Available online at www.sciencedirect.com
SCIENCE DIRECT®
Environmental Science & Policy xxx (2005) xxx–xxx
Environmental Science & Policy
www.elsevier.com/locate/envsci

Misdefining ''climate change'': consequences for science and action

Roger A. Pielke Jr.

Center for Science and Technology Policy Research, University of Colorado, 1333 Grandview Avenue, UCB 488, Boulder, CO 80309-0488, USA

Abstract

The restricted definition of ''climate change'' used by the Framework Convention on Climate Change (FCCC) has profoundly affected the science, politics, and policy processes associated with the international response to the climate issue. Specifically, the FCCC definition has contributed to the gridlock and ineffectiveness of the global response to the challenge of climate change. This paper argues that the consequences of misdefining ''climate change'' create a bias against adaptation policies and set the stage for the politicization of climate science. The paper discusses options for bringing science, policy and politics in line with a more appropriate definition of climate change such as the more comprehensive perspective used by the Intergovernmental Panel on Climate Change.

Keywords: Climate policy; Science policy

1. Introduction

In December 2004, delegates from around the world met in Buenos Aires, Argentina at the Meeting of the 10th Conference of Parties (COP-10) to the Framework Convention on Climate Change (FCCC). Continuing its long tradition of providing summaries from such international meetings the International Institute for Sustainable Development reported on ''the core problem of addressing adaptation in the context of the UNFCCC.'' The report continues,

Adaptation is an integral part of development, and as such, no project directed at adaptation will fall squarely within the scope of the UNFCCC, but will rather have components that include other aspects of development, such as disaster preparedness, water management, desertification prevention, or biodiversity protection. This problem was highlighted with great honesty by a GEF [Global Environment Facility] project director who said that when projects fall under many categories, rather than being easily adopted due to their clear synergies and multiple benefits, they become more complex and difficult to approve due to a series of successive revisions needed by different focal areas. To add to this problem, adaptation projects are generally built on, or embedded in, larger national or local development projects and, therefore, the funding by the GEF would only cover a portion of the costs. In other words, if a country seeks funding for a project on flood prevention, the GEF would only be able to finance a portion proportional to the additional harm that floods have caused or will cause as a result of climate change, and the rest would have to be co-financed by some other body. The plea from LDCs [Least Developed Countries], particularly the SIDS [small island developing states], lies precisely on this paradox, in that even if funds are available in the LDC Fund, their difficulty of finding adequate co-financing, and the costly and cumbersome calculation of the additional costs, renders the financial resources in the LDC Fund, in practice, almost inaccessible (International Institute for Sustainable Development, 2004).

In other words, in order for LDCs to receive funding for adaptation under the GEF, it is necessary for them to identify the marginal impacts of human-caused climate change above those impacts that these countries already experience. For most LDCs, for whom the toll of climate-related events is viscerally tangible, the fact that these resources lie out of their reach because of the difficulties in cleanly identifying the exact part resulting from climate change must seem like an experience out of a Joseph Heller novel.

While the need for action on climate change seems clear the FCCC, the predominate global approach to climate change, is hopelessly mired in political gridlock over its

E-mail address: pielke@colorado.edu.

1462-9011/$ – see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envsci.2005.06.013

Kyoto Protocol. If present trends continue, it will fall short of its own goals. This paper argues that gridlock has resulted in large part from the basic design of the FCCC, which at its foundation is based on a highly restricted definition of ''climate change'' focused only on changes in climate that result from greenhouse gas forcing of the climate system. This restricted definition may make sense from some abstract, theoretical perspective, but it has also set the stage for inaction in the real world of politics and policy—it creates a built-in bias against adaptation and sets the stage for the politicization of climate science. Supporters of business-as-usual could not have wished for a more effective recipe for protracted inaction. This paper seeks to explain how ''climate change'' has been misdefined under the FCCC, discusses some of the implications and suggests a possible alternative.

2. Understanding the basic argument: a thought experiment as prologue

Consider the following thought experiment. Let us begin with the world as described by the FCCC. In this world the human use of fossil fuels leads to emissions of greenhouse gases, which lead to changes in the climate, which in turn result in undesirable effects on people and the environment. Let us call this FCCC World. Now imagine an alternative world. In this alternative world everything is as it is in FCCC World, but with one important difference. In this world instead of the human use of fossil fuels leading to changes in climate, the source of change is instead a small strengthening of the intensity of the Sun. In Bright Sun World the changes in climate and effects on people and the environment are identical to FCCC World; the two worlds differ only in the source of the climate forcing.

In my classes on policy related to climate change, I introduce this thought experiment and then ask the students to discuss how their policy recommendations might differ between FCCC World and Bright Sun World. Someone in every class starts out by saying that in Bright Sun World we would not need any policy beyond business-as-usual because the source of change is natural, coming from the Sun. This is quickly challenged when someone else points out that we would still want to adopt policies to respond to the effects—for instance, in either scenario if you live on the coast you will still want to build a wind-resistant home and buy hurricane insurance.

This typically leads someone to claim that in Bright Sun World adaptation policies would be preferred and in FCCC World mitigation would be preferred. A whole set of Socratic questions then follows to uncover the hidden assumptions that support these conclusions, such as: if we expect to modulate the Earth system in desirable ways if the cause of change is anthropogenic, then why would we not wish to modulate the system if the cause is natural (we dam rivers after all, someone inevitably chimes in)?[1] If we would focus on adaptation in Bright Sun World why would not we also focus on adaptation in FCCC World? Is changing the energy habits of six billion people really more tractable than modulating the global earth system via carbon sequestration or other strategies of geoengineering? Such questions quickly begin to reveal many assumptions that underlie approaches to dealing with global climate change, assumptions that are rarely discussed, much less evaluated. One of these assumptions focuses on organizing policy around the source of the forcing of the climate system, which is the primary approach under the FCCC.

Under the FCCC the term ''climate change'' is 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 over comparable time periods.'' This narrow definition stands in stark contrast to the broader definition used by the Intergovernmental Panel on Climate Change (IPCC), the United Nations group tasked with assessing climate science for policy makers, which states that climate change is ''any change in climate over time whether due to natural variability or as a result of human activity.''[2]

Of these two different definitions, John Zillman, an active participant in the IPCC, wrote in 1997,

> There is a serious inconsistency between what the IPCC Working Group (WG) I scientific community regard as ''climate change'' and what constitutes ''climate change'' in the language of the Convention – an inconsistency which cannot help but lead to confusion in the public mind on one of the threshold issues of the debate, viz whether human activities have, or have not, yet been conclusively shown to have affected global climate. According to the Convention, ''climate change'' is that which is due to human activity and is in addition to natural variability. The IPCC WG I, on the other hand, regards ''climate change'' as including natural variations. Thus, when the IPCC says ''climate has changed over the past century,'' it is simply saying the climate now is not the same as it was a century ago (whatever the cause) whereas the FCCC listener will reasonably interpret such a statement as the scientific community affirming that human influence has changed climate over the past century (Zillman, 1997).[3]

So if the sun were to get a little more intense resulting in ''climate changes,'' these would in fact not qualify as climate changes under the FCCC definition.[4] Moreover, climate changes resulting from human-caused influences on the climate system other than those that affect the chemistry

[1] Compare Keith (2001).
[2] On the IPCC definition, which is a product of its Working Group I, see its Second Assessment Report (IPCC, 1995, p. 56).
[3] See also Zillman (2003a).
[4] This notion may or may not be too far from reality, consider, e.g. Willson and Mordvinov (2003).

of the atmosphere – such as particulates like black soot or land use effects on climate – are similarly excluded under the FCCC (Hansen et al., 1998; Pielke, 2002).

This thought experiment sets the stage for this paper's argument that the FCCC has misdefined climate change. The paper proceeds with a short critique of the current approach to climate policy as proposed under the FCCC. The paper then discusses the illogic of Article 2 of the FCCC, which calls for prevention of dangerous interference in the climate system. The paper concludes with a discussion of alternative approaches to climate policy that may offer greater likelihood of moving beyond the present gridlock to the benefit of people and the global environment.

