

Article 2 of the UNFCCC: Historical Origins, Recent Interpretations

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Abstract

Article 2 of the UN Framework Convention on Climate Change, which states the treaty's long-term objective, is the subject of a growing literature that examines means to interpret and implement this provision. Here we provide context for these studies by exploring the intertwined scientific, legal, economic, and political history of Article 2. We review proposed definitions for “dangerous anthropogenic interference” and frameworks that have been proposed for implementing these definitions. The implications of Article 2 for near term restrictions on greenhouse-gas emissions, e.g., the Kyoto Protocol, are also discussed.

Introduction

During the latter half of the 1990s, the policy debate over global warming largely focused on negotiation, ratification, and entry into force of the Kyoto Protocol (Kyoto Protocol, 1997), which sets near term (decadal) objectives for reduction of greenhouse-gas (GHG) emissions by the accord's industrialized-country parties. Recently, attention has focused increasingly on the parent agreement of the Kyoto Protocol, the UN Framework Convention on Climate Change (UNFCCC, 1992). In particular, Article 2 of the

Convention sets out a long-term objective, stabilization of greenhouse gas concentrations at levels that avoid “dangerous anthropogenic interference” with the climate, which may be of equal importance as the Protocol’s near term targets. No other international agreement has a long-term objective that is both so sweeping in its potential implications yet so much in need of near-term definition (Oppenheimer and Petsonk, 2003).

Until recently, the question of how to interpret and implement Article 2 received relatively cursory treatment (cf. Bodansky, 1993). Since the publication of the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC) in 2001 (Houghton et al., 2001; McCarthy et al., 2001; Metz et al., 2001), a variety of governmental efforts, such as the COOL (Tuinstra et al., 2002) and HOT (Gupta et al., 2003) dialogues sponsored by the Netherlands, and nongovernmental collaborations (Pew Center, 2001; Diringer, 2003; Michel, 2003; SWP, 2003) have explored alternative definitions of Article 2, as well as means to implement it.¹ These efforts have focused largely on scientific and economic considerations. But social, cultural, and ethical dimensions of “dangerous” warming, which may play a critical role in reaching a political consensus on Article 2, have drawn increasing attention (Rayner and Malone, 1998; Elzen and Berk, 2003; Gupta, 2003; Adger 2001). At the same time, discussion of Article 2 in the UNFCCC meetings has foundered, with the Group of 77 developing countries and China objecting to anything that might lead to emissions caps for them (Corfee-Morlot & Höhne, 2003), and the United States joining the G-77 in declaring such discussions “premature” (Pew Center, 2002; Peel, K., personal communication). Neither the 2002 Delhi Declaration nor the decisions adopted by the Ninth Conference of the

Parties to the UNFCCC in Milan in 2003 makes any explicit reference to Article 2 (Corfee-Morlot & Höhne, 2003; UNFCCC COP-9 Decisions, 2003).

In this Article we explore the history of the concept of long-term limits to climate change, emphasizing in particular the origins and development of Article 2 and evolution of the concept of “dangerous” climate change before and after the UNFCCC was adopted. We also explore historical linkages between Article 2 and near term targets like those embodied in the Kyoto Protocol, and discuss various frameworks that have been proposed for implementing Article 2. We focus narrowly on scientific, legal, economic, and political developments, drawing on primary sources such as the negotiation record and interviews with some key actors, as well as previous general histories of the climate issue. We do not discuss apportionment of national responsibility, or burden sharing (Baumert, 2002; Gupta, 2003). Nor do we discuss recent developments in the social dimension, which are reviewed by Dessai et al (2004) and have yet to be integrated into discussions of specific targets. Nor do we focus much on alternative frameworks for formulating long-term objectives, such as technology-based approaches, that are not consistent with that of Article 2.

In the climate change context, the history of an idea matters. History may illuminate the intended meaning of Article 2, and it could make apparent what notions of danger were cast aside during the debate over Article 2, and which notions have been omitted altogether. A clear understanding of the process through which the concept has evolved, including circumstances under which progress has occurred and those under which it has

not, could help shape current efforts to reach a consensus definition. Since a legal definition of danger in the context of Article 2 ultimately would occur through a diplomatic process, not least important is an understanding of the roles of particular countries as well as individuals and groups (e.g., epistemic communities, Haas, 1992) in the evolution of the concept.

1.0 The Scientific and Policy History of Limits-to-Warming

General histories of the climate change problem (see Clark et al., 2001; Weart, 2003 and references therein; see also Hecht and Tirpak, 1995) usually begin with Arrhenius (1896) or earlier. They generally note the signature scientific studies of Callendar, Plass, Revelle, Keeling, Manabe, and others through the 1960s. But it was not until the mid-1970s that a broader expert community, including policy-makers, began to focus on the questions of whether, when and how to limit warming.

In an early report of the US National Research Council (NRC, 1977), *Energy and Climate*, meteorologist J. Murray Mitchell, Jr. asked, “Can man establish which, if any, alternative scenarios would lead to “unacceptable” climatic consequences and are therefore to be avoided?” The foreword to the report, written by Philip Abelson, took a slightly different perspective (foreshadowing current discussions of cost optimization versus targets noted below), asking, “What *should* the atmospheric carbon dioxide content be over the next century or two to achieve an optimum global climate?”

Antecedents of the notion of dangerous warming are found in the comprehensive analyses of human modifications of the environment in general (SCEP, 1970) and climate in particular (SMIC, 1971) that appeared in preparation for the 1972 UN Conference on the Human Environment. Subsequent detailed assessments were spurred not only by interest in the greenhouse gases (NRC 1977, Williams 1978) but also by concerns about the potential effects of supersonic aircraft on climate and the ozone layer (CIAP, 1975). Also of concern was an apparent cooling of the northern hemisphere over the three preceding decades, attributed by some to emissions of particulates. The global perspective on climate generated a growing list of studies of specific impacts of climate variation and climate change that eventually provided a basis for developing and interpreting Article 2 (e.g., Houghton et al., 1990; McCarthy et al., 2001 and references therein).

