Turning the big knob: energy policy as a means to reduce weather impacts

by

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TURNING THE BIG KNOB: AN EVALUATION OF THE USE OF ENERGY POLICY TO MODULATE FUTURE CLIMATE IMPACTS

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ABSTRACT
Conventional wisdom on climate change policy is straightforward: Reducing greenhouse gas emissions will avoid the increased frequency and magnitude of climate impacts on environment and society that might occur if emissions are not controlled. The proponents of conventional wisdom widely consider energy policy to be the main policy tool available to decision makers to intentionally modulate future climate impacts. In this paper we challenge the notion that policy makers should intentionally use energy policy to modulate future climate impacts. The paper argues that policy makers may well make large changes in energy policy (and future emissions) without significantly affecting future 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 larger role in creating future *impacts* and are arguably more amenable to policy change. To illustrate this conclusion, the paper presents a sensitivity analysis under the assumptions of the Intergovernmental Panel on Climate Change for the case of tropical cyclones. One implication of the paper's conclusions is that policy responses to extreme weather events should be decoupled from considerations of energy policy. This decoupling is not intended to diminish either the importance of responding to climate change or of energy policy. Rather, it is to emphasise that there are many responses under the rubric of "adaptation" that could play a much role in reducing societal vulnerability to losses. One of the implications of this change is that scientific uncertainty need not stand in the way of effective "action" because the measures proposed make sense under any future climate scenario.

INTRODUCTION
Decision making, by its nature, is forward looking. We make choices and commitments based on some implicit or explicit conception of the future. For this

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reason, we seek mightily to catch a glimpse of what lies ahead. For if we could accurately predict the future, it is only logical that we would make choices and commitments more wisely and with better results. Such thinking underlies policies that have allocated tens of billions of dollars to the issue of global climate change "to gain an adequate predictive understanding of the interactive physical, geological, chemical, biological and social processes that regulate the total Earth system and, hence establish the scientific basis for national and international policy formulation and decisions..." (CES 1989).

Conventional wisdom on the climate change issue is straightforward (Figure 1, Pielke 1998). Anthropogenic 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). This logic was repeated by President Bill Clinton 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).

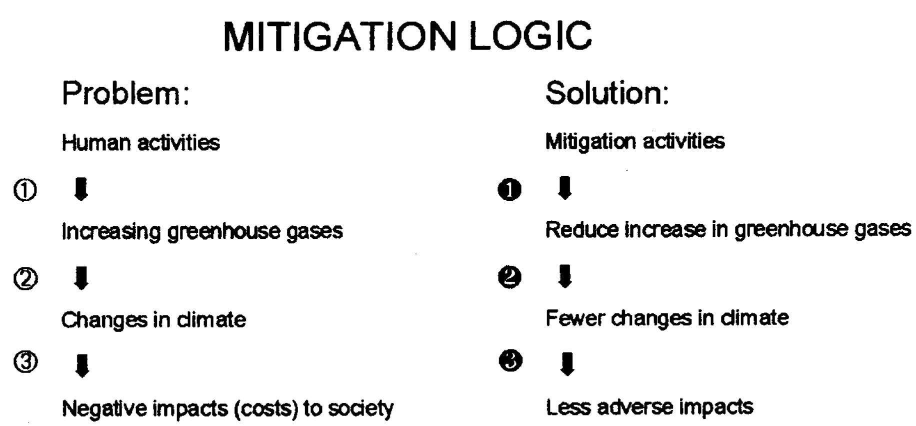

Figure 1

Proponents of conventional wisdom view energy policy as a "big knob" on the "control panel" of global policy makers. 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).[1] Energy policy is widely considered to be the main policy tool that can control the "global machinery" and thereby intentionally modulate future climate impacts.[2]

Consideration of energy policy as a means to modulate climate impacts is appealing for a number of reasons. First, it relies on centralized decision making and analysis, which some view as a prerequisite to dealing with climate change (Brunner and Klein 1999). For example, energy policies are often evaluated based on the global scenarios generated from so-called integrated assessment models (IAMS – see IPCC 1996b, pp. 367–396). Although the results of IAMS are subject to numerous qualifications, those who propose using such models as a basis for policy argue that they "combine knowledge from a wide range of disciplines to provide insights that would not be observed through traditional disciplinary research" (IPCC 1996b). Consider the following four examples that focus on the reduction in global climate impacts associated with various global energy policy strategies.