3. A critique of the current approach

One consequence of the FCCC's narrow definition of climate change is that it necessarily subjugates all of climate policy to energy policy (Fig. 1).[5] The logic of this approach is straightforward: human emissions of greenhouse gases will lead to changes in the global climate. These changes will have significant impacts on environment and society. The logic of the response is equally straightforward. Reducing emissions will avoid the increased frequency and magnitude of climate impacts on environment and society that might occur if emissions are not controlled. According to this logic, the predicted impacts of climate change should prompt decision makers to develop "energy policies *designed to alleviate such problems* (Herbert, 1999, emphasis added)." There is a rich set of invocations of this logic, such as when President Bill Clinton stated in his 2000 State of the Union Address, "If we fail to reduce the emission of greenhouse gases, deadly heat waves and droughts will become more frequent, coastal areas will flood, and economies will be disrupted. That is going to happen, unless we act (Clinton, 2000)."

Proponents of this approach view energy policy as a "big knob" on the "control panel" of global policy makers who seek to modulate the behavior of the climate system (Pielke et al., 2000). Such a metaphor was made explicit in 1990 when a United States Senator likened the Earth to a car, noting "when we have a car problem, we take the car to a repair shop or fix it ourselves using the operator's manual. For the global environment, however, there are no mechanics or manuals." He continued, arguing that society must "obtain the knowledge we need to train the mechanics and write the manual before this global machinery is irreversibly damaged (Hollings, 1990)." The latest incarnation of the control panel metaphor are calls to tune atmospheric concentrations of greenhouse gases in such a way as to maintain a specific temperature increase, such as 2 °C (see, e.g. O'Neill and Oppenheimer, 2002). Energy policy is widely considered to be the only policy tool that can control the "global machinery" and, according to the linear logic of Fig. 1, thereby intentionally modulate future climate impacts.

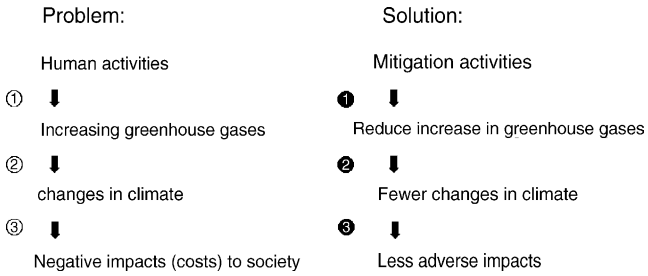

Fig. 1. Mitigation logic.

The logic of both the problem and solution appear elegant and theoretically sound. The Framework Convention simply reverses the lines of causality present in the problem and is based upon an assumption that "a global problem requires a global approach."[6] The solution further assumes that international action to reduce energy policy can have a direct and significant effect on future climate impacts on environment and society. Most effort in the political and scientific debate has addressed defining the problem, i.e., the questions illustrated in numbers under "Problem" in Fig. 1: Is there a problem? How bad is it? What are the consequences? The three-part structure of the IPCC – science-impacts-mitigation – follows explicitly the causality associated with the definition of the problem identified in Fig. 1. By comparison the IPCC has devoted little systematic effort evaluating the proposed solution and its prospects for success (i.e., the chain of causality highlighted in Fig. 1).

The research and experience at hand suggests that the solution cannot succeed. Consider the following three points, organized to follow the causality implied by Fig. 1.

3.1. Will the current approach to mitigation reduce the increase in greenhouse gases?

Experience since the 1992 Earth Summit, including promulgation of the 1997 Kyoto Protocol, is sobering from the standpoint of the future potential for nations to stabilize their greenhouse gas concentrations. In addition, a growing body of academic policy research concludes that the Kyoto Protocol is unworkable for technical and political reasons (see, e.g., Victor, 2001b; Nordhaus and Boyer, 1999; Laird,

[5] This section updates and extends a critique of the current approach first presented in Pielke (1998). See also, Pielke and Sarewitz (2003), Pielke et al. (2000), Sarewitz and Pielke (2000), and Pielke (1994).

[6] This quote is illustrative and comes from the Clinton Administrations 1997 climate change proposal (United States White House, 1997). This view of the structure of the policy response does not appear to have any correlation with political positions on global warming. For instance the International Iron and Steel Institute states that "A global problem requires a global approach (International Iron and Steel Institute, 2002)".

2000; Pielke et al., 2000; Hammitt, 2000). This body of work is significant because, unlike other critics of the Kyoto Protocol, it *accepts the findings of the IPCC* that climate change presents a problem, but finds fault in the mechanics of the proposed solution. David Victor writes that

Even as it becomes clear that most governments could not deliver on their Kyoto promises, powerful environmental groups and influential Green parties redoubled their support for the [Kyoto] treaty rather than admit the need for adjustment. Under this pressure, every government in every industrialized nation has officially pretended the protocol was workable (Victor, 2001b).[7]

One of the important roles of policy research in any policy setting is to ask and answer, "Can the policy work with respect to its stated objectives?" In the case of climate change, a growing consensus concludes that, irrespective of the importance of the problem or logic of the solution, the Kyoto Protocol is highly unlikely to succeed according to its own goals. Proponents of the Kyoto Protocol argue that it is just the first step to more ambitious mitigation policies. Opponents argue that it is a dead end. In either case, these differing views agree that considerable additional action would be needed beyond to Kyoto Protocol to achieve the goals of the FCCC. The difficulties implementing the Kyoto Protocol highlight the significant political challenges facing full implementation of the FCCC. Today the Kyoto Protocol is increasingly discussed in terms of its significance for international relations and diplomacy (e.g., between the US and Europe) than for its ability to address the challenges of climate change.[8]

3.2. Will a reduction greenhouse gas emissions lead to fewer climate changes?

Consider for the purposes of argument that the technical and political barriers to the Kyoto Protocol are overcome and that it becomes fully implemented. What can be said about its potential effects on future climate? Tom Wigley, a scientist at the National Center for Atmospheric Research in Boulder, Colorado and long-time participant in climate change assessment activities, sought to answer this question following Kyoto using a climate model similar to those underlying the IPCC report. He ran a climate model under two scenarios: in the first, future greenhouse gas emissions were projected to follow a business-as-usual path, and in the second emissions were constrained under the assumption that the Kyoto Protocol is fully and successfully implemented. Wigley found that

[The] rate of slow-down in temperature rise is small, with no sign of any approach to climate stabilization.... The influence of the [Kyoto] Protocol would, furthermore, be undetectable for many decades (Wigley, 1998).

The finding is significant because it is based upon the same methodologies used by the IPCC to project that human emissions of greenhouse gases will have a discernible influence on the future climate. Thus, if one accepts the conclusions of the IPCC, one is also bound to accept that the Kyoto Protocol if successfully implemented would have an indiscernible influence on future climate.

An essential, but frequently overlooked conclusion of the IPCC is that "even under the most ambitious abatement policies some climate change is likely to occur," (IPCC, 1995) and that "anthropogenic climate change will persist for many centuries" (IPCC, 2001).[9] Consequently, if the IPCC is correct, then the world will inevitably see some degree of climate change in the coming century and that the Kyoto Protocol or even more ambitious policies will be unable to prevent under any emissions future.[10] Hence, prevention of all future climate impacts is simply not a viable option. This is of course not an argument against mitigation activities, but frank recognition that under no scenario does conceivable mitigation policies alone fully address the problems to society posed by climate.

3.3. Will fewer climate changes lead to less adverse impacts?

The linear causality suggested under the logic of the FCCC underplays the fact that the future impacts of climate on environment and society are a joint function of climate *and* society. We have written elsewhere that

Policymakers may well make large changes in energy policy (and future emissions) without significantly affecting actual climate impacts. In other words, even if a theoretical case could be made that energy policy could be used intentionally to modulate future *climate*, other factors will play a much larger role in creating future *impacts* and are arguably more amenable to policy change (Pielke et al., 2000, op. cit., p. 258, emphasis in original).