In a series of articles beginning in 1975, Nordhaus (1979, and references cited therein) appears to have been the first to systematically address questions like those raised by Mitchell and Abelson, and the first to attempt to model the economics of limiting carbon dioxide concentrations. Drawing on early carbon cycle models that indicated that a stable or falling atmospheric concentration could be achieved by reducing emissions, he wrote:

Up to now there has been no serious thought of the level of standard on carbon dioxide. As a first approximation, it seems reasonable to argue that the climate

effects of carbon dioxide should be kept within the normal range of long-term variation.

(Nordhaus, 1979). He went on to argue that 2° C. warming, comparable to what was thought to be the maximum sustained global mean temperature during the Holocene, marked the limit of “normal” and linked this change to a doubling of carbon dioxide concentrations, based on the results of early climate models. But he emphasized that “the proposed standards are deeply unsatisfactory...I am not certain that I have even judged the *direction* of the desired movement in carbon dioxide correctly, to say nothing of the absolute levels” (Nordhaus, 1979).

At the same time, some scientists ignored or were unaware of the possibility that stabilization of concentrations and climate were theoretically possible.² For example, Cooper (1978) asserted that “even an appreciable decrease in the rate of fossil fuel burning will only delay the time of maximum climate effect. It will not prevent it.” The first USEPA report on climate change (Seidel and Keyes, 1983) explored only options for slowing warming, rather than stabilizing carbon dioxide or climate.

1.1 Early Political Developments

One of the first policymakers to consider the issue and specifically link increasing concentrations of carbon dioxide to dangerous outcomes was U.S. Senator Abraham

Ribicoff of Connecticut. Ribicoff had been told of the problem by German Chancellor Helmut Schmidt, who saw climate change as a “major threat to the future of mankind” (Schmidt, 1979; Ribicoff, 1979a). At the peak of the 1979–80 oil supply crisis, Ribicoff learned that synthetic fuels, widely advocated as a substitute for oil and natural gas, emitted twice the CO₂ per unit of usable energy compared with conventional fossil fuels, and would lead to sharply increased atmospheric concentrations – a “Faustian bargain,” in his view (Ribicoff, 1979a).³ As a consequence, he amended the Energy Security Act of 1980 to request that the NRC conduct a comprehensive assessment of the impact of projected fossil-fuel combustion on the accumulation of CO₂ in the atmosphere (Ribicoff, 1979a, b, c; United States Senate Committee on Governmental Affairs, 1979; NRC, 1979⁴; Handler, 1979; AAAS, 1979; Pomerance, 1989). The resulting NRC report emerged in 1983, thoroughly assessing the problem, including many policy options, but not mentioning concentration limits or stabilization (NRC, 1983).

Stimulated by same concerns over synthetic fuels as well as by the debate then underway over reauthorization of the Clean Air Act (Pomerance, 1989), the White House Council on Environmental Quality (CEQ) issued two relevant reports in 1981. The reports warned that projections of global energy use indicated that CO₂ concentrations could reach twice pre-industrial levels by the middle of the twenty-first century. According to this early view, the resulting climatic changes could “markedly affect agricultural productivity over large areas,” trigger sea level rise of five meters with significant coastal flooding, and “markedly affect the less managed biosphere, including fisheries and forests.” CEQ examined the energy policy implications of a range of fossil-fuel uses

based on limiting CO₂ concentrations to several of the values that Arrhenius had considered in the nineteenth century: 1.5, 2.0, and 3.0 times the preindustrial level. Noting that “there are a limitless number of scenarios for burning fossil fuels that could each lead ultimately to the same level of atmospheric CO₂,” CEQ nevertheless pointed out that “the more rapidly the world increases fossil fuel use now, the sooner and more rapidly it must begin its reduction in order to avoid exceeding any given CO₂ ceiling.” It concluded (as had Nordhaus earlier) that CO₂ concentrations could double between 2020 and 2050 and that preventing this would require global fossil-fuel use to peak and begin declining in the 2000–2020 period (CEQ, 1981a,b). But despite these reports, the option of stabilizing concentrations remained largely unrecognized or ignored in early discussions of specific policy responses (as pointed out by Firor, 1988).

The idea of using long-term concentration targets as a policy goal gained momentum after the International Conference on The Assessment of the Role of Carbon Dioxide and Other Greenhouse Gases in Climate Variations and Associated Impacts. This meeting, held in October, 1985 at Villach, Austria under the auspices of the UN Environment Programme (UNEP), the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) (Bolin et al., 1986), convened a few months after the signing of the 1985 Vienna Convention for the Protection of the Ozone Layer. The conference developed an influential consensus on the policy implications of greenhouse gas emissions. Less noticed was the fact that the report presented a handful of emissions scenarios that resulted in stabilization of CO₂ concentrations. The same year, the US Department of Energy published a series of ground-breaking studies on the

potential impacts of increasing concentrations of carbon dioxide (Strain and Cure, 1985; White, 1985; Ad Hoc Committee, 1985).

The summer following the Villach meeting, US Senator John Chafee of Rhode Island, then chair of the Environment and Public Works Committee, convened hearings on changes in the climate and ozone depletion, and began an effort to shape U.S. policy on greenhouse gases and climate change. In September 1986 Senators Chafee, George Mitchell of Maine, and others wrote to Lee Thomas, administrator of the U.S. Environmental Protection Agency, requesting two studies, one of the impacts of climate change on human health and the environment, and the other of policy options for stabilization (Mitchell, Senator J. et al., 1986). While the letter referred to stabilization of *emissions*, prior and subsequent writing makes clear that Senator Chafee's concern was for stabilization of *concentrations* (Chafee, Senator J., 1986; Chafee, Senator J., et al., 1986). Chafee took significant legislative steps to clarify that distinction, amending a climate change provision in the foreign relations bill introduced by Senators Biden and Pell to make clear that U.S. policy should “identify existing and potential strategies...to stabilize global climate, and atmospheric concentrations of greenhouse gases, at current levels...” (Chafee, Senator J., 1987; Pomerance, 1989), but the mix-up complicated climate policy up to and through the adoption of the Framework Convention.

