a policy of immediate action must be determined by the state of the science of climate change and the uncertainties which surround it. Hence, whatever regime is adopted must be flexible enough to adjust to changes in the science. While there is always the danger that early regulation may result in the institutionalization of what could ultimately be incorrect policies, this danger is less in the international setting than in

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[136]An analogous case is the gross underestimation by models of the stratospheric ozone depletion due to the use of CFCs prior to the discovery of the "ozone" hole. Although stratospheric ozone depletion had been predicted to occur, they were originally calculated to be of the order of 1% per decade. In fact what has been observed is ozone depletion many times larger for extensive regions at high and middle latitudes. With this sad experience in fresh memory, we should be extremely cautious in assuming that future climate changes will be only a fraction as bad as current climate models predict. See Crutzen & Golitsyn, *supra* note 89 at 30. See also RICHARD ELLIOT BENEDICK, OZONE DIPLOMACY Chapter 2 (1991).

[137]JOSEPH G. MORONE and EDWARD J. WOODHOUSE, AVERTING CATASTROPHE 4 (1986).

the domestic arena.[138] This is because the dynamics of international policymaking are driven less by legislated rules and more by political considerations. Moreover, recent developments in international environmental law, such as the ozone negotiations, illustrate the possibility of establishing flexible legal regimes.

A final word must be said about scientific uncertainty and the options of acting and waiting in the context of the international legal process. It must be noted that the usual period of time which lapses from the point a treaty or protocol (with specific policies) is signed and adopted to the time it comes into effect (when enough States have ratified it) would probably be enough time for new information on climate change to present itself for consideration. Protocols to the Framework Convention on Climate Change which are expected to incorporate specific strategies on reducing or stabilizing GHG emissions could, at the earliest, come into effect within four to six years.[139] While this period of time is probably insufficient to resolve all the scientific uncertainties in climate change, the picture would probably be much clearer at that time than it is today. Hence, all talk about waiting or acting could be immaterial in that many of the scientific uncertainties could be understood better, if not resolved, while the negotiations continue on what stabilization measures to take. The important thing is that states begin negotiating in earnest now, that various policy approaches already be considered, debated, and decided upon, and that steps be taken to put these strategies into place. In the meantime, while these negotiations continue, the science will hopefully become clearer.

V. AN INTERNATIONAL NORM FOR RESOLVING UNCERTAINTY: THE PRECAUTIONARY PRINCIPLE

There is an emerging international norm that could be used to decide how the world community can proceed in the face of the uncertainties

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[138]Elliot observes that "environmental policies, once established, have proved remarkably resistant to fundamental change. The failure of a statute to achieve its goals often becomes an argument for more of the same,rather than an occasion for fundamental reassessments of approaches to the problem." *See* Elliott, *supra* note 125, at 265.

[139]The Framework Convention will probably come into effect by late 1994 when it obtains a sufficient number of ratifications. As of February, 1993, it had been ratified by 8 out of the 160 countries which signed the treaty during the United Nations Conference on Environment and Development held in Rio in June 1992.

surrounding climate change. This is the Precautionary Principle[140] which states that

> Environmental measures must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.[141]

Gro Harlem Brundtland, Prime Minister of Norway and Chairperson of the World Commission on Environment and Development (WCED) explains the necessity of the principle :

> I will add my strong support to those who say that we cannot delay action until all scientific facts are on our tables. We already know enough to start to act -- and to act more forcefully. We know the time it takes from decision through implementation to practical effects. We know that it costs more to repair environmental damage than to prevent it. If we err in our decisions affecting the future of our children and our planet, let us err on the side of caution.[142]

The origins of the precautionary principle lie in concepts of German domestic law, notably the German law Vorsorgeprinzip, which some consider as the most important principle of German environmental policy.[143] Internationally, the precautionary principle was first invoked a decade ago when concern was mounting over the state of the Shallow Wadden Sea which borders the North Sea coast of the Netherlands, Germany and Denmark.[144]

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[140]For an overview of how this principle has evolved, *see* James Cameron and Juli Abouchar, *The Precautionary Principle: A Fundamental Principle of Law and Policy for the Protection of the Global Environment* 14 B.C. INT'L & COMP. L. REV. 1; *See* also Per L. Gundling, *The Status in International Law of the Principle of Precautionary Action* in THE NORTH SEA: PERSPECTIVES ON REGIONAL ENVIRONMENTAL COOPERATION 23-30 (D. Freestone and T. Ijlstra eds., 1990).