Fig. 2 illustrates this point in the context of tropical cyclones (called hurricanes in the western hemisphere, and typhoons in the eastern hemisphere). The bottom bars show IPCC conclusions for the sensitivity of future impacts (i.e., other things being equal) related to changes in the frequency and intensity of tropical cyclones for 2050 relative to 1995, based on the results of three methodologies labeled in the legend for their respective authors.[11] Alternatively, the top bars show the sensitivity of global tropical cyclone impacts

[7] See also, Victor (2001a).
[8] See, e.g., Purvis (2004).
[9] The first quote is from the Second Assessment report of the IPCC (IPCC, 1995), the second quote is from the Policymakers summary of the Third Assessment Report (IPCC, 2001).
[10] Furthermore, this analysis neglects potential changes in climate that might result from other human or non-human causes, such as those resulting from land-use change or ocean circulation changes. See, e.g., Kabat et al. (2003).
[11] In Fig. 2, the bottom bars assume a 10% increase in tropical cyclone maximum potential intensity.

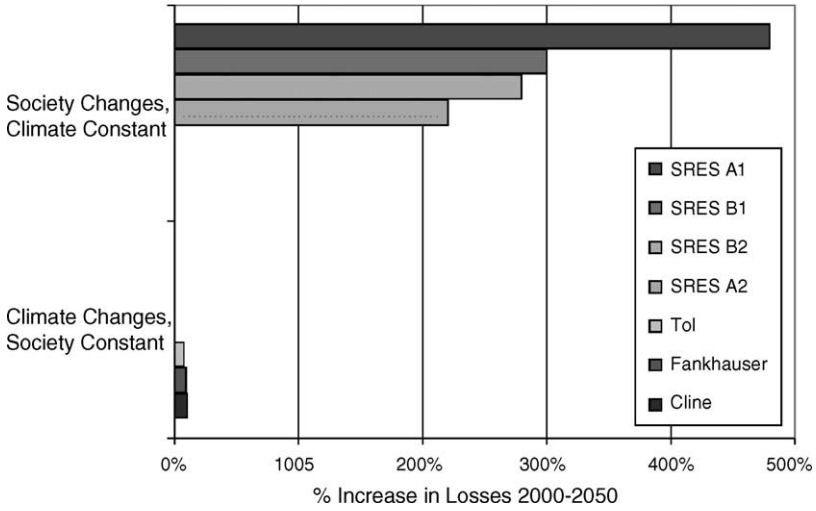

Fig. 2. Sensitivity analysis of 2XCO2 worldwide global tropical cyclone loss estimation for 2050.

in 2050 relative to 1995 for four IPCC population and wealth scenarios (i.e., other things, including climate, being equal).[12] The sensitivity analysis summarized in Fig. 2 illustrates that *under the IPCC assumptions* climate impacts related to tropical cyclones are 22 to 60 times more sensitive to societal changes than to climate changes.

We suggest that "the case of tropical cyclones is not unique, and could be considered representative of the relative contributions of climate and society to future weather- and climate-related impacts (Pielke et al., 2000, op. cit., p. 264)." Consider another example from a recent exchange in Science magazine on malaria, another condition often cited as a primary reason for concern about climate change. In the exchange between Indur M. Goklany, of the Office of Policy Analysis, U.S. Department of the Interior and Sir David A. King, Chief Scientific Adviser to U.K. Prime Minister Tony Blair and Head of the Office of Science and Technology, Goklany writes that King justifies action to mitigate climate change based on the argument that because "of continued warming, millions more people around the world may in future be exposed to the risk of hunger, drought, flooding, and debilitating diseases such as malaria. Poor people in developing countries are likely to be most vulnerable (Goklany, 2004)." Goklany's response places climatic factors into their broader context:

. . . the population at risk of malaria (PAR-M) in the absence of climate change is projected to double between 1990 and the 2080s, to 8,820 million. However, unmitigated climate change would, by the 2080s, further increase PAR-M by another 257 to 323 million. Thus, by the 2080s, halting further climate change would, at best, reduce total PAR-M by 3.5% [=100 × 323/(323 + 8,820)]. On the other hand, reducing carbon dioxide emissions with the goal of eventually stabilizing carbon dioxide at 550 ppm would reduce total PAR-M by 2.8% at a cost to developed nations, according to King, of 1% of GDP in 2050, or about $280 billion in today's terms. But malaria's current annual death toll of about 1 million could be halved at an annual cost of $1.25 billion or less, according to the World Health Organization, through a combination of measures such as residual home spraying with insecticides, insecticide-treated bednets, improved case management, and more comprehensive antenatal care. Clearly, implementing such measures now would provide greater malaria benefits over the next few decades than would climate stabilization at any level. It would also reduce vulnerability to malaria from all causes – man-made or natural – now and in the future.

King's response to Goklany simply avoids the issue:

There is no real choice between action on climate change and action on poverty, disease, hunger, and other millennium development goals. These are part of the same sustainable development agenda. Climate change is already affecting developing countries, and it is the poorest regions of the world – such as Africa and Southeast Asia – that are most at risk. The many people who have died and the millions now homeless through the monsoon flooding in Bangladesh will bear witness to that. This kind of event can be expected to become more frequent and more extreme as global warming accelerates, exacerbated by rising sea levels (King, 2004).[13]

Similar findings have resulted from research into floods and other extreme events as well as water resources and other areas (see, e.g., Pielke and Downton, 2000; Changnon

[12] For technical details of the calculation, see Pielke et al. (2000), op. cit.

[13] More generally on malaria, see Tol and Dowlatabadi (2001) and Reiter (2001).

et al., 2000; Vörösmarty et al., 2000; Lettenmaier et al., 1999). The implications of this research are that policies related to climate have an important dimension that is unrelated to energy policy, namely human and environmental vulnerability to weather and climate.[14] An analogous argument would apply to ecosystem functioning in addition to societal impacts.

To summarize the critique of the current approach:

- Policy research and recent experience offer little reason to expect that the Kyoto Protocol, and by extension the Framework Convention on Climate Change, can succeed according to their own goals.
- Even assuming full implementation of the Kyoto Protocol, climate would still change according to the IPCC, and would be indistinguishable for many decades from a world without Kyoto's implementation.
- Climate is only one of many variables related to the impacts of weather and climate on society and the environment. In some (most?) cases other societal changes are more important determinants of future impacts than is climate per se.

These conclusions suggest that the ongoing debate over the Kyoto Protocol with respect to future climate and climate impacts misses much of what is important in the climate issue. Whether nations implement or do not implement the Kyoto Protocol, it is hard to see anything more than symbolic value in the outcome. It is nonetheless critical not to undervalue the symbolic value, e.g., in international relations.[15] One could make a convincing argument that full implementation of the Kyoto Protocol makes sense on the basis of non-climate factors. But from the standpoint of climate change, perhaps the worst outcome is prolonged debate over the Kyoto Protocol and its derivatives taking scarce attention and resources away from actions that might actually result in a tangible difference on society and the environment.

4. The misdefinition of climate change is centered on the illogic of FCCC Article 2

As the example from COP-10 presented in the introduction to this paper indicates, the focus in the FCCC on only those climate changes that result from anthropogenic greenhouse gas emissions means that a prerequisite for action, politically if not practically, is the ability to identify climate changes related to the greenhouse gas forcing and to ascribe a cause to those changes. In the jargon of the climate community, identification of climate changes and their causes is called "detection and attribution." The need for science to detect and attribute climate change is codified in the FCCC Article 2, which states that the ultimate objective of the FCCC is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous atmospheric interference with the climate system (United Nations, 1992)."[16] Under the FCCC, without such detection and attribution there is no reason to act, as there would be no evidence of "climate change" under its narrow definition.

The notion of "dangerous interference" is consistent with the FCCC definition of climate change. The implementation of the FCCC in terms of specific emissions concentration targets thus depends upon determining some threshold above which climate change becomes dangerous and detecting that change and attributing it to greenhouse forcing. If climate change is not detected, or is not attributed to greenhouse gas forcing, then the FCCC has no formal basis for action. While this approach may have created a clear separation between the FCCC and broader development activities of the United Nations, it has also influenced the dynamics of climate policy.