- The MERGE model predicts that reducing greenhouse gas emissions to 30% of 1990 levels by the year 2030 would reduce global damages caused by global climate change by about $2.5 trillion relative to "business as usual." Stabilizing emissions at 1990 levels would reduce these damages by a slightly smaller amount (Manne et al. 1995).
- The PAGE model predicts that an aggressive emissions reduction policy would result in an increase in greenhouse gas emissions of 60% over their 1990 levels by the year 2100 compared to an increase of 200% under a no action policy, thereby reducing global impacts by about $2 trillion (Hope et al. 1993).
- The DICE model predicts that an "optimal path" policy that reduces emissions by 10% in the near future and 15% late in the next century would produce approximately $271 billion in net benefits, compared to a no controls policy (Nordhaus 1994, pp. 82, 93).
- The CETA model predicts that reducing worldwide emissions by one-third over what they would be in the "no control" case would produce benefits of about $1.2 trillion worldwide if the developing countries were not participating in reduction policies, or about $1.5 trillion if they were (Peck and Teisberg 1995).

Second, many in the environmental community have long viewed energy policy as the keystone of environmental policy. In 1988, Senator Timothy Wirth (D-CO)

[1]Senator Hollings had previously noted that his "hope is that a long-term coordinated research effort will one day give Congress the information it needs to take corrective action and avert a future disaster" (Senate Committee on Commerce, Science, and Transportation 1988, p. 7). In these statements of Senator Hollings and other officials, it is clear that "action" is a euphemism for reduction in greenhouse gas emissions.

[2]Other policy tools that might be used to intentionally modulate future climate include including geoengineering (e.g., seeding the ocean with iron), and have not received the same degree of attention from policy makers as energy policy.

captured this logic: "What we've got to do in energy conservation is try to ride the global warming issue. Even if the theory of global warming is wrong, to have approached global warming as if it is real means energy conservation, so we will be doing the right thing anyway in terms of economic policy and environmental policy" (Stanfield 1988). The issue of global climate change subsumed much of the preexisting advocacy of greater energy efficiency (Sarewitz and Pielke 2000).

And third, the wisdom of the approach depends on the authoritativeness of science (Sarewitz 1996). In 1984, Representative Albert Gore observed that "the ability of political and economic institutions to respond to a challenge of this magnitude will depend in large part upon how the scientific community explains the problem, how much certainty it invests in that explanation, and how actively involved it becomes in spelling out what the clearly sensible choice might be" (Subcommittee on Investigations and Oversight 1984, p. 19). Thus, policy makers with opposing perspectives on climate change could take credit for action by funding research, assuming that research would, one way or another, create a scientific and political consensus (Pielke 2000a and b, Boehmer-Christiansen 1994a and b). The scientific community welcomed and encouraged this challenge to produce "usable information for policy" (Pielke 1995).

A growing body of research and experience challenges assumptions underlying conventional wisdom concerning the global climate change issue. For example,

- Centralized decision making may not be the most effective means to increase energy efficiency or reduce emissions (Brunner and Klein 1999).
- Climate change may not be the most effective integrating theme for the environmental community (Sarewitz and Pielke 2000).
- Predictive science may not be an impartial, authoritative, and practical basis for policy (Sarewitz et al. 2000, Shackley et al. 1998).

These various challenges to the assumptions of conventional wisdom are largely outside the legitimated processes of the Intergovernmental Panel on Climate Change (IPCC) and the Framework Convention on Climate Change (FCCC) that shape debate and decision making related to climate change. To the degree that these challenges reflect actual weaknesses in the current approach, resources are ineffectively allocated, which means in turn that societal and environmental problems associated with climate change may persist unaddressed.

In the following sections of this paper we challenge an implication of conventional wisdom: that policy makes should intentionally use energy policy to modulate future climate impacts. The paper argues that energy policy is not a "big knob" that policy makers can "turn" to intentionally reduce the negative impacts of climate on society and environment. Policy makers 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 larger role in creating future *impacts* and are arguably more amenable to policy change.