[141]The Bergen Declaration on Sustainable development (1990), reprinted in INTERNATIONAL LAW AND CLIMATE CHANGE, *supra* note 33, at 344.

[142]Gro Harlem Brundtland, Keynote Speech, Opening Session, Conference on "Action for a Common Future", in Bergen, Norway (8 May 1990), cited in Cameron and Abouchar, *supra* note 142, at 1.

[143]In practice, the environmental policies of the German Government balance precaution and economic considerations in a what is known as the cooperation principle, a precautionary policy balanced against economic considerations. This has resulted in environmental strategies that are in fact less than precautionary. *See id.*, at 6.

[144]David Freestone, *The Precautionary Principle* in INTERNATIONAL LAW AND GLOBAL CLIMATE CHANGE, *supra* note 33, at 21.

The first express reference to the precautionary principle is in the 1987 London Declaration, issued by the North Sea states at the end of the Second International North Sea Conference. These states declared that

> VII . . . in order to protect the North Sea from possibly damaging effects of the most dangerous substances, a precautionary approach is necessary which may require action to control inputs of such substances even before a causal link has been established by absolutely clear scientific evidence.[145]

Putting this principle into effect, the North Sea states also agreed to

> XVI.1. accept the principle of safeguarding the marine ecosystem of the North Sea by reducing pollution emissions of substances that are persistent, toxic and liable to bioaccumulate at source . . . This applies especially when there is reason to assume that certain damage or harmful effects on the living resources of the sea are likely to be caused by such substances, even where there is no scientific evidence to prove a causal link between emissions and effects.[146]

Since the 1987 London Declaration, the precautionary principle has become increasingly recognized in international environmental law. It has been advocated by many governments and many leading policy makers, including the United Nations Environment Programme (UNEP), the Intergovernmental Panel on Climate Change and the World Commission on Environment and Development.[147] This has led one scholar to make the following observation:

> The speed with which the precautionary principle has been brought on to the international agenda, and the range and variety of international forums which have explicitly accepted it within the recent past, are quite staggering. There is no question that it is now the most important new policy approach in international environmental cooperation.[148]

The principle was accepted by the UNEP at the Fifteenth Session of its Governing Council on May 25, 1989. The Governing Council called on all states to adopt the precautionary principle as the basis of their policy with regard to the prevention and elimination of marine pollution. It recognized that "waiting for scientific proof regarding the impact of pollutants

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[145]Second International Conference on the Protection of the North Sea, Ministerial declaration (London, November 1987). *See id.*, at 22.

[146]*Id.*

[147]Churchill, *supra* note 33, at 151.

[148]Freestone, *supra* note 146, at 36.

discharged into the marine environment may result in irreversible damage to the marine environment and in human suffering."[149]

In May 1990, Ministers from 34 countries issued the Bergen Declaration on Sustainable Development, paragraph 7 of which stated: "In order to achieve sustainable development, policies must be based on the precautionary principle."[150] This was echoed in October 1990 at a Ministerial Conference on the environment held in Bangkok by the UN Economic and Social Commission for Asia and the Pacific (ESCAP). In that conference, the delegates issued a Declaration on Environmentally Sound and Sustainable Development in Asia and the Pacific, saying that they "believe that in order to achieve sustainable development, policies must be based on the precautionary principle."[151]

The preamble of the Montreal Protocol likewise endorses the precautionary principle:[152] "The parties are determined to protect the ozone layer by taking precautionary measures to control equitably total global emissions of substances that deplete it."[153]

Finally, the Rio Declaration on Environment and Development, signed by states attending the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil in May 1992, also recommends the precautionary principle. Principle 15 of the said declaration reads:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall

[149]UN General Assembly. Official Records: Forty-fourth Session, Supplement No. 25 (A/44/25), p. 152.

[150]Bergen Declaration on Sustainable Development, *supra* note 143.

[151]Declaration on Environmentally Sound and Sustainable Development in Asia and the Pacific, Report of UN ESCAP Minsiterial Conference on the Environment, Bangkok, 15-16 October 1990, Appendix 2, pp. 8-10.

[152]Cameron and Abouchar notes that in practice, the Montreal Protocol does not really advance the principle since it fails to regulate ali stages of the ozone-depleting substance's life cycle. The Montreal Protocol merely controls but does not eliminate or prevent the dangerous emissions of CFCs into the ecosystem. See Cameron and Abouchar, *supra* note 142, at 17-18.