One consequence is that this approach contributes to the mapping of pre-existing interests onto the notion of "dangerous." If the "threshold" of dangerous interference is subject to interpretation then it becomes possible (and convenient) for various adherents to map the threshold onto their political positions determined through other means. For example, the Administration of George W. Bush claims that "no one can say with any certainty what constitutes a dangerous level of warming, and therefore what level must be avoided (United States White House, 2001)." One scholar observes that "like a Rorschach test, reactions to the Kyoto Protocol generally reveal more about the speaker than about the protocol (Bodansky, 2002)." Not only does the notion of "dangerous interference" emplace science as arbiter of what ultimately are political considerations that science cannot resolve, it is inconsistent with how climate actually affects society and the environment.[17] Article 2 is an obstacle to effective action on climate change because of its focus on the notions of both "dangerous" and "interference."

The notion of a "dangerous" interference suggests that a threshold exists that separates a "dangerous" interference from one that is "not dangerous." But the impacts of climate

[14] For discussion see Pielke and Sarewitz (2005) and Sarewitz and Pielke (2005).

[15] Compare Zillman (2003b), "I have worried ... about the Kyoto Protocol; in particular whether, given the very small impact that even full implementation of Kyoto could be expected to have on global warming, the substantial economic cost of the emissions reductions it requires is justified. In my view such justification as exits for proceeding with Kyoto must be based on the symbolic significance of making a start on a much bigger challenge ..."

[16] The FCCC further states: "Adverse effects of climate change' means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare (United Nations, 1992)."

[17] There is a large literature on the notion of "dangerous interference". Several recent pieces are: O'Neill and Oppenheimer (2002), Schneider (2001), and Parry et al. (2001).

are not the result of a process in which climate disrupts a static society or the environment. Reality is much more complex for two reasons. First, society and the environment undergo constant and dramatic change as a result of human activities. People build on exposed coastlines and floodplains. Development, demographics, wealth, policies and political leadership change and evolve over time. These factors and many more contribute to the vulnerability of populations to the impacts of climate-related phenomena. Different levels of vulnerability help to explain, e.g., why a tropical cyclone that makes landfall in the United States has profoundly different impacts than a similar storm that makes landfall in Central America. Consequently, the degree to which climate is ''dangerous'' differs around the world and further depends upon how different communities value security and risk. The IPCC asserts that defining ''dangerous interference'' (as found in Article 2 of the FCCC) necessitates ''value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk (IPCC, 2001).'' In a world where for many communities climate is already quite ''dangerous,'' identifying a threshold becomes a matter of judgment, subject to differing perspectives and interests (Dessai et al., 2004).[18] But ''dangerous'' also is variable in an objective sense, precisely because vulnerability varies with levels and patterns of development and other societal factors.

But not only is the notion of what is ''dangerous'' problematic, so too is the notion of ''interference.'' This is the case for two reasons. First, because the adverse effects of climate are the consequence of human and climate (and other environmental) variables, there are many reasons why a particular community or ecosystem may experience adverse climate impacts under conditions of climate stationarity (i.e., under conditions of no climate change, human caused or otherwise). For example, a historic flood in an unoccupied floodplain may be noteworthy, but a similar flood in a vastly populated floodplain is a disaster. The development of the floodplain could be the change that results in a phenomenon becoming dangerous, thus the *interference* that leads to adverse impacts results from human occupancy of the floodplain. Under the FCCC, any such change would not be cause for action, even though adverse effects may still result. Climate occurs in a context of dramatic and rapid societal changes that affect not only society itself, but the environment in which society inhabits. In many contexts, the ''interference'' of climate to human or environmental systems is considerably less significant than the ''interference'' to such systems resulting from large-scale societal changes (Pielke and Sarewitz, 2005, op. cit.). The sensitivity analysis on tropical cyclones presented in the previous section is a vivid example of this situation.

[18] More generally, on challenges in the management of highly complex systems. See Gunderson and Holling (2002) and Kasperson and Kasperson (2001).

A second challenge in documenting ''interference'' has to do with the nature of the global earth system itself. Climate changes at all times scales and for many reasons, not all of which are fully understood or quantified. Consider e.g. abrupt climate change. A review paper in *Science* observes that ''such abrupt changes could have natural causes, or could be triggered by humans and be among the 'dangerous anthropogenic interferences' referred to in the [FCCC]. Thus, abrupt climate change is relevant to, but broader than, the FCCC and consequently requires a broader scientific and policy foundation (Alley et al., 2003).'' In an important respect, the phrase ''climate change'' is redundant.

Consider another example. A group of researchers suggests that changes in regional land use patterns have potential to alter regional and global climate,

> The Kyoto Protocol to the UNFCCC is concerned with limiting ''anthropogenic carbon dioxide equivalent emissions of the greenhouse gases . . .'' And yet, anthropogenic climate change also involves other elements of the Earth's energy balance and the internal distribution of energy within the Earth's climate system. These can be driven by land-surface changes at local and regional scales; and they are quite separate from changes driven by the concentrations of greenhouse gases in the atmosphere . . . Changes in land surface can result in emission or removal of CO_2 to the atmosphere and thus to changes in the Earth's radiation balance. Changes in land surface can also change the radiation balance by altering the Earth's surface albedo. In addition, changes in land surface can alter the fluxes of sensible and latent heat to the atmosphere and thus the distribution of energy within the climate system; and in so doing can alter climate at the local, regional, and even global scale. Mitigation strategies that give credits or debits for changing the flux of CO_2 to the atmosphere but do not simultaneously acknowledge the importance of changes in the albedo or in the flows of energy within the Earth system might lead to land management decisions that do not produce the intended climatic results (Marland et al., 2003).

These researchers raise the possibility that efforts to extract carbon dioxide from the atmosphere and store it in vegetation may have the perverse effect of changing the energy balance of the earth system, resulting in an additional source of human disruption of the climate system, the exact opposite of the intentions for sequestration. Preventing interference in the climate system by focusing only on greenhouse gas forcing makes sense from a scientific perspective only if other potential natural and human-caused changes in the climate system are by comparison insignificant. This assumption appears to be the perspective of the FCCC, which in 1996 observed that its definition of ''climate change'' did not differ significantly from that of the IPCC because ''in many instances the two uses will in effect be the same, and this is particularly true for projections of climate change over the next century (IPCC, 1996a).'' *For the IPCC and FCCC usages of the phrase ''climate change''*

to be equivalent there must be no other significant sources of changes to the climate system other than greenhouse gas forcing. If this assumption about the basic science of the global earth system is incorrect, then the FCCC has set the stage for significant problems in its implementation.[19]

In short, the idea that science can ''detect and attribute'' interference in the climate system related only to greenhouse forcing is problematic in a world where climate changes on all time scales because of a range of both natural and human forcings. And even if science could detect and attribute climate change, such changes occur in a world in which climate already dangerous in varying degrees, based both differing perceptions of what is or is not ''dangerous'' but also because of decisions that affect socioeconomic conditions that, in turn, affect vulnerability, and hence ''danger.'' Because of the illogic of Article 2 of the Framework Convention, considerably more attention has been paid not only by researchers but also political advocates to the details of detection and attribution than to providing decision makers with useful knowledge that might help them to improve energy policies and reduce vulnerabilities to climate.[20]

5. Consequences of misdefining climate change for policy

This paper does not address *why* the FCCC and IPCC have different definitions of the phrase ''climate change.'' This could have occurred for intellectual reasons, e.g., the assumption that the climate system is otherwise stationary absent an anthropogenic greenhouse gas forcing, for pragmatic reasons, e.g., there are already international efforts focused on development and natural disasters, or political reasons, e.g., a focus on greenhouse gases locates the problem in the domain of energy policy. Whatever the underlying reasons for the different definitions, it is clear that it has had a pathological impact on the policy and politics of climate change. Specifically, the FCCC definition of climate change leads to bias against adaptation and politicization of science.

5.1. A bias against adaptation

For decades, the options available to deal with climate change have been clear. We can act to *mitigate* the future impacts of climate change by addressing the factors that cause changes in climate. And we can *adapt* to changes in climate by addressing the factors which cause societal and environmental vulnerabilities to the effects of climate. Mitigation policies focus on either controlling the emissions of greenhouse gases or capturing and sequestering those emissions. Adaptation policies focus on taking steps to make social and environmental systems more resilient to the effects of climate. Effective climate policy will necessarily require a combination of mitigation and adaptation policies. However, climate policy has for the past decade reflected a bias against adaptation in large part due to the differing definitions of climate change.