CONVENTIONAL WISDOM:

Using Energy Policy to Reduce Expected Tropical Cyclone Impacts

During the last week of October 1998, Hurricane Mitch stalled over Central America, in places dumping more than three feet of rain in less than 48 hours, killing more than 10,000 people in landslides and floods, triggering a cholera epidemic, and virtually wiping out the economies of Honduras and Nicaragua. Several days later, about 1,500 official delegates, accompanied by thousands of advocates and media representatives, met in Buenos Aires at the fourth Conference of Parties to the United Nations Framework Convention on Climate Change. Many at the conference pointed to Hurricane Mitch as a harbinger of the catastrophes that await us if society does not act immediately to reduce emissions of greenhouse gases that could destabilise the Earth's climate. Delegates passed an official resolution of "Solidarity with Central America," in which they expressed concern "that global warming may be contributing to the worsening of weather," and urged "governments... and society in general to continue their efforts to find permanent solutions to the factors which cause or may cause climate events" (UNFCCC 1998). In addition, the Sierra Club, the International Federation of Red Cross and Red Crescent Societies, members of the news media, and the former administrator of the U.S. Agency for International Development, among others, have pointed to increasingly damaging weather events like Hurricane Mitch as evidence that global warming is upon us (Glick undated, IFRCRC 1999, Herbert 1999, Atwood 1998).

Hurricanes, a subset of tropical cyclones, are but one example of extreme weather events that have been linked to global climate change (IPCC 1996b). The following section discussed conventional wisdom concerning climate change and extreme events, using tropical cyclones as an illustrative case study of how conventional wisdom more generally treats climate impacts on environment and society.

After reviewing the science of climate change and tropical cyclones, the IPCC Second Assessment Report (SAR) *Working Group I* concluded "it is not possible to say whether the frequency, area of occurrence, time of occurrence, mean intensity or maximum intensity of tropical cyclones will change" (IPCC 1996a, p. 334).[3] Nonetheless IPCC *Working Group III* (IPCC 1996b, pp. 201–202) estimated that additional annual average hurricane-related damage from a doubling of atmospheric greenhouse gases could be as costly as $750 million in the U.S.and $2.7 billion worldwide. One of the primary solutions discussed by the IPCC to the problem of increasing hurricane losses from rising greenhouse gases is adoption of emissions reduction policies.

Table 1 summarizes the studies cited in the IPCC SAR related to tropical cyclone damage. Each study assumes that future damages are the product of present damages and a factor that represents the projected increase in tropical cyclone activity. The studies and their underlying assumptions are as follows:

[3]Emmanuel (1987) provided the theoretical basis for the conventional wisdom concerning the relationship of rising greenhouse gas emissions and hurricanes, suggesting that a doubling of atmospheric carbon dioxide levels could produce a 40-50% increase in the destructive potential of tropical cyclones.

- Cline (1992) relied on Emanuel's (1987) estimate that the destructive potential of tropical cyclones could rise by 40-50% under a doubling of greenhouse gases. The study assumed U.S. annual average hurricane losses of $1.5 billion and that damage would rise linearly with increasing intensity. Cline thus multiplied $1.5 billion by 50% to project an increase in annual U.S. hurricane-caused damages of $750 million. Cline assumed that increased damage from global warming would be more than linear in relation to rising temperatures and estimated that annual hurricane-related damages from a 10° C warming could be as high as $6.4 billion (Cline 1992).

- Fankhauser (1995) assumed worldwide annual average tropical cyclone damages of $1.5 billion and loss of 15,000–23,000 lives. This study also relied on Emanuel's estimate of a 40–50% increase in tropical cyclone intensity resulting from a 4.2°C warming. It adjusted this to 28% for a 2.5°C warming and assumed storm damages increase exponentially with intensity. Thus, the study multiplied 28% by 1.5 by $1.5 billion to arrive at an estimate of $630 million in additional worldwide annual average hurricane-related damages due to a 2.5°C warming. It also estimated that an additional 8,000 deaths would occur, which were valued at $2.1 billion, bringing total additional tropical cyclone-related worldwide losses to $2.7 billion. Fankhauser estimated that the U.S. share of these damages would be $223 million ($115 million from destruction, $108 million from lost lives).

- Tol (1995) assumed that tropical cyclone intensity will increase 50% due to a 2.5°C warming, and that a fraction of the damages are related quadratically to an increase in intensity. This study estimated that additional tropical cyclone-related damages from a doubling of greenhouse gases in 1988 dollars will be $.3 billion in the U.S. and Canada and $1.4 billion worldwide, but did not describe the baseline damage estimates.

- Nordhaus (1991) estimated that net economic tangible and intangible damage from a 3° warming might be between 1 and 2% of total global income. The IPCC indicated – apparently mistakenly – that Nordhaus included hurricane damage in this estimate. However, there is no indication that this study considered hurricane damage. In fact, Nordhaus questioned Cline's inclusion of estimates of the impact of losses from storms because "both the IPCC and the National Academy studies concluded that the effect of warming on storm intensity is ambiguous" (Nordhaus 1994).