[153]See Preamble, Montreal Protocol, *supra* note 54.

> not be used as a reason for postponing cost-effective measures to prevent environmental degradation.[154]

The acceptance of the precautionary principle demonstrates the progress of international environmental law from the Trail Smelter Case, the so-called grandfather of international environmental law, which established the rule requiring "clear and convincing evidence" of serious injury. Indeed, the continuing endorsement of the principle "may well have reached the point at which it has begun to change the existing purely preventive requirements of due diligence and foreseeability."[155] At any rate, if current trends continue, the precautionary principle may soon be a general requirement of international environmental law, becoming part of international customary law.[156]

The precautionary principle lays down a stricter form of preventive environmental policy, going beyond repair of damage or prevention of risks. Application of the principle demands "reduction and prevention of environmental impacts irrespective of the existence of risks."[157] This means that environmental impacts are reduced or prevented even before the threshold of risks is reached. Measures must be implemented to make sure that the loading capacity of the environment is not exhausted. Moreover, the precautionary principle demands action "if risks are not yet certain but only probable, or even less, not excluded."[158]

The precautionary principle is a norm which ensures that a substance or activity posing a threat to the environment is precluded from harming the environment, even without conclusive scientific proof relating that particular substance or activity to environmental damage. Its design is to encourage, perhaps even oblige, policy-makers to appraise the probable detrimental effects of human activities on the environment before those activities are pursued.[159] Its application covers a wide spectrum of possible obligations and actions.

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[154] Rio Declaration on Environment and Development, Adopted at Rio de Janeiro, 14 June 1992, reproduced from UNCED document A/CONF.151/5/Rev.1 and reprinted in 31 I.L.M. 874 (1992).

[155] Freestone, *supra* note 146, at 37.

[156] *Id.*

[157] Gundling, *supra* note 142, at 26.

[158] *Id.*

[159] Cameron and Abouchar, *supra* note 142, at 2.

In its weakest form, the precautionary principle is analogous to the preventive principle, already well known in international environmental law, which imposes an obligation on states to prevent known or foreseeable harm outside their territory.[160] Freestone observes that the obligation imposed by the preventive principle is not generally considered as strict. Its application is regarded as dependent upon the concept of foreseeability. Hence, the preventive principle is concerned mainly with the prevention of harm and risks which are known and have been scientifically proven. The precautionary principle, however, goes beyond this, arguing that even where there is scientific uncertainty, when the environmental risks are predicted but not scientifically provable, anticipatory or precautionary action should nevertheless be taken.[161]

At its strongest, the precautionary principle is interpreted as a reversal of the normal burden of proof, so that a potential polluter must prove that his activity will not result in damage before it can be sanctioned.[162]

The rationale of the precautionary approach is the inadequacy of the scientific knowledge about the impact of many human activities on the environment. Scientists will be the first to admit that it is "methodologically very difficult, if not impossible, for them to prove a negative proposition,"[163] *i.e.*, that no environmental damage will be caused by a particular substance or activity. There is no doubt however that these activities exact a terrible price on the environment.

Awareness of the extent of ecological damage has led to this rethinking of international environmental law. The established approach has always been to permit activities unless there was evidence proving damage. Under the precautionary principle, these activities are restricted once there is reason to believe that damage or harmful effects are likely. The shift is in the fact that the threshold of significant risk has become easier to cross. All that the principle requires is establishing a *prima facie* case that a risk exists. Scientific uncertainty would then work against the potential polluter rather than, as in the past, in his favor. Hence, the

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[160]The preventive principle is codified in Principle 21 of the Stockholm Declaration and in a large number of treaty provisions. *See Declaration on the Human Environment*, The Stockholm Conference of 1972 (16 June 1972) U.N. Doc. A/Conf. 48/14 (1972).

[161]Freestone, *supra* note 146, at 30.