The bias against adaptation is reflected in the schizophrenic attitude that the IPCC has taken toward the definition of climate change. Its working group on science prefers (and indeed developed) the broad IPCC definition. The working group on mitigation prefers the FCCC definition, and the working group on impacts, adaptation, and vulnerability uses both definitions.[21] One result of this schizophrenia is an implicit bias against adaptations policies in the IPCC reports, and by extension, in policy discussions. As the limitations of mitigation-only approaches emerge and policy making necessarily turns toward adaptation, addressing this bias becomes increasingly important.

Under the FCCC definition, ''adaptation'' refers only to actions in response to climate changes attributed to greenhouse gas emissions. Absent the increasing greenhouse gases, climate – by definition – would not change and the adaptive measures would be unnecessary. This means that under the FCCC adaptation can have only costs because the measures represent costs that would incurred only because of the changes in climate that result from greenhouse gas emissions. That is, the narrow definition excludes other benefits of adaptive measures. This exclusion of benefits may seem like a peculiarity of accounting but it has practical consequences. One IPCC report used the FCCC definition to discuss climate policy alternatives in exactly this way, affecting how policy makers perceive alternative courses of action (IPCC, 1996b). The IPCC report discusses mitigation policies in terms of both costs and benefits, but discusses adaptation policies only in terms of their costs. The bias against adaptation comes from disallowing consideration of its ancillary benefits while by contrast mitigation's ancillary benefits are considered. This ''stacks the deck'' against adaptation policies and ensures that mitigation will look better from a benefit-cost standpoint.

The bias against adaptation is particularly unfortunate not only because the world is already committed to some degree of climate change (as the IPCC makes inescapable), but also because many communities around the world are maladapted to current climate. Many, if not most, adaptive measures would make sense even if there were no greenhouse gas-related climate change (Pielke and Sarewitz, 2005, op. cit.). The FCCC definition of climate change provides little justification for efforts to reduce societal or ecological vulnerability to climate variability and change

[19] A recent NRC report suggests that this key assumption may be incorrect. See NRC (2004b).

[20] See, e.g., the controversy over Chapter 8 in ''Paranoia Within Reason: A Casebook on Conspiracy as Explanation'' (on detection and attribution) of the IPCC Second Assessment report (Lahsen, 1999).

[21] A comprehensive treatment of the inconsistency in definitions of ''climate change'' goes beyond the present scope but is a subject worth further investigation. See, e.g., Larsson (2004).

beyond those impacts caused by greenhouse gases. From the perspective of the broader IPCC definition of climate change, adaptation policies also have benefits to the extent that they lead to greater resilience of communities and ecosystems to climate change, variability and particular weather phenomena.

The restricted perspective of the FCCC definition makes adaptation and mitigation seem to be opposing strategies rather than complements, and creates an incentive to recommend adaptive responses only to the extent that proposed mitigation strategies cannot prevent changes in climate. From the perspective of adaptation, the FCCC approach serves as a set of blinders, directing attention away from adaptation measures that make sense under any scenario of future climate change. As nations around the world necessarily move toward a greater emphasis on adaptation in the face of the unavoidably obvious limitations of mitigation-only policies, reconciling the different definitions of climate change becomes more important.

5.2. Politicization of climate science

A February 2003 article in *The Guardian* relates details of climate policy debate in Russia that show the absurdity of the present approach (Brown, 2003). The article reports that several Russian scientists ''believe global warming might pep up cold regions and allow more grain and potatoes to be grown, making the country wealthier. They argue that from the Russian perspective nothing needs to be done to stop climate change (2003).'' They believe that not only will climate change not result in ''dangerous interference'' but that it will result in what might be called ''beneficial interference.'' As a result, ''To try to counter establishment scientists who believe climate change could be good for Russia, a report on how the country will suffer will be circulated in the coming weeks (2003).'' Science is thus enlisted not only to show that human activities affect the climate, but to show that resulting changes will become dangerous.

Why does this matter? The FCCC forces political combatants to assert certainty about the climate future (dangerous or not?) when in reality uncertainty may be irreducible. Such certainty is necessary to promote or campaign against ratification of the Kyoto Protocol. For example, Paul Jeffries, head of environment policy at Britain's Royal Society for the Protection of Birds, observes, ''Russia's ratification [of the Protocol] is vitally important. If she doesn't go ahead, years of hard-won agreements will be placed in jeopardy, and meanwhile the climate continues to change (2003).'' Any scientific result that suggests that Russia might benefit from climate change stood in opposition to Russia's ratification. Science that shows the opposite supported Russia's participation. In this manner, the science of climate change becomes irrevocably politicized. Left in the wake of this situation remains the challenges of promulgating Russian agricultural policies, which depend upon many more factors than just climate, and need to be considered under conditions of irreducible uncertainty about the details of the climate future. The FCCC definition of climate change provides a political motivation for science that shows or dispels ''dangerous interference.'' The FCCC makes it difficult to consider, much less enact, policies that do not depend upon certainty in future outcomes or are robust with respect to the climate future, irrespective of the source of change (Lempert and Schlesinger, 2000). There is no room under FCCC Article 2 for uncertainty about the climate future; it will either be dangerously interfered with or it will not. Conversely, the IPCC notes that climate change requires ''decision making under uncertainty (IPCC, 2001).''

Accordingly, some dismiss uncertainty by arguing that there will be no benefits of climate change. For example, according to Klaus Topfer, Executive Director of the United Nations Environment Programme, ''There are no winners, only losers, in the climate change scenario. Now is time to act collectively and decisively (United Nations Environment Programme, 2001).'' These anecdotes reflects the prescience of an analysis made by Glantz (1995, p. 44),

> If winners and losers are identified with some degree of reliability, the potential for unified action against the global warming may be reduced. Winners will not necessarily want to relinquish any portion of their benefits to losers in order to mitigate the impacts of their losses.[22]

Glantz further notes that ignoring the issue of winners and losers can be problematic as well,

> While scientists and policymakers formally discuss only losses associated with a global warming, others may perceive that there will be positive benefits as well . . . This could sharply reduce the credibility of the proponents for taking action, lessening the chances for *any* response, preventive, mitigative, or adaptive (1995, p. 44).

Not only does Article 2 create a bias against adaptation the FCCC forces claims to certainty which inevitably lead to a politicization of the science of climate change (Sarewitz, 2004). An approach that is more consistent with the realities of science and needs of decision makers would begin with a framing commensurate with these realities. Under the FCCC climate change is viewed as a single problem, when in fact it is many.

6. An alternative: reconsidering climate and energy policies from a broader perspective on climate change

Effective global warming policy does not depend upon consensus on whether or not future climate changes will

[22] The notion that there may be both winners and losers under climate change is not new, see, e.g., Glantz (1995).

constitute "dangerous interference." So as a point of departure, it is worth considering how policies might be different if the framework for action was based on the IPCC definition of climate change.[23] This alternative perspective argues that as a first step it is necessary to consider climate policy as distinct from energy policy and to take those steps already recognized as serving common interests, commonly called "no regrets." The underlying hypothesis is that these common interest actions will be more effective in addressing issues of climate change than would be continuation of the present approach.

6.1. Climate policy

Climate policy refers to the actions that organizations and individuals take to reduce their vulnerability to (or enhance opportunities afforded by) climate change (and variability). From this perspective governments and businesses are already heavily invested in climate policy. Most familiar are responses to extremes like hurricanes and floods, but many industries, such as energy and agriculture are dependent upon seemingly more mundane climate attributes such as (relatively) small variations in temperature and precipitation. Consider the following examples:

- *Extreme events*. The International Red Cross estimates that in the 1990s around the world, weather and climate events are directly related to more than 300,000 deaths and more than US$ 700 billion in damages. Floods alone affected 1.5 billion people and caused more than US$240 billion in damages.[24] Many of these human losses are preventable and economic losses are manageable with today's knowledge and technologies.[25] Steps taken to reduce societal vulnerability to extreme events could make society more resilient to future climate variability and change.
- *Public health*. The impacts of disease dwarf those of extreme events. The International Red Cross estimates that in 1999 alone 13 million people died around the world from infectious disease, most of which "could be prevented for US$ 5 per person (IFRC, 2000, op. cit., p. 9)." Malaria alone kills between 1 and 2.6 million people a year, yet as Jeffery Sachs observes

  > [A]dvances in biotechnology ... point to a possible malaria vaccine. One would think that it would be high on the agendas of both the international community and private pharmaceutical firms. It is not ... the malaria problem reflects, in microcosm, a vast range of problems facing [poor countries] in health, agriculture, and environmental management. They are profound, accessible to science and utterly neglected (Sachs, 1999).