An outcome of Senator Chafee's concern was the Global Climate Protection Act of 1987, which mandated that U.S. policy should seek to “limit mankind's adverse effect on the global climate by (a) slowing the rate of increase of concentrations of greenhouse gases

in the atmosphere in the near term; and (b) stabilizing or reducing atmospheric concentrations of greenhouse gases over the long term.” Congress directed EPA to analyze policy options accordingly (Global Climate Protection Act of 1987). In the course of enacting this law the US Senate Foreign Relations Committee noted the threat to agriculture in particular, and stated its belief that “global warming is a potential environmental disaster on a scale only exceeded by nuclear war” (Foreign Relations Committee, 1987). Thus the US Congress established that U.S. climate policy should focus on stabilizing GHG concentrations and preventing extremely deleterious outcomes.

With the Congress having established this dual objective, U.S. negotiators supported the concepts in various parts of the recommendations of the government-sponsored World Conference on the Changing Atmosphere in Toronto in 1988 (World Conference, 1988), the Noordwijk Ministerial Conference on Atmospheric Pollution and Climate Change in November 1989 (Noordwijk Declaration, 1989; Bodansky, 1993), and the Second World Climate Conference in Geneva in 1990 (SWCC, 1990).

1.2 Targets and the International Regime

In the late 1980s, proposals to limit climate change coalesced around two very different approaches, one based on environmental objectives, and the other, around political and economic feasibility. The feasibility approach was influenced by the 1985 Vienna Convention on the Ozone Layer and its 1987 Montreal Protocol, the latter mandating a freeze in production and consumption of ozone-depleting chemicals followed by a 50%

reduction (Vienna Convention, 1985; Montreal Protocol, 1987; Benedick, 1998; Agarwala, 1999).⁵

Environmental targets were subject to consideration by delegates to the Toronto, Noordwijk, and Geneva meetings. Participants had before them work done under the auspices of the Advisory Group on Greenhouse Gases (AGGG), which had been established by the three sponsoring organizations of the 1985 Villach meeting to advance the conference's recommendations, among them, consideration of a framework convention (Agrawala 1999, Andresen and Agrawala 2002). The AGGG experts proposed a target framed in terms of a *rate of warming*, which would provide a useful long-term objective (called a *tolerable rate*) for limiting emissions. The Advisory Group recognized that both natural and social systems adjust more easily to slow than to rapid change but the ability of natural systems to adjust was much more limited. Based on the expected responses of forests and coastlines to warming and sea level rise, respectively, the Advisory Group proposed a targeted warming rate of one-tenth degree Celsius per decade (WMO, 1988). Later, after broader examination of impacts, including those on coral reefs, the rate approach was augmented by a proposed limit of one or two degrees Celsius on total warming (Oppenheimer, 1989; Rijsberman and Swart, 1990).⁶

The AGGG conception of targets received close attention from the Netherlands government. Based in part on the AGGG's work, the Dutch were convinced of the plausibility of disastrous climate changes. It followed that quantitative limits for stabilization of concentrations ought to be established, and be set at levels that would

avert such changes. The Dutch also believed that rapid rates of climate change would pose particular challenges for developing countries, with emphasis on the agricultural sector, and for natural ecosystems. Accordingly, the Dutch government proposed that GHG concentrations should be stabilized at levels that would keep climate change within “tolerable limits,” and that the Intergovernmental Panel on Climate Change (IPCC), which had been established by UNEP and WMO the preceding year, should report on options for doing so (Vellinga, 1996 and Vellinga, personal communication; WMO, 1988). At the Noordwijk conference, most negotiators accepted the Dutch formulation. Some, however, asked for a further element, namely, that economies should not suffer, and language was included to that effect:

For the long term safeguarding of our planet and maintaining its ecological balance, joint effort and action should aim at limiting or reducing emissions and increasing sinks for greenhouse gases to a level consistent with the natural capacity of the planet. Such a level should be reached within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and permit economic activity to develop in a sustainable and environmentally sound manner. Stabilizing the atmospheric concentrations for greenhouse gases is an imperative goal. The IPCC will need to report on the best scientific knowledge as to the options for containing climate change within tolerable limits. Some currently available estimates indicate that this could require a reduction of global anthropogenic greenhouse gas emissions by more than 50 per cent.

(Noordwijk Declaration, 1989)

The U.S. and Dutch approaches focusing on stabilization of concentrations may be contrasted with the German government's lack of reference to this concept in its deliberations: The 1989 Enquete Commission proposed an 80 percent reduction in fossil-fuel use by 2050 to avoid a warming of one-to-two degrees Celsius but did not mention stabilizing either concentration or temperature (Enquete Commission, 1989).

A different kind of target—based not on environmental objectives but on political and economic considerations (Clark and Dickson, 2001) and particular policies and measures to limit emissions such as a more efficient use of energy by the electricity sector—had been introduced at the 1988 Toronto Conference (Levy et al., 2001; Andresen and Agrawala, 2002; Clark et al., 2001). This proposal, calling for a 20 percent reduction in *industrial countries'* emissions of carbon dioxide from 1988 levels by 2005, set in motion discussions along an entirely different track. The conferees also referred to stabilization of atmospheric concentrations, which they called “an imperative goal,” and noted that its attainment in the near future would require yet larger reductions in *global* emissions – on the order of greater than fifty percent (World Conference, 1988).