[162]*Id.*

[163]*Id.*, at 32.

required policy response would be to adopt and develop clean technologies immediately rather than assess the risks of various levels of pollutant emission.[164]

Considering the climate change issue, it is obvious that a precautionary approach must be taken to stabilize GHG concentrations in the atmosphere. Given the time lag before any measures to reduce emissions would have a noticeable effect on the atmospheric concentrations of GHGs, waiting until global warming is fully established may be too late to take effective action.[165] It should be obvious that, at the very least, a *prima facie* case has been made out that there is significant risk of serious ecological damage if emissions of greenhouse gases are not substantially reduced. This makes the climate change issue a classic situation for applying the precautionary principle.[166] It is therefore not surprising that the principle has been incorporated into the Framework Convention:

> The Parties should take precautionary measures to anticipate, prevent or *minimize* the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost . . .[167]

VI. RESOLVING UNCERTAINTY: THE POLITICAL PROCESS

Uncertainties are intrinsic and avoidable in science. As scientific knowledge is "probabilistic rather than absolute, and provisional rather than final, it can never be devoid of uncertainty or the possibility of inaccuracy or incompleteness."[168] There is a myth of certainty surrounding science, and such a view, held by some scientists, is unfortunate and scary because "certainty, like uncertainty, also has a dark side."[169] Belief in the absolute certainty of one's facts, opinion or conviction leads to rigid rather than flexible policy responses to problems which are usually characterized by continuing change. The truth is that science offers no quick fix or easy

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[164]*Id.*

[165]Churchill, *supra* note 33, at 151.

[166]Freestone, *supra* note 146, at 38.

[167]*Framework Convention on Climate Change, supra* note 6 at Article 3, No. 3.

[168]Ellen K. Silbergeld, *Risk Assessment and Risk Management: An Uneasy Divorce* in ACCEPTABLE EVIDENCE 99, 101 (Deborah G. Mayo and Rachelle D. Hollander eds., 1991).

[169]Victor Baker, *Uncertainty and Tolerance in Science and Decisionmaking*, 9 ARIZ. J. INT'L & COMP. L. 253, 255 (1992).

solution. Instead, the problem faced by societies -- whether local, national or international -- is that of risk management, particularly in environmental issues. How societies handle risk is more of a political, cultural and economic issue than a scientific one.[170]

A decision to do or not to do something about climate change or any other environmental risk depends upon the alternatives, values, and beliefs under consideration. There is no "single all-purpose number" that expresses "acceptable risk" for a society.[171] Uncertainties and values are present in all acceptable-risk problems. It is impossible to find value-free processes for choosing between risky alternatives. Looking for an "objective method" is not only bound to fail but it may give scientists or policy-makers the illusion that they have avoided value-laden assumptions in making policy decisions.[172] Indeed, the "choice of a method is a political decision with a distinct message about who should rule and what should matter."[173]

To clarify risk management issues, policy-makers must be committed to distinguishing between issues of fact and issues of value. Unfortunately, an absolute separation is impossible. Convictions about the facts influence values. Values in turn shape the facts sought and how they are interpreted.[174] This is particularly true when there is much ambiguity in the state of the science, as in climate change. Facts alone are insufficient to compel a choice. In such a case, choosing a policy requires a mixture of technical and policy considerations where decision-makers are constrained to go beyond science in order to legitimize their preferred interpretation of the data.[175] As a result, political and cultural divergences should be anticipated as policymakers will tend to fall back on "established, possibly nation-specific, repertoires of institutional and procedural approaches to securing political legitimacy."[176]

The notion of uncertainty, the process of deciding acceptable levels of uncertainty, and the method for resolving disagreements regarding

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[170]Mintzer, *supra* note 107, at 13.

[171]BARUCH FISCHOFF ET AL, ACCEPTABLE RISK xii (1981).

[172]Jasanoff, for example, makes the point that the political need for accountability in the United States pushes regulators toward finding a "scientifically correct" answer even when there is none. See Sheila Jasanoff, *Acceptable Evidence in a Pluralistic Society* in ACCEPTABLE EVIDENCE, *supra* note 170, at 29.

[173]*Id.*

[174]Fischoff *et al*, *supra* note 173.

[175]Jasanoff, *supra* note 174, at 29-30.

[176]*Id.*

uncertainty in environmental issues are value-laden. The manner in which policymakers deal with scientific uncertainty ultimately conforms "to deeper patterns of political culture, incorporating a nation's norms and standards of governmental accountability."[177] Hence, while facts are critical in making decisions about climate change to the extent that they identify and clarify the debatable issues, "disagreements over current values (traditional economic values versus new environmental values) and over issues of equity (global, regional, and inter-generational) inevitably drive the debate."[178] Having such conflict of values which often arises in environmental debates is not necessarily evil. Ashby once observed:

> The conflicts themselves are immensely useful, for they provoke a continuing debate about moral choice: choice between hard and soft values, choice between indulgence in the present and consideration for the future. They oblige people to strike a balance between counting what can be quantified and caring for what cannot be quantified. Every choice redefines the goal for environmental policy. In the process of choice the protection of nature is becoming more securely implanted into the culture.[179]

The policy process is further complicated by basic cultural differences between scientists and policy-makers that can obstruct communication. The scientist is cautious, frequently qualifying his or her conclusions with so many caveats that they are virtually useless to the policymaker. On the other hand, politics, the art of the possible, demands that decisions be made in the face of uncertainty.[180] Moreover, there is often a gap between what scientists consider as critical issues and the perceptions and priorities prevailing in governments, international agencies and the public at large. The fact is that an issue becomes critical to a government only when it is perceived as such by its political constituency.[181]

At the other extreme, some scientists can become so involved with the gravity and urgency of some problems that they have emerged from the laboratories to lend the authority of science to political lobbies. Given the shortage of facts, the scientific community too can be inevitably polarized "between the risk-takers and the risk-averse."[182]

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[177] *Id.*

[178] John H. Gibbons, *Decisionmaking in the Face of Uncertainty*, 9 ARIZ. J. INT'L & COMP. L. 231 (1992).

[179] ERIC ASHBY, RECONCILING MAN WITH THE ENVIRONMENT 87 (1977).

[180] Hoffert, *supra* note 94, at 50.

[181] LYNN KEITH CALDWELL, INTERNATIONAL ENVIRONMENTAL POLICY 16 (1990 2nd ed.).

[182] MARY DOUGLAS and AARON WILDAVSKY, RISK AND CULTURE 64 (1982).

Dealing with environmental degradation is one issue which has polarized the scientific community. On one hand, there are those scientists who are suspicious, if not hostile, to environmentalism. Consider, for example, these excerpts from the so-called Heidelberg Appeal[183] which was signed by 264 scientists, including at least 27 Nobel Prize winners:

> We are . . . worried, at the dawn of the twenty-first century, at the emergence of an irrational ideology which is opposed to scientific and industrial progress and impedes economic and social development. We contend that a Natural State, sometimes idealized by movements with a tendency to look toward the past, does not exist and has probably never existed since man's first appearance in the biosphere, insofar as humanity has always progressed by increasingly harnessing Nature to its needs and not the reverse.
>
> We fully subscribe to the objectives of a scientific ecology for a universe whose resources must be taken stock of, monitored and preserved.
>
> But we herewith demand that this stock-taking, monitoring and preservation be founded on scientific criteria and not on irrational preconceptions. . . .
>
> We do however forewarn the authorities in charge of our planet's destiny against decisions which are supported by pseudo-scientific arguments or false and non relevant data.[184]

Contrast the above declaration with that issued by 1,580 scientists in November 1992. These scientists, who come from 70 countries and include 99 of the 196 living Nobel Prize Science laureates, issued a "warning to humanity", calling for "fundamental changes in human stewardship of the earth".[185] They called for all nations to divert the funds they now devote to their military establishments – more than one trillion dollars annually – to tackling global environmental crises. These scientists explained their position thus:

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[183]The Appeal takes its name from a conference on harzardous substance use held in Heidelberg, Germany on April 14, 1992 and attended by some 50 European scientists. The Appeal was presented to officials of the Earth Summit in Rio in June 1992. *See Twenty-seven U.S. Nobel Prize Winners Join 237 World Scientists in an Appeal to Heads of States Attending World Summit on Environment*, Business Wire, June 1, 1992, available in LEXIS, Nexis Library, Business Wire File.

[184]*Id.*

[185]This statement was sponsored by the Union of Concerned Scientists (UCS) and sent to 160 heads of state. *See Environment: Leading Scientists Issue "Warning to Humanity"*, Inter Press Service, November 18, 1992, Available in LEXIS, Nexis Library, Inter Press File.