  The World Health Organization estimates that 500,000 malaria deaths a year could be prevented with US$ 1 billion in additional spending on strengthened health systems (IFRC, 2000, op. cit, p. 15).[26]
- *Ecosystem sustainability*. A 2000 report of the President's Council of Advisors on Science and Technology concluded, "the continued loss of biodiversity will greatly impact human society as well as ecosystems and their valuable services (Alonso et al., 2001)." The factors responsible for biodiversity loss include habitat loss, invasive species, overuse of resources, and pollution in addition to changes in climate. Potential policy responses therefore focus on restoration and management to foster sustainable ecosystems in the face of an inevitable human impact.[27]

Each of these issues is worthy of consideration on its own merits, but typically only becomes part of climate policy when used by advocates on both sides as ammunition in the debate over the Kyoto Protocol and "dangerous interference." But clearly, improving policies in the context of extreme events, public health, and ecosystem sustainability depends on a wide range of factors other than changes to global energy policy. And in some cases, energy policy is far from an important element in more effective outcomes in these areas. Consequently, a common interest objective of climate policy would be to improve societal and environmental resilience to climate, independent of the causes of variability and change.

6.2. Energy policy

Decoupling climate policy from energy policy would not mean that the nations of the world should then forget about the climate effects of greenhouse gas emissions. To the contrary, a new approach might even offer an opportunity to address energy policy in a more comprehensive manner, focusing on pollution, efficiency, and independence, thereby perhaps removing the barrier of scientific uncertainty and creating a broader justification for early action. A return to energy efficiency and conservation as a central organizing theme for global energy policy would diminish the obstacle presented by global warming as a political issue, and elevate other the other reasons for cleaner use of fossil fuels. Lee Raymond, CEO of ExxonMobil a company famously opposed to implementation of the Kyoto Protocol, has stated "This world shouldn't be wasting energy, and it absolutely does waste energy; we shouldn't use any natural resource inefficiently, as the world will eventually run out

[23] The results of IPCC Working Group I can be found at http://www.meto.gov.uk/sec5/CR_div/ipcc/wg1, Working Group II at http://www.usgcrp.gov/ipcc/, and Working Group III at http://www.rivm.nl/env/int/ipcc.
[24] Data from International Federation of Red Cross and Red Crescent Societies (IFRC, 2000).
[25] For a comprehensive overview, see Mileti (2000).
[26] See also TDR (2004).
[27] For discussion see World Resources Institute (2000).

(Vaitheeswaran, 2001).''[28] This apparent window of opportunity led *The Economist* to suggest a perspective on energy policy arguably more in line with common interests, ''A more suitable target for green ire would be the gross inefficiency of the world's energy systems (2001).''

Some clearly believe that that the global warming issue can carry all of energy policy on its back. The Boston Globe (2001) editorialized that:

> . . . the energy shortage and global warming can be cured by the same medicine: reducing US reliance on fossil fuels. The energy efficiency standards required to meet the Kyoto goals would also ease the United States out of its oil dependence.

The arguments provided in this paper (and by others elsewhere) suggest that this ''two birds with one stone'' approach has been and will continue to be a dramatic failure with respect to both climate and energy policies. Alternatively, an energy policy focused on the human and environmental costs of fossil fuels, where costs are defined beyond simple markets economics to include their typically ignored broader human and environmental impacts, an ample case can be made for increased efficiency, greater conservation, enhanced energy research and development, and technology diffusion.

For many of the poorest nations of the world the future threats posed by climate pale in comparison to the immediate benefits to be achieved by greater use of energy. As Naresh Chandra, Ambassador to the U.S. from India commented,

> At the moment we [in India] have a much higher and urgent priority, and that is eradication of poverty, removal of backwardness, and improving the level of living of our people. That is a much greater, urgent necessity than the long-term aim of controlling greenhouse gas emissions . . . We have a huge power shortage in India (Newshour, 1997).

Thus, energy policy, as well as climate policy, has dimensions that go well beyond consideration of climate change to include issues such as pollution, efficiency, and independence. Each of these issues forms an immediate, practical grounding on which to address the many policy problems that comprise the climate change issue. Any progress on these problems would have the additional benefit of reducing greenhouse gases emissions, arguably at a pace much quicker than the current approach.

7. Concluding thoughts

There is no doubt that FCCC and the Kyoto Protocol represent tremendous diplomatic accomplishments. Negotiations have raised awareness of countries around the world to the importance of climate and focused them on shared objectives. But at the same time, this approach does not get at the core societal and environmental problems of climate change. One essential factor in motivating positive evolution of the FCCC is to consider how it might be structured around a broader definition that allows for a clearer distinction of energy policy and climate policy. Such an approach offers no panacea to dealing with the challenges of climate change, but at a minimum it offers a radial reframing of the issue that may open up discussion of paths not seen and options not previously considered.

In terms of climate policy, such a reframing would mean a transition from a focus on ''dangerous anthropogenic interference'' to a focus on the impacts and opportunities related to climate, recognizing that the word ''climate'' by definition includes the notion of variability and change. With such a framing the FCCC could form the basis for international climate and energy policies that actually serve to diminish environmental degradation and improve human lives.[29]

The basic principle of a more mature international climate policy is that the climate ''winners'' of the world would bear some responsibility for the climate ''losers'' of the world. Of course, the international community has for many years discussed disaster relief, debt forgiveness, and development assistance. A new climate policy would bring these oft-neglected issues of climate policy (but central elsewhere) into the core of discussions about how to reduce the future impacts of climate on society and environment. When, at some point in the future, the distribution of climate winners and losers changes, then the relative roles and responsibilities of nations would change accordingly. In this manner, the FCCC could lead to immediate, demonstrable results. There would be no need to rely on documentation of changes in climate or attribution to a human cause as the basis for action. The impacts of climate are painfully apparent and are with us today, not in some hypothetical future.

A modified FCCC might focus on ''catalytic . . . processes that will enable, encourage, and facilitate actions that will help nations protect their populations from the consequences of climate change and help them reduce their production of greenhouse gases (Laird, 2000, op. cit.; Rayner and Malone, 1997).'' This would include the mechanisms of technology transfer already being considered. The IPCC could also serve as a resource of scientific information for participating countries to prioritize needs assessments, assistance, aid, and development resources, rather than its current narrow focus on the needs of those focused on ratification of the FCCC. Arguably, the IPCC has begun to move in this direction. Actual decisions about how best to reduce societal and environmental vulnerability to climate would be made in local contexts based on assessments of costs, benefits, and risks as

[28] On ExxonMobil's political view of climate change see *The New York Times* op-ed page of 16 August 2000 in which ExxonMobil ran an advertisement titled ''Political cart before a scientific horse.''

[29] Alternative proposals are presented by Rayner (2004), Pielke and Sarewitz (2003), Laird (2000, op. cit.), Victor (2001a, op. cit.), Hammitt (2000), Coppock (1998), and Brunner and Klein (1999).

well as local values about climate as a resource and a threat. The IPCC might empower decision makers to follow the old environmental adage, ''think globally, act locally'' rather than the misplaced current focus on ''think globally, act globally.''