The damage projections rely on assumptions about the increase in tropical cyclone intensity in a doubled greenhouse gas world, whether damages rise linearly or more than linearly with increased hurricane intensity, baseline average annual hurricane damages, and how to value the loss of a human life. Changing any of these assumptions would change the outcomes, sometimes drastically.

For example, the analyses assume a 50% increase in tropical cyclone intensity from

Table 1. Comparison of IPCC SAR methodologies and assumptions for estimating future tropical cyclone-related damage caused by doubling of greenhouse gas emissions

Study	Methodology	Assumptions
Cline (1992)	Projected increase in hurricane intensity times average annual U.S. hurricane damages	Hurricane intensity increases 40–50% for a 2.3–4.8°C warming Average annual U.S. hurricane damages are \$1.5 billion 50% X \$1.5 billion = \$750 million additional annual U.S. hurricane damages from doubling of greenhouse gases
Fankhauser (1995)	Projected increase in hurricane intensity times 1.5 time average annual worldwide hurricane damages	Hurricane intensity increases 28% for a 2.5°C warming Damages rise at rate of 1.5 with storm intensity Annual average worldwide hurricane damages of \$1.5 billion 28% X 1.5 X \$1.5 billion = \$630 million additional annual worldwide hurricane damages from doubling of greenhouse gases
Tol (1995)	Cost functions are quadratic forms, $f(X) = \alpha X + \beta X2$.	Damages from enhanced natural disasters assumed to be quadratic in total hurricane increase Climate change damage cost function for tangible damages from natural hazards for PI is .75, and for PI^2 is .25 Benchmark hurricane intensity is expected to increase 40- 50% due to warming of 2.5°C Damage from hurricanes in the U.S. is expected to increase .3 billion in the U.S. and 1.4 billion worldwide for doubling of greenhouse gases

a doubling of greenhouse gases. Substituting the more recent estimates of a 10–20% increase in maximum intensity (Henderson-Sellers et al. 1998) would cause the loss estimates to drop. On the other hand, all of these estimates would be much higher if they relied on the assumption that annual average U.S. hurricane damages are about $5 billion (Pielke and Landsea 1998).

A CRITIQUE OF CONVENTIONAL WISDOM

Research shows no clear trend of an *actual* increase in tropical cyclone frequency or intensity corresponding with increasing levels of atmospheric greenhouse gases in the 20th century (Landsea et al. 1999). Even if an increase in frequency or intensity is eventually documented, detecting a greenhouse signal will be very difficult because any changes are expected to be relatively modest in comparison to larger natural variability (cf. Henderson-Sellers et al. 1998). Given the difficulties in determining whether human-induced climate change has led to a change in tropical cyclone frequency or intensity, there presently is little scientific evidence to support the notion that society intentionally can control hurricane frequencies and/or magnitudes through energy policies (Landsea et al. 1999).[4]

But even if the IPCC could document an unequivocal relationship between greenhouse emissions and increased tropical cyclone activity, there is little evidence that the international political process will enact emissions reduction policies of the magnitude needed to stabilise greenhouse gas concentrations at levels deemed necessary by the IPCC to avoid climate change (cf. Weyant 1999, Wigley 1998). The IPCC concludes, "even with the most ambitious abatement policy, some climate change seems likely to occur" (IPCC 1996b, p. 188).

The most significant problem with conventional wisdom, however, is its failure to recognize that increased tropical cyclone damage from societal factors such as growth in population could easily dwarf projected additional losses from changes in climate, even under the most aggressive assumptions (cf. Landsea et al. 1999). In the 20th century, increases in hurricane-related losses have been more closely related to societal change than to changes in climate (Pielke and Landsea 1998).

As documented above, many have pointed to Hurricane Mitch's path of destruction through Central America as a preview of what can be expected in a greenhouse gas-enriched world. While Mitch was at one time a Category 5 hurricane, it had lost much of its ability to produce powerful winds by the time it made landfall.

Most destruction occurred in cities in the central and southern parts of these countries where large numbers of poor people had built homes on hillsides and destroyed much of the vegetation in the process (DeWalt 1999). The torrential rains resulted in landslides and flooding that washed away many of these settlements. Mitch, more than anything, highlighted the role that societal changes play in increasing vulnerability to extreme events. And in the developing world more generally, continued population growth, coupled with poverty, inappropriate development, and environmental degradation, likely will dramatically increase human vulnerability to tropical cyclones (Pielke et al. in prep.). In short, if present societal trends continue,

[4]This statement is unlikely to be controversial with the overwhelming majority of tropical cyclone experts.