> We are fast approaching many of the earth's limits. No more than a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished.
>
> Current economic practices which damage the environment, in both developed and underdeveloped nations, cannot be continued without the risk that vital global systems will be damaged beyond repair.
>
> Our massive tampering with the world's interdependent web of life -- coupled with the environmental damage inflicted by deforestation, species loss, and climate change -- could trigger widespread adverse effects, including unpredictable collapses of critical biological systems whose interactions and dynamics we only imperfectly understand.
>
> Uncertainty over the extent of these effects cannot excuse complacency or delay in facing the threats.[186]

The divergent perceptions of these two groups of distinguished scientists illustrate how difficult it would be to resolve the issue of how to appreciate the uncertainties in the science of climate change. What lies behind these perceptions is not really a conviction about the facts but the values that each group consider paramount. In the case of those scientists critical of environmentalism, the most important value is that human capacity and freedom to harness or manipulate nature should be as unrestrained as possible, as it is through harnessing or manipulating nature that human societies will be able to solve their problems. On the other hand, the scientists in the second group see the danger of such freedom and capacity and are therefore more supportive of measures to limit or restrain them.

People, including scientists, may disagree about what action to take in the face of uncertainty, does not mean that the world community is doomed to inaction. Ultimately, the resolution of both technical and regulatory uncertainty -- utilizing Elliott's terms -- must be made within a political process. In the case of climate change, such resolution must be made within institutions and procedures agreed upon by the members of the world community. Since this basically involves the making of public policy -- a process, and not an event -- uncertainty is not really as important as it might otherwise be.[187]

The fact is

[186] *Id.*
[187] Gibbons, *supra* note 180, at 244.

> policy-makers thrive on uncertainty. The challenge of making educated guesses, balancing costs and benefits, weighing the consequences of action versus inaction lures intelligent, creative people into decision-making roles. Scientific uncertainty often serves equally well as sword and shield in the battles over values that actually result in international and national policy.[188]

Recognizing the existence of persistent uncertainties and the inevitability of political, cultural and economic biases does not mean that science has no role in environmental debates. Science will continue to play a critical role. The substantial scientific component of international environmental cooperation is a factor that can help to reduce, if not offset, political antagonism. If governments can agree upon the implications of demonstrable facts, they may, to the same extent, also agree to cooperation in the policies thereby implied, even though they may continue to disagree on other matters.[189] In climate change, for example, science is already helpful if it provides ways of detecting evidence of climate change that are sufficiently convincing to sustain political support.[190]

In sum, the issue in the subject of climate change is not so much the scientific uncertainties *per se,* but how to ensure that the process of deciding when and how to act would be a process fair to all members of the international community. The question is whether the decision should be made by an "independent" scientific body or by an openly political entity.

If, on one hand, the decision were left to an "independent" scientific body such as the Intergovernmental Panel on Climate Change, the problem would be that such a body would probably be dominated by scientists from the Northern industrial states. Already, countries from the South have objected to the composition of the IPCC. Ambassador Tariq Osman Hyder, Pakistani representative to the climate negotiations under the auspices of the Inter-governmental Negotiating Committee and spokesman of the G-77, observes that the developing world is not completely at ease with the work of the IPCC as it reflects the prevailing dominance of the Western countries in the field of scientific observation and study.[191] He notes that Western scientists often agree on many things due to frequent intercommunications and meetings while scientists from developing countries do not have these

[188] *Id.*, at 231.

[189] *See* Caldwell, *supra* note 183, at 312.

[190] *See* Gibbons, *supra* note 180, at 236.

[191] Tariq Osman Hyder, *Climate Negotiations: The North/South Perspective*, in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 323, 326.

facilities and opportunities.[192] The IPCC has responded by creating a committee -- the Special Committee on the Participation of Developing Countries -- that will ensure that more scientists from the developing world become involved in its work.[193] It is hoped that the future work of the IPCC will reflect a more balanced composition.

If on the other hand, the decision were made by openly political bodies -- such as the conference of the Parties to a treaty -- participating states will exercise influence and control most of the time.

The advantage of working through "independent" bodies is that powerful states once involved in putting together an environmental protection regime may be constrained by environmental norms provided by the interaction of states, non-governmental organizations, and the independent body itself. Even if these powerful states seek at first to dominate the body politically, they may not succeed. In this sense, international environmental regimes may be "transformative, resulting in the empowerment of new groups of actors who can change state interests and practices."[194]

The argument for the resolution of uncertainty in a purely political fashion is that it is the only practical means of dealing with an issue like climate change. Whatever regulatory regime is finally instituted to respond to the issue will surely have a tremendous impact on the economies of many states. Given the range and the scale of the interests involved, it would be unrealistic to expect states to allow a scientific or technical entity to make major decisions for the world community.