An approach that decouples climate policy and energy policy implies a more productive role for the scientific community in contributing to the information needs of decision makers. There would remain need for periodic snapshots of the state of the science, as currently done via the IPCC. But the sorts of questions to be addressed would change dramatically. There would be a decreased emphasis on research that seeks to attribute or predict changes in climate over century-long time scales, because policy action would no longer be dependent upon a presumption of accurate predictions. There would be instead an increased emphasis on research that seeks to understand the interactions of climate, society, and environment in ways that lead to vulnerabilities (as well as opportunities) in local and regional contexts, rather than at global scales. Research would focus more on providing information useful for addressing problems of today – such as malaria and extreme events – that we know will also be problems of tomorrow. An emphasis on policy-centered research under conditions of irreducible uncertainty would help decision makers to evaluate what sorts of actions work to reduce vulnerabilities and which ones do not. Science would thus place itself in role of being a tool for policy action rather than a tool for political advocacy. The science has been moving in this direction, but too slowly and it is held back by the focus of the FCCC.[30]

It seems clear that inherent limitations in accurately predicting the future climate and attributing specific climate events to human emissions of greenhouse gases will for the foreseeable future remain uncertain enough to fuel continued public debate (Sarewitz et al., 2000). And even if uncertainties about the future were to be reduced, as Glantz has noted there is no reason to believe that would make the politics any easier. On the one hand, this suggests that scientists will continue to benefit from the intractable status quo as each side of the debate demands greater certainty (Pielke and Sarewitz, 2003). But on the other hand, more research could very easily lead to greater uncertainties and thus there exists a real possibility that the scientific community could suffer a backlash of public criticism that not only affects their role in the climate issue, but also public support for science more generally (Crichton, 2004). Climate science offers the promise of great benefits to humanity; it is incumbent upon the scientific community to reshape the current debate in ways that enhance the contributions of research to worthwhile objectives.

A critical first step in reshaping the current debate is to highlight the pervasive consequences of the narrow definition of ''climate change'' used under the FCCC and considering how policy might be more effective if designed under the more appropriate definition used by the IPCC. With a reframed policy that decouples climate policy and energy policy, the community of scientists, advocates, and diplomats might find the surprising result that they will not only see multiple paths to reduce human and environmental vulnerability to climate but also create a more effective possibilities to achieving in practice a goal of greenhouse gas reductions.

[30] In the case of the U.S., see the recent NRC evaluation of the proposed Climate Change Science Program (NRC, 2004a).

References

Alley, R.B., Marotzke, J., Nordhaus, W.D., Overpeck, J.T., Peteet, D.M., Pielke Jr., R.A., Pierrehumbert, R.T., Rhines, P.B., Stocker, T.F., Talley, L.D., Wallace, J.M., 2003. Abrupt climate change. Science 299, 2005–2010.

Alonso, A., Dallmeier, F., Granek, E., Raven, P., 2001. Biodiversity: Connecting with the tapestry of life. Smithsonian Institution/Monitoring and Assessment of Biodiversity Program and President's Committee of Advisors on Science and Technology, Washington, DC.

Bodansky, D., 2002. US Climate Policy after Kyoto: Elements for Success. Carnegie Endowment for International Peace Policy Brief, http://www.ceip.org/files/pdf/Policybrief15.pdf.

Boston Globe, 2001. Global Flip-flop. The Boston Globe.

Brown, P., 2003. Russia urged to rescue Kyoto pact. The Guardian, http://www.guardian.co.uk/climatechange/story/0,12374,903094,00.html.

Brunner, R., Klein, R., 1999. Harvesting experience: a reappraisal of the U.S. Climate Change Action Plan. Policy Sci. 32, 133–161.

Changnon, S., Pielke Jr., R.A., Changnon, Sylves, R.T., Pulwarty, R., 2000. Human factors explain the increased losses from weather and climate extremes. Bull. Am. Meteorol. Soc. 81 (3), 437–442.

Clinton, W., 2000. State of the Union address. The White House, Office of the Press Secretary, http://clinton4.nara.gov/WH/SOTU00/sotu-text.html.

Coppock, R., 1998. Implementing the Kyoto Protocol. Issues in Science and Technology, http://www.issues.org/issues/14.3/coppock.htm.

Crichton, M., 2004. State of Fear. Harper Collins.

Dessai, S., Adger, W.N., Hulme, M., Turnpenny, J., Köhler, J., Warren, R., 2004. Defining and experiencing dangerous climate change. Clim. Change 64, 11–25.

Glantz, M.H., 1995. Assessing the impacts of climate: the issue of winners and losers in a global climate change context. In: Zwerver, S., van Rompaey, R.S.A.R., Kok, M.T.J., Berk, M.M. (Eds.), Climate Change Research: Evaluation and Policy Implications. Elsevier, Amsterdam, pp. 41–54.

Goklany, I., 2004. Climate change and malaria. Science 306, 55–56 http://www.sciencemag.org/cgi/reprint/306/5693/54a.pdf.

Gunderson, L., Holling, C.S., 2002. Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, DC.

Hammitt, J.K., 2000. Climate Change Won't Wait for Kyoto. The Washington Post, p. A39.

Hansen, J.E., Sato, M., Lacis, A., Ruedy, R., Tegen, I., Matthews, E., 1998. Climate forcings in the industrial era. Proc. Natl. Acad. Sci. 95, 12753–12758 http://www.usyd.edu.au/su/envsci/students/notes/2004/air/forcings1.pdf.

Herbert, B., 1999. In America; Dark Clouds. New York Times.

Hollings, E., 1990. Congressional Record, p. 17739, http://thomas.loc.gov/cgi-bin/query/F?r101:1:./temp/~r101cxv35I:e28860.

IFRC, 2000. World Disasters Report. International Federation of Red Cross and Red Crescent Societies. Oxford University Press, New York, http://www.ifrc.org.

International Institute for Sustainable Development, 2004. Summary of the Tenth Conference of the Parties to the UN Framework Convention on Climate Change: 6–18 December 2004. Earth Negotiations Bull. 12 (260), http://www.iisd.ca/vol12/enb12260e.html.

International Iron and Steel Institute, 2002. The Steel Industry. Industry Sector Report for the United Nations World Summit on Sustainable Development, http://www.natural-resources.org/minerals/general-forum/docs/pdfs/UNEP%20WSSD%20Sector%20Report%20-%20Steel.pdf.

IPCC, 1995. IPCC Second Assessment Report: Climate Change. Cambridge University Press.

IPCC, 1996a. Scientific Assessments: Consideration of the Second Assessment Report of the Intergovernmental Panel on Climate Change. Addendum, The Science of Climate Change: Contribution of Working Group I of the Intergovernmental Panel on Climate Change, http://unfccc.int/cop4/07a01r1.htm.

IPCC, 1996b. IPCC Second Assessment Synthesis of Scientific-Technical Information relevant to interpreting Article 2 of the UN Framework Convention on Climate Change. Summaries for Policymakers of the three Working Group Reports, http://www.unep.ch/ipcc/pub/sarsyn.htm.

IPCC, 2001. IPCC Third Assessment Report: Climate Change 2001: Synthesis Report. Summary for Policy Makers, http://www.ipcc.ch/pub/un/syreng/spm.pdf.

Kabat, P., Claussen, M., Dirmeyer, P.A., Gash, J.H.C., Bravo de Guenni, L., Meybeck, M., Pielke, Sr., R.A., Vörösmarty, C.J., Hutjes, R.W.A., Lütkemeier, S. (Eds.), 2003. Vegetation, water, humans, and the climate—a new perspective on an integrative system. A Synthesis of the IGBP Core Project, IGBP-Biospheric Aspects of the Hydrologic Cycle. Springer, New York.

Kasperson, J.X., Kasperson, R.E., 2001. Global Environmental Risk. United Nations University Press, Earthscan, Tokyo.

Keith, D.W., 2001. Geoengineering the climate: history and prospect. Annu. Rev. Energy Environ. 25, 245–284.

King, D., 2004. Response to climate change and malaria. Science 306, 57 http://www.sciencemag.org/cgi/reprint/306/5693/54a.pdf.

Lahsen, M., 1999. The Detection and Attribution of Conspiracies: The Controversy Over Chapter 8. In: Marcus, G.E. (Ed.), Paranoia Within Reason: A Casebook on Conspiracy as Explanation, vol. 6, Late Editions Series of Cultural Studies for the End of the Century.

Laird, F., 2000. Just Say No to Greenhouse Gas Emissions Targets. Issues in Science and Technology, http://www.issues.org/issues/17.2/laird.htm.