Table 2. Four IPCC scenarios for population and per capita GNP growth 2000–2050

Scenario	2000–2050 Population (millions)	Change (2050/2000)	2000–2050 per capita GNP	Change (2050/2000)
SRES A1	6000–8704	1.45	5,161–20,830	4.0
SRES A2	6000–11296	1.88	4,295–7,224	1.68
SRES B1	6000–8933	1.49	4,712–12,755	2.71
SRES B2	6000–9367	1.56	4,851–11,690	2.41

(Data from IPCC 1999)[1]

Table 3. Estimated annual average worldwide tropical cyclone-related losses based on the four IPCC scenarios from Table 2

Scenario	Normalization	Result
SRES A1	\$10 billion X 1.45 X 4	\$58 billion
SRES A2	\$10 billion X 1.88 X 1.68	\$32 billion
SRES B1	\$10 billion X 1.49 X 2.71	\$40 billion
SRES B2	\$10 billion X 1.56 X 2.41	\$38 billion

[1]Each of the four SRES scenarios provides population and per capita GNP estimates for the years 1990, 2020, and 2050. This paper assumes year 2000 population to be 6 billion for all four scenarios. Year 2000 per capita GNP for each scenario was calculated by subtracting 1990 per capita GNP from 2020 per capita GNP, dividing by 30 years, then multiplying by 10 years and adding this figure to the 1990 figure. If the year 2000 figure had been interpolated by subtracting 1990 per capita GNP from 2050 per capita GNP, dividing by 60 years and multiplying by 10, then adding this figure to the 1990 figure, year 200 per capita GNP would have been \$6,782 (SRES A1), \$4,513 (SRES A2), \$5,430 (SRES B1), and \$5,258 (SRES B2).

the future will hold significant increases in tropical cyclone damages even without any change in the location, frequency, or intensity of the storms themselves.

Climate and Society:
A Sensitivity Analysis of Projected Losses Under IPCC Scenarios

Perhaps surprisingly, the conclusion that future losses are more sensitive to societal change than to climate change follows from the assumptions of the IPCC. The IPCC Third Assessment Report *Working Group III* has developed four scenarios based on projections of worldwide population, GNP, and per capita GNP growth from 1990 through 2100 (IPCC 1999).[5] Table 2 shows the four scenarios for worldwide changes in population and per capita GNP from 2000 to 2050. Assume for present purposes that annual average worldwide hurricane-related damages are twice United States damages (based on Pielke and Landsea 1998) – or \$10 billion. Applying Cline, Fankhauser, and Tol's assumptions and estimates used in the IPCC SAR to average annual worldwide hurricane-related damages of \$10 billion results in the following projected losses:

[5]As of May 2000 these scenarios have not yet been approved formally by the IPCC.

- Under Cline's assumption of a 50% increase in average annual hurricane-related monetary losses, costs would increase to $15 billion per year;
- Under Fankhauser's assumption of a 42% increase in average annual hurricane-related costs, costs would increase to $14.2 billion per year;
- Under Tol's assumption of a 50% increase in hurricane intensity with one-quarter of the costs associated with the quadratic term, costs would increase to $15.3 billion worldwide per year.

However, using the more recent estimates of a 10% increase in hurricane intensity due to a doubling of greenhouse gases, these estimates would be $11, $109.9 and $10.8 billion per year, respectively. Table 3 shows annual average worldwide hurricane losses in a doubled greenhouse gas world under the assumptions of the four IPCC scenarios.

Figure 2 shows the percentage increase in losses from 2000 to 2050 for the three IPCC methods (i.e., Cline, Fankhauser, and Tol) and an adjustment based on the four IPCC population and wealth scenarios.[6] Even when comparing the most conservative IPCC population and economic scenarios with the most aggressive climate change scenarios, the growth in tropical cyclone-related losses resulting from increases in population and wealth are about three times greater than the IPCC projections.

Even under the assumptions of the IPCC, societal changes are a more important factor than climate change in projected losses.

This suggests that policies addressing societal factors, rather than policies that attempt to alter tropical cyclone frequency and intensity, should play the predominant role in societal response to future extreme weather events.[7]

We offer as a hypothesis and a challenge the notion 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 (cf. Changnon et al. 2000).