The two types of targets - one based on environmental objectives and the other based on near term political feasibility – came together in the June 1990 report of the Response Strategies Working Group of the IPCC (IPCC RSWG, 1990; see also Hecht and Tirpak, 1995). The RSWG, chaired by the United States, had been interested in concentrations as

an object of policy, and the U.S. administration's advocacy of a 'comprehensive approach' to climate policy arose in part because of that interest (Discussion Paper, 1990; Task Force on the Comprehensive Approach, 1991). Recognizing the inadequacy of existing legal instruments to address climate change, the RSWG suggested a framework convention modeled on the 1985 ozone treaty, to which subsequent protocols could be added in the future; and it asked whether a climate treaty should include, among other elements, "a provision setting any specific goals with respect to levels of emissions (global or national) or atmospheric concentrations of greenhouse gases." The "goal with respect to levels of emissions" paralleled the kind of target that the 1987 ozone layer treaty set with regard to freezing and cutting back on production and consumption of ozone-depleting chemicals⁷. But the Montreal Protocol contains no parallel to the concept of stabilization of atmospheric concentrations of greenhouse gases. The Montreal Protocol does contain a non-binding, hortatory goal of eventually eliminating the production of ozone-depleting chemicals (Montreal Protocol, 1987). But this language did not create an obligation to stabilize atmospheric concentrations of stratospheric ozone, although that concept had been discussed around the time the ozone accord was adopted (Titus, 1986; Fay, K., personal communication).⁸

The Second World Climate Conference (SWCC, 1990), held in Geneva in November 1990 following publication of the RSWG report, was, in the words of former U.S. State Department lawyer Daniel Bodansky, a "dress rehearsal" for the negotiation of the climate treaty (Bodansky, 1993). The SWCC issued a declaration, stating, "the ultimate global objective should be to stabilize greenhouse-gas concentrations at a level that

would prevent dangerous anthropogenic interference with climate” and stressing, “as a first step,” the need to stabilize greenhouse gas emissions. (The “first step” language is important: while some people today (see, e.g., Inhofe, Senator J., 2003) object that the Kyoto Protocol will not solve the problem of global warming, stabilization of emissions has long been recognized as a “first step” toward the subsequent stabilization of concentrations, which would require, as was well known then, further emission reductions.)

Who was responsible for ensuring that the “ultimate global objective” language was included in the SWCC? The negotiating history indicates that the Austrian delegation played a crucial role. Austria had been involved extensively in the ozone layer treaty talks, and took pride in the Vienna Convention, concluded in its national capital. The Austrian delegation was aware that neither the Vienna Convention nor the Montreal Protocol included a measurable long term atmospheric concentration objective that would constrain future negotiations of quantitative interim targets. The delegation was determined that the Climate Treaty should not make this same mistake. Moreover, while the Dutch delegation also played a vital role, the Austrian delegation could maneuver with greater alacrity than the Dutch, who were bound to a time-consuming process of coordination with other EU member states. Consequently, at the SWCC, it was the Austrian delegation that introduced the long-term objective language (Crist, R., personal communication; Schally, H., personal communication).

When climate treaty negotiators met at Chantilly, Virginia, early in 1991, many focused on the kind of emissions limitation target that had been proposed at Toronto. Article 4 of the Climate Treaty, reflecting the Toronto approach, directed industrialized nations to “aim at” returning their total GHG emissions to 1990 levels by the year 2000⁹. But the Noordwijk Declaration’s formulation for limiting overall climate change had also been incorporated into both the IPCC report and the SWCC. While RSWG did not endorse the notion of tolerable rates as a basis for a target (Haas and McCabe, 2001), the Austrian delegation to the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change proposed that the treaty include a long-term objective squarely premised on the concept of stabilization of concentrations in the context of ecological limits:

Long term global objective:

The long term global objective must be the stabilization of greenhouse gas concentrations in the atmosphere at a level which minimizes risks to ecosystems, ecological processes, and climatic conditions essential for the functioning of the biosphere and which will ensure sustainable development.

(Austrian Government, 1991)¹⁰

Building on the Austrian proposal, negotiators finally agreed on treaty language that combined elements of the Noordwijk and SWCC statements to form Article 2 of the Climate Treaty:

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the

relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

(UNFCCC 1992, Article 2)

1.3 Article 2 and the Kyoto Protocol

Agreement on the Framework Convention led to a spate of activity in the scientific and economic communities, much of it occurring under IPCC auspices, aimed at providing a basis for interpreting Article 2 by exploring the implications of concentration stabilization for allowable emissions as well as for future temperature and sea level changes (Enting, et al., 1994; IPCC, 1994; Schimmel et al., 1995; Schimmel, et al., 1997; Wigley, 1995; Wigley et al., 1996; Jacoby et al., 1996). To a limited degree, some of these developments influenced the framing of the Kyoto Protocol, which as a “related legal instrument” is required to share the objective of the Convention.

But it was the formal reviews of progress under the Framework Convention in the mid-1990s, commenced pursuant to Article 7 of the treaty,¹¹ that led the Parties to conclude that the voluntary “aim” approach was inadequate to achieve the treaty’s objective, (UNFCCC COP, 1995), and thus provided the legal predicate for the Kyoto Protocol.

The Kyoto accord requires industrialized nations to limit their GHG emissions to a legally binding budget, or cumulative emissions, for the years 2008 to 2012, with the budget level set at an average of approximately 5 percent below their 1990 emissions levels (Kyoto Protocol, 1997).

The influence of Article 2 of the Convention on the Kyoto Protocol occurred via the concept of a “safe corridor”, a set of emissions trajectories that would preserve options for stabilizing long-term concentrations at levels that would limit warming to acceptable rates and amounts. Several analyses considered a value of two degrees total warming (Dutch National Research Program, 1994; Alcamo and Kreileman, 1996a, b; EDF, 1997), and such an objective, along with a corresponding concentration target of 550 parts per million (ppm) CO₂ equivalents, received informal endorsement from the European Commission. The safe corridor concept, which arose among European scientists, had been emphasized to many governments in the period prior to the 1997 Kyoto conference. At the same time, leading U.S. ecologists had written President Bill Clinton that more than one degree of warming over the next century—in particular, the stabilization of CO₂ at levels above 450 ppm—could be dangerous to vulnerable ecosystems (Mooney et al 1997).