Larsson, E., 2004. Science and policy in the international framing of the climate change issue. Master of Science These. Environmental Science Programme, Department of Thematic Studies, Campus Norrkoping, Linkopings universitet, SE-601, 74 Norkopping, Sweden.

Lempert, R.J., Schlesinger, M.E., 2000. Robust strategies for abating climate change. Clim. Change 45 (3/4), 387–401.

Lettenmaier, D.P., Wood, A.W., Palmer, R.N., Wood, E.F., Stakhiv, E.Z., 1999. Water resources implications of global warming: a U.S. regional perspective. Clim. Change 43 (3), 537–579.

Marland, G., Pielke Sr., R.A., Apps, M., Avissar, R., Betts, R.A., Davis, K.J., Frumhoff, P.C., Jackson, S.T., Joyce, L., Kauppi, P., Katzenberger, J., MacDicken, K.G., Neilson, R., Niles, J.O., Dutta, D., Niyogi, S., Norby, R.J., Pena, N., Sampson, N., Xue, Y., 2003. The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Clim. Policy 3, 149–157 http://www.fs.fed.us/pnw/corvallis/mdr/mapss/marland2003.pdf.

Mileti, D., 2000. Second Assessment of Natural Hazards. Joseph Henry Press.

Newshour, 1997. Unfair Burden? Newshour Transcript, http://www.pbs.org/newshour/bb/environment/july-dec97/india_12-9.html.

Nordhaus, W., Boyer, J., 1999. Requiem for Kyoto: an economic analysis. Energy J. Spec. Issue Costs Kyoto Protocol 93–130.

NRC, 2004a. Implementing climate and global change research: a review of the Final U.S. Climate Change Science Program Strategic Plan. Committee to Review the U.S. Climate Change Science Program Strategic Plan, National Research Council of the National Academies, Washington, DC, http://www.nap.edu/catalog/10635.html.

NRC, 2004b. Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties. National Research Council, Washington, DC, http://www.nap.edu/catalog/11175.html.

O'Neill, B.C., Oppenheimer, M., 2002. Dangerous climate impacts and the Kyoto protocol. Science 296 (5575), 1971–1972 http://www.sciencemag.org/cgi/content/full/296/5575/1971?ijkey=jVqsttm/anqYc&keytype=ref&siteid=sci.

Parry, M., Arnell, N., McMichael, A., Nicholls, R., Martens, P., Kovats, S., Livermore, M., Rosenweig, C., Iglesias, A., Fischer, G., 2001. Millions at risk: defining critical climate change threats and targets. Global Environ. Change 11 (3), 181–183.

Pielke Jr., R.A., 1994. Scientific information and global change policy-making. Clim. Change 28, 315–319.

Pielke Jr., R.A., 1998. Rethinking the role of adaptation in climate policy. Global Environ. Change 8 (2), 159–170.

Pielke Jr., R.A., Downton, M.W., 2000. Precipitation and damaging floods: trends in the United States, 1932–1997. J. Clim. 13, 3625–3637.

Pielke Jr., R.A., Klein, R., Sarewitz, D., 2000. Turning the big knob: an evaluation of the use of energy policy to modulate future climate impacts. Energy Environ. 11, 255–276.

Pielke Jr., R.A., Sarewitz, D., 2003. Wanted: scientific leadership on climate. Issues in Science and Technology, 27–30, http://www.issues.org/issues/19.2/p_pielke.htm.

Pielke Jr., R.A., Sarewitz, D., 2005. Bringing society back into the climate debate. Popul. Environ. 26 (3), 255–268.

Pielke Sr., R.A., 2002. Overlooked issues in the U.S. National Climate and IPCC assessments. Clim. Change 52, 1–11.

Purvis, N., 2004. Leaving America behind: the real importance of the Kyoto treaty. International Herald Tribune, http://www.iht.com/articles/2004/12/15/edpurvis_ed3_php.

Rayner, S., 2004. The International Challenge of Climate Change: UK Leadership in the G8 and EU. A memorandum to the Environmental Audit Committee of the United Kingdom's House of Commons, 23 November.

Rayner, S., Malone, E., 1997. Zen and the art of climate maintenance. Nature 390, 332–334.

Reiter, P., 2001. Climate change and mosquito-borne disease. Environ. Health Perspect. 109 (S1), 141–161 http://ehp.niehs.nih.gov/members/2001/suppl-1/141-161reiter/reiter-full.html.

Sachs, J., 1999. Helping the world's poorest. The Economist 17–20 http://economist.com/displaystory.cfm?story_id=231482.

Sarewitz, D., 2004. How science makes environmental controversies worse. Environ. Sci. Policy 7 (5), 385–403.

Sarewitz, D., Pielke Jr., R.A., 2000. Breaking the global-warming gridlock. The Atlantic Monthly 286 (1), 55–64.

Sarewitz, D., Pielke Jr., R.A., 2005.In: Rising Tide: The Tsunami's Real Cause. The New Republic.

Sarewitz, D., Pielke, Jr., R.A., Byerly, R. (Eds.), 2000. Prediction: Science, Decision Making and the Future of Nature. Island Press, Washington, DC.

Schneider, S., 2001. What is 'dangerous' climate change? Nature 411, 17–19.

TDR, 2004. Multilateral Initiative on Malaria (MIM). Special Programme for Research and Training in Tropical Diseases, http://www.who.int/tdr/diseases/malaria/mim.htm.

Tol, R., Dowlatabadi, H., 2001. Vector-borne diseases, development and climate change. Integr. Assess. 2, 173–181 http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/iavector.pdf.

United Nations Environment Programme, 2001. UNEP Press Release, Global Warming: Asia Vulnerable, http://www.roap.unep.org/html/nr/nr01-01.htm.

United Nations, 1992. United Nations Framework Convention on Climate Change, http://unfccc.int/resource/docs/convkp/conveng.pdf.

United States White House, 1997. Background Material on President Clinton's Climate Change Proposal, http://www.state.gov/www/global/global_issues/climate/background.html.

United States White House, 2001. President Bush Discusses Global Climate Change. Office of the Press Secretary, http://www.whitehouse.gov/news/releases/2001/06/20010611-2.html.

Vaitheeswaran, V., 2001. Survey: energy, a brighter future? The Economist, http://www.economist.com/surveys/showsurvey.cfm?issue=20010210.
Victor, D., 2001a. The Collapse of the Kyoto Protocol and the Struggle to Slow Global Warming. Princeton University Press, Princeton, NJ.
Victor, D., 2001b. Piety at Kyoto Didn't Cool the Planet. The New York Times.
Vörösmarty, C.J., Green, P., Salisbury, J., Lammers, R.B., 2000. Global water resources: vulnerability from climate change and population growth. Science 289 (5477), 284–288 http://www.sciencemag.org/cgi/content/full/289/5477/284?ijkey=1MhrTYh/br7M6&keytype=ref&siteid=sci.
Wigley, T.M.L., 1998. The Kyoto Protocol: CO_2, CH_4 and climate implications. Geophys. Res. Lett. 25 (13), 2285–2288.
Willson, R.C., Mordvinov, A.V., 2003. Secular total solar irradiance trend during solar cycles 21–23. Geophys. Res. Lett. 30 (5), 1199.
World Resources Institute, 2000. World resources 2000–2001: people and ecosystems: the fraying web of life. United Nations Development Programme, United Nations Environment Programme, World Bank, Washington, DC, http://pubs.wri.org/pubs_description.cfm?PubID=3027.
Zillman, J., 1997. The IPCC: A View from the Inside. Australian APEC Study Centre, http://www.apec.org.au/docs/zillman.pdf.
Zillman, J., 2003a. Climate Change. Australian Bureau of Statistics, 2003 Yearbook Australia, pp. 34–44.
Zillman, J., 2003b. Our Future Climate: World Meteorological Day Address 2003. Commonwealth Bureau of Meteorology, Australia, p. 13.

Roger Pielke Jr. is a Professor in the Environmental Studies Program and a Fellow of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado. He also serves as the Director of the CIRES Center for Science and Technology Policy Research. His interests lie in the two-way connection of decision making and science and technology.