The optimum approach is probably to have a scientific body and a political entity share the responsibility of making the decisions with the latter having the ultimate say. This is the approach followed by the Framework Convention on Climate Change which created a Subsidiary Body for Scientific and Technological Advice.[195] This entity was established to provide the Conference of the Parties and, as appropriate, its

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[192]*Id.*

[193]*See* Kilapartu Ramakrishna and Oran Young, *International Organizations in A Warming World: Building a Global Climate Regime*, in CONFRONTING CLIMATE CHANGE, *supra* note 72, at 253, 256.

[194]Comment, *Developments in the Law -- International Environmental Law*, 104 HARV. L. REV. 1484, 1560-1561 (1991).

[195]*Framework Convention on Climate Change*, *supra* note 6, at Art. 9.

other subsidiary bodies, with timely information and advice on scientific and technological matters relating to the Convention. It is open to participation by all Parties and shall be multi-disciplinary. Its functions are as follows:

> (a) Provide assessments of the state of scientific knowledge relating to climate change and its effects;
>
> (b) Prepare scientific assessments on the effects of measures taken in the implementation of the Convention;
>
> (c) Identify innovative, efficient and state-of-the-art technologies and know-how and advise on the ways and means of promoting development and/or transferring such technologies;
>
> (d) Provide advice on scientific programmes, international cooperation in research and development related to climate change, as well as on ways and means of supporting endogenous capacity-building in developing countries; and
>
> (e) Respond to scientific, technological and methodological questions that the Conference of the Parties and its subsidiary bodies may put to the body.[196]

The final decision, however, on when to act and how to act to stabilize GHG emissions still belongs to the Conference of the Parties.[197] This is proper given the reality that the scientific uncertainties can ultimately be resolved only in the context of a political process.

The Ozone Depletion Analogy

The problem which first drew popular attention to the atmosphere's condition was not climate change; it was the thinning of the ozone layer in Earth's upper atmosphere. Like climate change, ozone loss is not fully understood but scientists believe that CFCs are the primary contributor. The ozone layer, extending from about 18 to 30 miles above the earth, shields the planet from the sun's ultraviolet rays which can be harmful to many forms of life. In human beings, for example, damages from ozone depletion can range from skin cancer to immunity disorder to eye cataracts.[198]

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[196] *Id.*
[197] *Id.*, at Art. 7.
[198] LYMAN, *supra* note 9, at 12 (1990).

The Montreal Protocol on Substances that Deplete the Ozone Layer is the landmark international environmental accord that was negotiated, entered into force, and amended in record time in response to scientific information on damage to the ozone layer by synthetic chemicals like CFCs. The process by which the international community resolved both technical and regulatory uncertainties in the course of the ozone negotiations offers important lessons for those policy-makers working on climate change.[199]

The original agreement, the Vienna Convention for the Protection of the Ozone Layer, was signed in 1985.[200] The Vienna Convention did not establish any control strategies regarding the use of CFCs. In fact, it did not identify any chemical as an ozone-depleting substance. The Convention created a general obligation for nations to take "appropriate measures" to protect the ozone layer, but there was no effort to define such measures.[201]

The Vienna Convention, although criticized for not establishing a regulatory regime, was a significant achievement. For the first time, the international community dealt with an environmental danger before it was scientifically proven. The convention not only instituted a mechanism for international cooperation in research, monitoring, and exchange of data on the state of the ozone layer and on emissions and concentrations of CFCs and other ozone-depleting chemicals; more importantly, it established the framework for a future protocol to control ozone-modifying substances.

The Montreal Protocol is the result of the process established by the Vienna Convention. It was signed in September 1987 by 24 nations and entered into force, as scheduled, on January 1, 1989. A revised version was agreed upon and signed in London by 93 nations on June 29, 1990.

The Montreal Protocol requires parties to restrict production and consumption of controlled substances, placing a limit on the total calculated level of production, based on 1986 levels, of any combination of substances in a group. The updated accord tightens the restrictions of the 1987 Agreement by expanding its scope and stringency.[202]

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[199] *See* generally BENEDICK, *supra* note 136, at Chapter 1.

[200] *See* the *Vienna Convention on Substances that Deplete the Ozone Layer*, (Nairobi: UNEP, 1985).

[201] *See id.*, at Art. 1, No. 1.

[202] *See* BENEDICK, *supra* note 136, at 190-195 where he compares the 1987 provisions with the 1990 amendments.