In 1996 the ministers attending the UNFCCC Conference of the Parties in Geneva adopted a declaration stating their belief that “the continued rise of greenhouse gas concentrations in the atmosphere will lead to dangerous interference with the climate system,” and noting IPCC findings that “stabilization of atmospheric concentrations at

twice pre-industrial levels will eventually require global emissions to be less than 50 per cent of current levels” (Ministerial Declaration, 1996). The chief U.S. climate treaty negotiator at the time, Undersecretary of State Tim Wirth, clearly understood the connection between dangerous impacts and rising concentrations, and in Geneva enunciated the U.S. view that while nations moved toward legally binding emission targets, they should “continue working toward a longer term concentration goal” (U.S. Statement to the COP, 1996). Consequently, although the Kyoto targets were developed mainly according to the feasibility criterion, they also were influenced by the ideas of stabilizing concentrations and limiting climate changes so as to avoid “danger”.

After the Protocol was signed, however, there was a hiatus in interest in Article 2 in the legal, political, and diplomatic communities. During this period, discussion focused largely on implementation of the Kyoto agreement. The question of what constitutes dangerous anthropogenic interference in the climate system largely proceeded on a separate track, with IPCC undertaking a scientific assessment of key vulnerabilities that would eventually form the basis of current discussions on Article 2 (Smith, et al., 2001).

2.0 What Does “Dangerous” Mean?

The period since Kyoto has been characterized by attempts by scientists and economists to interpret Article 2, e.g., to determine what is “dangerous anthropogenic interference”, and to create frameworks for actually implementing Article 2 by determining emissions

pathways consistent with any particular definition. As noted above, early scientific assessments of global warming often focused on the expected response to a constant concentration of carbon dioxide equal to a doubling of its pre-industrial level. Because fully-transient simulations using both a time-dependent model of climate and time-varying emissions were not published until 1988 (Hansen et al., 1988), little information was available before then on the consequences of different emissions pathways. In addressing the stabilization of concentrations, the IPCC in its first full report (Houghton et al., 1990), noted merely that emissions reductions of 60 percent or more would be necessary if carbon dioxide concentrations were to be stabilized at 1990 levels.

In adopting the objective of the Framework Convention, the drafters set out the three separate principles of (a) stabilizing GHG concentrations; (b) slowing rates of climate change (as indicated by the words “in a time frame”); and (c) thus assuring that ecosystems can adapt, food production is not threatened, and nations can develop in a sustainable manner. The emphasis on ecological and social impacts means that temperature changes, rates of temperature change, amount and rates of sea-level rise, and perhaps other measures of climate change each may be important to subsequent discussions of Article 2. Although the drafters deferred selecting a numerical value and timetable for achieving the concentration target, such choices are necessary for determining emissions pathways that are effective in satisfying Article 2 (Schimmel et al., 1997).

We also note that concentration has several advantages over global mean temperature as a regulatory tool: its legal status in Article 2; the fact that it is less variable, compared to its current trend, than mean temperature; and that concentrations lead climate change while temperatures lag concentrations. The apparent advantage of temperature, that it is a more direct measure of impact, does not carry over to the global mean since local climate parameters determine actual impacts.

Over the years, a very broad set of phenomena were proposed as means of defining what is potentially dangerous, even before the Framework Convention (WMO, 1988; Rijsberman & Swart, 1990). Some dangers derive directly from geophysical changes, some from biological responses to the climate, and others from socioeconomic responses. Their impacts range from local to regional to global and from human-made infrastructure to human health to ecosystem and species viability, and sometimes all of the above. In some cases, the absolute level of warming determines the impact, whereas in other cases, the rate of warming is more important.

Rather than attempt to define “dangerous”, which it views as beyond its legal ambit, the IPCC (Smith et al., 2001) organized such vulnerabilities into five categories called “reasons for concern”:

1. Threats to unique ecosystems and species, e.g., coral reefs.
2. Significant increase in extreme events, e.g., droughts and floods.
3. Net negative regional costs of impacts, e.g., submergence of small islands.

4. Net negative global costs of impacts, e.g., increased population at risk of disease, or water or food insufficiency.
5. Significant threat of discontinuities (e.g., disintegration of the West Antarctic ice sheet, shutdown of the thermohaline circulation).

The order provided by this taxonomy, famously illustrated by figure TS-12 of McCarthy et al (2001) and figure 19-7 of Smith et al (2001), clarified the issues and must be seen as a watershed event in the evolution of thinking on Article 2. But the taxonomy itself leads to other difficult questions. How might countries globally, in large regional groupings, or in groupings of common economic interest agree on which categories above, or phenomena within the categories, could be used to define danger, and thereby begin the process of implementing Article 2? One plausible view is that the larger, more abrupt, less reversible, and more global the impact is, the easier may be agreement on a particular definition of danger regardless of uncertainty (O'Neill and Oppenheimer, 2002). Another is that the more certain and immediate the impact is, the easier may be agreement. The fact that these two views do not overlap very much for many of the impacts proposed signals some of the diplomatic difficulties that lie ahead.

For example among potential impacts of climate change, the disintegration of the West Antarctic ice sheet (WAIS) may create the greatest social and ecological danger in the long run, with the longest timescale for reversal. But because of the inadequacies of ice sheet models and the difficulty in determining WAIS's behavior in past warm epochs, there is much we do not know yet. Uncertainties include the requisite level of warming

around Antarctica to make the ice sheet disintegrate, which may be quite high ($\sim 10^{\circ}\text{C}$ above 1990) or rather modest ($\sim 2^{\circ}\text{C}$), as well as when the disintegration might begin, which may be quite distant (millennia) or rather near (starting in about a century), according to various estimates (Oppenheimer and Alley, 2003; Vaughan and Spouge 2002; Oppenheimer, 1998).

The destruction of coral reefs through mass thermal bleaching (Hughes et al., 2003) provides a contrast: it already appears to be under way episodically and may become a permanent feature with the additional one or two degrees Celsius of warming that may already be locked into the climate system as a result of anthropogenic perturbation. The economic consequences of coral reef loss, restricted to various locales and the tourism and fishing industries, may be too limited to bring about political consensus on using it as a definition of danger. Of course, other ecological changes also are important in the near term (decades) and, taken together, may cause widespread concern.