For example, conventional wisdom regarding floods is that "as global climate warms, more floods are expected" (NOAA 1997). According to the IPCC, "there is now mounting evidence to suggest that a warmer climate will be one in which the hydrological cycle will in general be more intense, leading to more heavy rain events" (IPCC 1996a, p. 335). Some scientists have already suggested a cause and effect

[6]The "normalization" methodology is based on an assumption that losses are proportional to changes in population and wealth (Pielke and Landsea 1998). Evidence for the appropriateness of such assumptions can be found in Pielke and Landsea 1999 and Pielke et al. 1999. Of course, using global average figures for growth in population and wealth could very easily underestimate the growth in loss potential as many locations exposed to tropical cyclones have easily experienced growth at a much higher rate than the global average.

[7]We wish to be clear that this should not be interpreted to mean that reducing emissions for other reasons might not make sense.

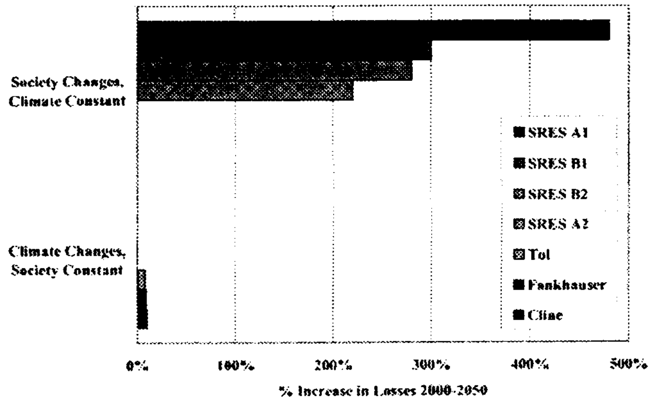

Figure 2. Sensitivity Analysis of $2xCO_2$ Worldwide Global Tropical Cyclone Loss Estimates for 2050. The Frankhauser estimate includes only estimated monetary losses, but does not include additional losses associated with the economic value of human life.

relationship between the increase in precipitation and recent hydrologic flooding (Karl and Knight 1998). This relationship would seem to be supported by the fact that precipitation intensity has increased during the twentieth century (Karl et al. 1995). But unlike in the case of tropical cyclones where it did project damages, the IPCC (1996b, p. 202) concluded "little information is currently available regarding the socioeconomic impact of changes in the frequency and intensity of river floods."

Changnon (1998) attributed the increase in U.S. flood damages to "trends in societal activities and river management... [with] heavy losses... largely a result of changing societal factors that have enhanced the nation's vulnerability to flood damage." The Office of Technology Assessment (OTA) of the U.S. Congress cited continued population growth in and near flood-prone areas, destruction of wetlands, inadequate control of increased runoff from development, lack of mapping, people moving into flood-prone areas without adequate information about risk, dam and levee deterioration, and policies that encourage development of flood plains as factors that likely will increase vulnerability to flood damage. It concluded, "floods... will continue to occur even if they cannot be linked definitively to climate change" (OTA 1993, p. 262). Pielke and Downtown (1999) found that precipitation alone could not explain the rising trend in national flood damages and concluded that societal factors play a predominant role in explaining this trend.

Even without an increase in precipitation (a predicted consequence of climate change), total flood damage will continue to increase with growing population and wealth. As a result, "the greatest potential for reducing future flood losses is for policy makers to continue to focus attention on flood plain management, rather than on seeking to prevent future floods by modifying (or stabilizing) the climate" (Pielke and Downton 1999). We hypothesize that the policy implications presented here for tropical cyclones and climate change apply as well to floods and other extreme events.

To summarize, if a policy goal is to reduce the future impacts of climate on society and environment, then adaptation – which we discuss in the following section – deserves a considerably larger role in climate policy. We would hypothesize that this finding holds across the spectrum of the interactions of climate with society and environment.