The Montreal Protocol was significant for two reasons. First, it was aggressive in that it set target dates for reduction even though technologies for compliance with the goals do not yet exist. Second, it was the first international agreement to provide for an international Secretariat for monitoring, reporting and organizational purposes. Thus, a valuable precedent was established: a supranational organization can be employed to supervise the implementation of international environmental treaties.[203]

The Montreal Protocol is also an important convention because it symbolizes a fundamental change both in the kind of problems facing the modern world and in the way the international community can approach these problems. Ozone depletion, like global warming, reflects this new generation of issues manifesting the interconnection of life and its natural support systems on this small planet, "where localized activities can have global consequences, and where dangers are slow in developing, long-term in their effects, and not readily reversible."[204] The international community confronted a threat which could affect every nation and all life on earth, and although the consequences were potentially disastrous, they could not be observed or predicted with certitude. Thus the Montreal Protocol is a model for decision-making under uncertainty: "International consensus was forged on a balance of probabilities, where the risks of waiting for more complete evidence were finally deemed to be too great."[205] Ambassador Benedick, chief negotiator of the United States for the Montreal Protocol explained:

> The negotiators weighed the social and economic costs of replacing substances which contribute in many ways to modern standards of living, against hypothetical dangers based on analysis at the frontiers of modern science. All this was done before there was measurable evidence either of ozone depletion or of actual damages from increased radiation or from climate change.[206]

CONCLUSION

While scientific understanding of the greenhouse phenomenon is still incomplete, it does not mean that the international community should wait before instituting measures that would respond to global climate

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[203]Susan E. Holley, *Global Warming: Construction and Enforcement of an International Accord*, 10 STAN. ENVTL. L.J. 44, 77 (1991).

[204]Richard Elliot Benedick, *"The Montreal Ozone Treaty: Implications for Global Warming"*, 5 AM. U.J. INT'L. L. POL'Y 227, 228 (1990).

[205]*Id.*

[206]*Id.*

change. There is every need to address the question of global climate change within the framework of international law as soon as possible.

For a long time, governments, citing uncertainties in the science, have acted as if the threat of global warming was unimportant, exaggerated or premature. This attitude must be changed if the worst consequences of climate change are to be avoided. The fact is that by adding infra-red absorbing gases to the atmosphere, we are effectively "playing Russian roulette with our climate".[207] Today, human activity can disrupt the earth's biosphere totally, either deliberately or unwittingly. Given that humanity has this extraordinary power, caution -- including legally-binding constraint -- is called for.[208] In the words of Mostafa Tolba, the former UNEP Executive Director, explains in these words:

> It is now true that uncertainty is not a signal to advance; it is a signal to move prudently. Until the modern era it could be argued that uncertainty was no obstacle to development. If one forest or one lake was destroyed, then there was always one more forest and one more lake. Now, however, we have the capacity to disrupt massively not only a few forests and lakes, but the entire biosphere. We have the capacity to destroy this world if we are not careful, and therefore we must be careful.[209]

This does not mean that the scientific uncertainties should be ignored. A unique characteristic of the global climate change issue is the crucial linkage between science and policy. Because of the complexities involved and the many different sectors in which action is required, there is no simple solution or technological quick fix. The problem will need to be aggregated and partial solutions sought; as exemplified in the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer.[210] Since policy decisions will have to take place under conditions of scientific uncertainty, the aim should be interim decision points for policy action based on the best available scientific evidence and consensus.

What the climate change issue requires is a regulatory regime based on the best available scientific understanding of the problem. Because of the uncertainties in the science, this regime should be characterized by as much

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[207]*See* Wallace S. Broecker, "Unpleasant Surprises in the Greenhouse?", 328 Nature 123, 123 (1987), quoted in Leggett, *supra* note 3, at 24.

[208]Mostafa Tolba, *Heeding Nature's Tug: An Environmental Agenda For International Relations*, 14 THE FLETCHER FORUM 239 (1990), 245.

[209]*Id.*

[210]*See* BENEDICK, *supra* note 136, at 7.

flexibility as possible to allow for adjustments in response to new information. The regulatory regime must seek not only to stimulate the growth of knowledge but also to provide processes for incorporating new insights into the system without triggering a time-consuming and highly politicized ratification process. This would require procedures for adapting arrangements to new information while avoiding the complications associated with formal mechanisms.[211]

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[211] *See* ORAN R. YOUNG, GEORGE J. DEMKO, & KILAPARTI RAMAKRISHNA, GLOBAL ENVIRONMENTAL CHANGE AND INTERNATIONAL GOVERNANCE 14-21 (1991).