One obstacle to reaching a global view is that despite significant progress in understanding the psychological basis of individual views of risk (Thaler et al., 1997), there has been little discussion of how to apply this work in the context of climate change (Kasperson, et al., 1988; McDaniels et al., 1996; Sunstein, 2002). Regional and cultural differences also matter. For example, shutdown of the thermohaline circulation, should it occur, may present a greater threat to Europe than to the United States (Vellinga and Wood 2002). In contrast, modification of El Niño might prove more problematic for the United States. Of course both such evaluations are based on an extremely narrow view of

what “dangerous” would mean in a strongly interlinked world.

3.0 Options for Implementing Article 2

In this section, we review various proposals to implement Article 2 on paper, that is, to convert an environmental objective into hypothetical emissions pathways (see also Patwardhan et al., 2003). The objective must be used to infer limits on climate changes as measured by one or more of the impact parameters discussed above (O’Neill and Oppenheimer, 2002); limits on climate changes must then be used to infer limits on radiative forcing and concentrations (Caldeira et al., 2003); finally, limits on concentrations must be used to infer emissions pathways (Enting, et al., 1995; Wigley et al., 1996; Schimmel et al., 1997).¹² Uncertainties abound at each step, but are probably greatest for the first (cf. WAIS example discussed above).¹³

An additional difficulty is that a large number of emissions pathways can achieve a given concentration within a particular timeframe, but in practice, only a limited number of emissions pathways satisfy the additional constraints on rates of temperature change, rates of sea level rise, and so forth that may contribute to particular definitions of danger. Pathways may also be rejected due to lack of technical feasibility or high cost of implementation (Wigley et al., 1996; Metz et al., 2001).

In its most elaborate form, the simultaneous application of several criteria to limit the choice of emissions pathway is called the *tolerable window* approach (Petschel-Held et al., 1999; Toth et al., 2003). Two simplified versions that have been applied are a *population-based* (Parry et al., 2001) and a *sustainability approach* (Azar and Lindgren, 2003; Wright and Erickson, 2003; Schneider and Azar, 2001; O'Neill and Oppenheimer, 2002). The *population-based approach*, which resembles standard risk assessment, provides a means to implement avoidance of dangers falling into three of the IPCC “reasons for concern” - significant increase in extreme events, and net negative regional and global costs of impacts. This approach has been used to examine the increase in populations at risk for water shortages, hunger, malaria, and coastal flooding.

Distributional issues come into play, including equity considerations, ability of a country or group to adapt, and regional resource availability. A particular limitation of this approach is that although hundreds of millions of people are exposed to these risks, there is no bright line for distinguishing undesirable impacts from truly dangerous ones. In most scenarios, increasing population and secondarily, changing climate, gradually push more and more (or, in some cases, fewer and fewer) people into the risk category, so the number exposed increases (or decreases) gradually as the temperature or concentration rises.

The sustainability approach is particularly suited to implementing a definition of danger falling in two other IPCC categories, threats to unique ecosystems and species (Hare, 2003; Thomas et al., 2004), and significant threat of climatic discontinuities. Here, true physical and biological thresholds (Rial, 2004) may come into play,¹⁴ potentially

providing sharp distinctions among different temperatures or concentrations according to risk. Among the phenomena discussed in the context of Article 2 are shutdown of the thermohaline circulation and disintegration of the WAIS (O'Neill and Oppenheimer, 2002), forest-to-grassland transition in tropical and subtropical regions (Higgins, et al., 2002) and mass bleaching and demise of coral reefs (Hoegh-Guldberg, 1999). Recently, thresholds arising from the interaction of social and ecological systems have also been considered (Barnett & Adger, 2003; cf. Stipp, 2004). This area, which reaches outside the IPCC categorization, will merit further attention in the future.

While the sustainability approach may appear to provide the sort of dividing lines that would simplify life for policymakers, in reality the uncertainties of each phenomenon are substantial, blurring the lines, as in the case of the disintegration of the WAIS, discussed above. This difficulty seriously complicates the choice of distinct climate danger zones. Problems might be circumvented by invoking the precautionary principle, for example, by determining the target based on the lowest plausible value for its temperature or concentration threshold. Using this approach, two recent studies (O'Neill and Oppenheimer, 2002; and Schneider and Azar, 2001) have argued that a plausible definition for danger is any concentration greater than 450 ppm.

Alternatively, a benefit-cost framework (expected utility maximization), largely originating in the work of Nordhaus and co-workers (Nordhaus, 1992; Nordhaus and Boyer, 2000; Keller et al., 2000), may be used to simultaneously define danger and to prescribe optimal emissions pathways that would implement Article 2. This approach,

which may be particularly suitable for implementing avoidance of dangers falling in categories 3 and 4 above, contrasts sharply with the tolerable windows approach, variants of which prescribe economic constraints on emissions pathways but without explicit optimization.

A considerable advantage of the benefit-cost approach is that its assumptions are transparent and value judgments are rendered quantitatively. While it is true that a limited set of economic criteria are used to choose the ultimate objective, it is also true that the sufficiency of the basis of judgment can be analyzed quantitatively. In addition, this approach implicitly accounts for impacts arising from the rate of climate change during the transient period before stabilization is achieved, an aspect sometimes lacking in applications of the sustainability approach (Hammit, 1999).

Shortcomings of welfare maximization in its application to the climate problem have been discussed at length (Azar and Lindgren, 2003; Tol, 2003). With regard to Article 2 in particular, equity concerns arise because impacts and damages are aggregated globally or across different geographic regions, without taking account of whether, for example, flooding may affect residents of one locality differently than residents of another. The prospect that climate change impacts may affect persons of different ages differently (Bunyavanich et al., 2003) compounds the equity concerns. Representation of irreversible damages (e.g., loss of species) that cannot be readily monetized (Corfee-Morlot and Höhne, 2003) is also problematic. Also generally absent is evaluation of ancillary benefits of GHG emission control measures, such as improvements in human

health due to control of conventional pollutants, particularly in developing and transition economies (Metz et al., 2001; OECD, 2002; Dudek et al., 2003). One recent study highlights the potential national and global security concerns that may accompany abrupt climate changes (Stipp, 2004), yet welfare maximization has only begun to grapple with such changes (Alley et al. 2003).