Alternatives to Conventional Wisdom: Many Little Knobs

Numerous responses that fall under the rubric of "adaptation" could have a much more immediate impact on reducing societal vulnerability to climate (Pielke 1998). Adaptation refers to adjustments in individual, group, and institutional behaviour to reduce societal and environmental vulnerability to climate. Adaptation as a policy response to climate change has not received the same level of attention from policy makers or researchers as mitigation measures such as emissions reduction policies. Burton (1994) suggests that adaptation has occupied a lesser role in policy because it is seen as "an unacceptable, even politically incorrect, idea" that is "passive, resigned, accepting" rather than "active, combative, controlling." Mitigation is thus viewed as the preferred response. President Bill Clinton echoed this logic when he stated that "we can accept that preventing the disease and destruction climate change can bring will be infinitely cheaper than letting future generations try to clean up the mess" (Clinton 1999).[8]

One implication of the analysis presented in this paper is that policy responses to tropical cyclones and other extreme weather events should be decoupled from considerations of energy policy. This decoupling is not intended to diminish either the importance of responding to climate change or of energy policy. Rather, it is to emphasise that there are many "little knobs" that can be "turned." The following are examples of measures that could reduce societal vulnerability to tropical cyclones –

Table 4. IDNDR Expenditures 1990–1999

Biennium	Expenditure (USD)
1990/1991	$ 1,238,926
1992/1993	$ 2,636,483
1994/1995	$ 4,634,219
1996/1997	$ 5,080,404
1998/1999	$ 6,534,000 (budgeted)
Total	$20,124,032

(Source: Christine v. Schneider, IDNDR Secretariat, Management Support Unit, provided by authors)

Table 5. UNFCCC Core Budget 1998–1999

Year	Total approved budget (USD)
1998	$ 9,645,300
1999	$11,700,700
Total	$21,346,000

(Source: UNFCCC 1999)

[8]In Congress Representative Vernon Ehlers (R-MI) expressed a similar view when he stated that "preventing the problem is the best" (Subcommittee on Energy and Environment 1995).

and extreme weather events more generally – regardless of whether or not climate change turns out to be a factor in increasing damages from such events:

Correct spending and research distortions at the international and national levels
One important place to begin is to correct spending distortions created by the current reliance on conventional wisdom. Harvard economist Jeffery Sachs captured the effects of spending distortions when he observed that "advances in biotechnology... point to a possible malaria vaccine. One would think that this would be high on the agendas of both the international community and private pharmaceutical firms. It is not." He concluded, "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). Future impacts of malaria – like extreme weather events – are frequently used by advocates to justify emissions reduction policies. But spending on malaria research in the U.S. was about $22 million in 1999, almost *eighty times less* than what the government spent on, for example, research labelled as global change research; international comparisons suggest a similar imbalance (Sarewitz and Pielke 2000).[9]

Government support of research and policy on natural hazards shows evidence of similar distortions. For example, in 1989 the United Nations proclaimed the 1990s as the International Decade for Natural Disaster Reduction (IDNDR) to reduce loss of life, property damage, and social and economic disruption caused by natural disasters through international action and science and technology. IDNDR's goals included having "comprehensive national assessments of risks from natural hazards integrated into development plans, mitigation plans of practical measures for application at national and local levels to address long-term disaster prevention, preparedness and community awareness, and ready access to global, regional, national and local warming systems" (IDNDR 1999). In the 10 years of the IDNDR, donor nations allocated slightly over $20 million in U.S. dollars (current) – or about $2 million per year *worldwide* (Table 4) – to achieve goals that would address many of the problems of extreme weather events.

Compared to the IDNDR are the U.N. Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change which are focused on predicting future climate change and its impacts in support of efforts to reduce greenhouse gas emissions. The FCCC had a core 1998–1999 budget of over $21 million (current year) for items such as personnel, travel, and operating expenses (Table 5). This is more than all the expenditures on the IDNDR over its entire 10-year existence. The U.S. contributed $5 million in FY 1998 and $6.5 million in FY 1999 to the FCCC and IPCC; President Clinton requested $8 million in FY 2000 for these functions (UNA-USA 1999).

Other examples follow: Five U.S. governmental agencies spent over $693 million (current) in FY 1993–1995 on matters related to the objectives of the U.N. Framework

[9]In his 2000 State of the Union Address President Clinton announced a "Millennium Vaccine Initiative" in the 2001 budget that could be an important step toward addressing this issue (White House 2000).

Convention on Climate Change (US GAO 1996).[10] By way of contrast, the Federal Emergency Management Agency (FEMA), for example, proposed spending less than $60 million in FY 2000 on programs aimed at reducing the exposure to disaster losses in the U.S. alone, including keeping homes away from floodplains and creating and enforcing effective building codes to protect property from hurricanes (FEMA 1999a, 1999b). Another example: the U.S. Agency for International Development has a five-year, $1 billion program to help developing countries quantify, monitor, and reduce greenhouse gas emissions (Tarnoff 1997). It spent about $17 million in FY 1997 on disaster preparedness and prevention programs in recipient countries (Board on Natural Disasters 1999).