Nevertheless, progress has been made in aligning cost-benefit methods with the framework of Article 2. Previous applications yielded modest optimal emission reductions in the near-term (i.e., the next few decades; Nordhaus and Boyer, 2000) and optimal concentrations did not approach a stable value in this century. Recent studies taking into account the potential economic damages associated with crossing climate thresholds such as a collapse of the thermohaline circulation, however, suggest optimal pathways that entail significant near term reductions in allowable GHG emissions, as well as severely constrained long term concentrations (e.g., Keller et al. 2003, Alley et al, 2003).

Some studies explicitly combine optimization with an absolute constraint on concentration or temperature (Nordhaus, 1992; Keller et al., 2004) in order to draw on the different strengths of optimization and sustainability frameworks. Probabilistic approaches to implementing definitions of danger are now being explored as well (Keller et al., 2003; Keller et al., 2004). All such efforts will doubtless need to be updated in light of emerging policy proposals for addressing a wider range of GHG emissions (see, e.g., Santilli et al., 2003; Folha de São Paulo, 2003).

Which of these frameworks did the Framework Convention Parties intend to use to determine and implement danger? The answer is unclear. One former U.S. negotiator indicated that those who wanted to ensure that danger would be defined solely in economic terms “lost” their argument when language that would have required calculation of various costs including those of societal adaptation was excluded from the mandatory text of Article 2 (Reinstein, R., personal communication).¹⁵ Instead, language about the time frame for natural ecosystem adaptation was included. On the other hand, at least one author (Bodansky, 1993) believes that the text is neutral between adaptation and prevention, that “to the extent that adaptation to climate change is possible, such change could be viewed as benign.” Here it is worth noting that while cost-efficiency of mitigation is alluded to in Article 4 of the Convention, weighing costs and benefits is not. Yet the tension between environmental limits and optimization, apparent in the contrasting views of Mitchell and Abelson in the 1977 NRC report, remains very much alive in today’s discussions.

One option might be simply to postpone further elaboration of Article 2 until at least many of the uncertainties have been resolved. That course, however, brings into play a further set of confounding dangers. Because the problem is cumulative, delay increases the risk that particular pathways for stabilization will be effectively foreclosed (O’Neill & Oppenheimer, 2002; Oppenheimer & Peterson, 2003). Preliminary model studies of the tradeoffs among uncertainty, learning, irreversible change, damages, and mitigation

provide no definitive answers but do suggest that postponing decisions is not necessarily the optimal approach (Webster, 2002).

4.0 Conclusion

The long-term perspective, codified in Article 2 of the UN Framework Convention on Climate Change, has been a keystone of scientific, economic, and political components of climate policy discussions since the 1970s. With the adoption of the Framework Convention, attention in policy circles gradually shifted to the near term, particularly to the development, ratification, and implementation of the Kyoto Protocol. Until very recently, questions related to Article 2 were left largely unexplored.

Two related points emerge clearly from consideration of the history of long-term climate limits: Both U.S. and European government policy as well as U.S. and European expertise played pivotal roles in the evolution of the concepts underlying Article 2. As President Bush himself reaffirmed in 2002, the need for a long-term view, and a clear definition of Article 2, is now and has long been, a principal feature of U.S. climate policy (Bush, 2002). Renewed diplomatic attention to Article 2 may provide a route for re-engagement of the US in the international climate regime. Similarly, developing countries do not appear to have been active in discussions of Article 2, paying more attention to issues related to burden-sharing (for example, a proposal advanced by Brazil in 1997, discussed in Baumert, 2002). Yet the active engagement of these countries is a prerequisite for the emergence and implementation of any long-term target.

As to the meaning of Article 2, the political and diplomatic process through which it evolved paid much more attention to physical and biological vulnerabilities as sources of danger, and rather less attention to economic issues. Ethical and cultural considerations have been nearly absent. In the case of the latter, this neglect must surely be remedied in order for an adequate definition of danger to emerge. The history with regard to the role of economics is complex, with the concept of an optimum climate present in the earliest days of this issue. Rather than choosing a target by welfare optimization, there is successful precedent in US environmental law for giving economic considerations a secondary role in the definition of objective, but a primary role in implementation of the goal.¹⁶

Important lessons with regard to the process for building consensus can also be found in this history. Nongovernmental organizations, intergovernmental agencies of the UN, and individual experts in addition to a few governments, played key roles in development of the climate regime in general, and Article 2 in particular (Haas and McCabe, 2001). The impetus for interpreting Article 2 is unlikely to come in the first instance from the formal negotiation process among the Parties to the UNFCCC (Pershing and Tudela, 2003). One or perhaps several parallel private efforts, informed by the IPCC but with only modest government participation, may provide the intellectual spadework that ultimately generates governmental action (Oppenheimer and Petsonk, 2003).

A bundle of questions remain about the theory and mechanics of defining and implementing Article 2: What generic risks, and what specific impacts should guide long-term policy? What geographic scope is important? Populations of what size should be of concern? In what way should the distribution of impacts geographically, or among socioeconomic or cultural groups, be taken into account, as opposed to total human welfare? How much should natural ecosystems weigh in this accounting? Should costs and benefits be weighed quantitatively to define “dangerous” or should environmental criteria supplemented by bounds on implementation costs be employed, as in the tolerable window approach? What does a target for a global quantity actually mean, and how would responsibility for its attainment be apportioned and enforced? How much time do nations have to deliberate these questions before important pathways for avoiding dangerous climate changes are foreclosed? To what extent can a decision to follow one pathway be adjusted in the future in light of further learning?

The difficulty of resolving these issues will continually lead policy makers and others to ask: Does near term policy really need to be guided by Article 2? Can incremental measures, strung together, produce a desirable outcome? And, finally, could policies guided by technological goals rather environmental goals (Edmonds & Stokes, 2003) achieve such a result? With greenhouse gas concentrations rapidly approaching levels that are dangerous according to one or more of the proposed criteria, outcomes of the great geophysical experiment (Revelle and Seuss, 1957) may prevent us from completing the socio-political experiment which could answer these questions.

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Notes

¹ The COOL dialogue discussed means of implementing a 50-80% emissions reduction in the Netherlands by 2050. In 2003, the UK committed to a 60% reduction by 2050 (Blair, Prime Minister T., 2003), while Germany announced its commitment to seek to limit warming to not more than two degrees over the next century (Trittin, Minister J., 2003). Moreover, in late November 2003 the world's third-largest oil company, BP, announced that "based on our understanding of the range of the uncertainty around the scientific views, we've come to the judgment that to avoid serious impact upon societies or the environment it is necessary to stabilise atmospheric concentrations of greenhouse gases at around 500-550 parts per million" (Browne, Lord J., 2003). And in his February 2004 Speech from the Throne, Canada's new prime minister, Paul Martin, signaled that it is time to take a long-term perspective, as the UK and other EU member states are doing (Anderson, Minister D., 2004).

² Depending on assumptions made about the carbon cycle, stabilization might require enhancement of sinks, e.g., geologic sequestration, or approaching zero emissions over a multi-century time scale. But at least temporary stabilization at finite CO₂ emissions over the timescale of policy consideration, one or two centuries, was certainly plausible given models of the time (and today).

³ "Mr. President, the United States faces a serious dilemma. Our efforts to reduce our dependence on imported oil may include some exceptional dangers to our environment....The problem is the increased accumulation of carbon dioxide in the atmosphere caused by the use of fossil fuels" (Ribicoff, 1979a).

⁴ "We believe it to be important that the phenomenon of increasing carbon dioxide (CO₂) concentration in the atmosphere be widely understood as a major consideration in discussions of future energy policy....The CO₂ problem arises from both the total amount of CO₂ added to the atmosphere and the rate at which it is being added. If the rate were sufficiently slow, most of the CO₂ would be taken up by the oceans and there would be little effect on the atmosphere. If the rate is rapid and increasing geometrically, as has been the trend for the past 30 years with the ever increasing worldwide use of fossil fuels, a large fraction of the added CO₂ remains in the air. If this trend continues, the CO₂ content of the air will be doubled before the middle of the next century. By the year 2000, the projected increase over the present value of 335 parts per million will be much smaller, about 30 to 60 parts per million....We recognize that a synthetic fuel program based on coal is a major energy supply option. If, in the future, it appears that continuing increases in atmospheric CO₂ are likely to have significant deleterious effects, then it may be necessary to shift to other alternatives which introduce less CO₂ into the atmosphere. We therefore urge that provisions be made now to assure that such other alternatives will be available if and when they are needed" (NRC, 1979).

⁵ The Montreal Protocol's initial targets of a freeze followed by a 50% cut in production of ozone-depleting chemicals by industrial countries by the year 1999 were understood at the time to be scientifically rather arbitrary. The initial targets were politically and economically feasible, given the relatively few companies manufacturing ozone-depleting chemicals and the economic incentives that the protocol created for marketing more ozone-friendly substitutes. But immediate stabilization of stratospheric ozone concentrations at then-current levels would have required, according to USEPA, an immediate 85 percent production cut (Hoffman, 1986; Benedick, 1998; Benedick, 1999).

⁶ For additional discussion of the role played later by the AGGG targets, see Haas and McCabe, 2001.

⁷ See note (5) above.

⁸ Moreover, the understanding that the ozone hole first appeared when total chlorine exceeded atmospheric concentrations of roughly 2 parts per billion, while never formalized as a goal of the Montreal Protocol, nevertheless guided negotiations that led ultimately to a mandatory phase-out of ozone-depleting chemicals, with a 10-year grace period for developing countries (Montreal Protocol, 1987, as amended; Fay, K., personal communication).

⁹ Although President George H.W. Bush had announced as early as November 1989 that the United States had agreed with other industrialized nations that, "stabilization of carbon dioxide emissions should be achieved as soon as possible," and that it was "timely to investigate quantitative targets to limit or reduce carbon dioxide emissions" (White House 1989), at the insistence of the United States, the "return to 1990 levels" provision of Article 4.2 of the Framework Convention was made voluntary (UNFCCC, 1992).

¹⁰ Notwithstanding the increased focus on concentrations, a 1992 National Research Council report on the policy implications of greenhouse warming, like the NRC's 1983 report, contained virtually no analysis of concentration limits or stabilization scenarios (NRC, 1992).

¹¹ Article 7.2(a) of the Convention requires the Conference of the Parties to "Periodically examine the obligations of the Parties and the institutional arrangements under the Convention, in light of the objective of the Convention, the experience gained in its implementation and the evolution of scientific and technological knowledge."

¹² To remind the reader, while natural variations of GHG concentrations are generally small in the time frame of interest here, climate does vary randomly over such periods and also because of changes in solar intensity and in Earth's volcanic dust veil (which reflects sunlight). Natural and social systems influenced by climate also vary independently of climate. In addition, anthropogenic land-use changes and emissions of reflective particles affect climate. How to account for these fluctuations in determining what levels of greenhouse forcing are dangerous present critical, but as yet not much studied, issues.

¹³ Quantitative assessment of the regional impacts of particular climate changes on natural and social systems is in its infancy. Limited geographic resolution and other uncertainties in global climate models prevent accurate forecasts of many impacts following from particular GHG concentrations that occur on spatial scales on the order of a few thousand kilometers or smaller. . Quantitative estimates of the relation between emissions and concentrations, provided by carbon cycle models, have a broad range of uncertainty, due to relatively poor understanding of many important processes (like the absorption of carbon by forested ecosystems under varying carbon dioxide concentrations, temperatures, and precipitation rates).

¹⁴ See Levy et al (2001) for a discussion of the history of the use of thresholds for regulating other environmental problems.

¹⁵ Hortatory text was included in the famous "Principles". See UNFCCC Article 3.3 ("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 climate change, 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. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.”

¹⁶ See, e.g., the U.S. Clean Air Act, which mandates that EPA set targets for criteria pollutants based on health considerations, not net benefits; and that economic considerations be considered only in determining how best to meet the health-based standards (Reitze, 1999).

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