Given the protean quality of government budgets, it would be easy to quibble with the exact magnitude of the figures used in the above examples. But the central point seems unassailable: the framing of the climate change issue in terms of prediction and prevention of future impacts based on energy policy strategies has led policymakers, advocacy groups, and researchers to allocate finite resources in ways that overlook existing knowledge and action that can positively address societal and environmental vulnerabilities to climate. This represents a misframing of the climate issue.

To address resource allocation distortions, greater emphasis should be placed on the following areas:

Vulnerability mapping

Communities would benefit from a greater understanding of exposure and risk. Many Caribbean countries lack the resources to undertake such studies. Even some U.S. communities have never been evaluated for flood risk (Witt 1999). In addition to mapping where natural hazards could occur, community planners could map in which neighbourhoods highly vulnerable groups such as the disabled, poor, and elderly reside.

This information can provide a tool for targeting education and other mitigation programs, evacuation plans, distribution of relief supplies, and other response services directly where they are most needed (e.g, Morrow 2000).

Land use

Much development in the Caribbean is occurring in the most vulnerable locations – low-lying shorelines and inland flood-prone areas (Pielke et al. in prep.). Land use planning is in a rudimentary stage in this region. As in the Caribbean, the coastal areas of parts of the southeastern U.S. have experienced explosive growth over recent years. In 1990 Dade and Broward Counties in south Florida had larger populations than all 109 counties from Texas through Virginia on the Gulf and Atlantic coasts in 1930. Alternatives for managing land in vulnerable areas include zoning, regulation, taxing, creating special property districts in which governments may exercise eminent domain, and public acquisition of land at risk (e.g., Platt 1999).

[10]Although the GAO notes that much of this spending would have taken place without the FCCC, it nevertheless was directed toward the FCCC's objectives-prediction and prevention.

Promulgation and effective enforcement of building codes

Building codes are an important component in strengthening housing stock and reducing hurricane vulnerability (Cochran 2000). In hurricane-prone areas effective building codes should address factors such as the ability of structures to withstand wind velocities of a given speed and height. For example, south Florida's building code requires structures to be able to withstand wind velocities not less than 120 mph at a height of 30 feet above the ground. Many engineers maintain that using steel or composite fasteners to hold on a roof would save homes (Dye 1999). However, even the best codes will not reduce vulnerability without adequate enforcement. One study comparing damage from two hurricanes of roughly equal size and intensity found that building code enforcement was a primary factor in reducing structural damage to buildings during hurricanes (Mulady 1994). Other strategies are necessary in those parts of the developing world where much of the construction of homes occurs informally and does not go through a code review and inspection process.

Improved forecasts, warnings, and evacuations

While major improvements in tropical cyclone forecast accuracy have been made thanks to advances in technology, considerable opportunity exists for further improvement in both the technical production of forecasts and their use by decision makers (e.g., Marks et al. 1996, Raghavan and Sen Sarma 2000). In addition, some countries need better national communications systems to disseminate warnings. Dissemination of effective warnings can be a problem in countries such as India where warnings need to be translated into several languages (Raghavan and Sen Sarma 2000). It is likely that those who suffered the greatest impacts of Hurricane Mitch had little or no warning of its approach and little opportunity to evacuate even if warned.

For evacuation to be effective, communities must understand various factors including what areas need to be evacuated, how many people need to be evacuated, how the public will respond to an evacuation, what roads will be used, and where evacuees will be sheltered (Baker 2000). Improvements to the evacuation process can range from widening roads or building new causeways to limiting population growth in areas likely to need to evacuate (Baker 2000).

Reduce environmental degradation

Deforestation is occurring at alarming rates in some parts of the world. Loss of natural vegetation reduces the soil's ability to absorb rainwater and contributes to the instability of hill slopes. These factors can lead to highly dangerous landslides that result in hundreds of deaths. Development of wetlands and beaches interferes with the ability of these natural environmental features to absorb floodwaters and act as seawalls (e.g., Berke and Beatley 1997). Poor land use and natural resource management, while a reflection of poverty, is also caused by government policies that subsidize unsustainable activities and practices. These policies often result from conscious decisions and tradeoffs made by government officials. If the decision-making processes are opaque and corrupt, there is little people can do to exert pressure to correct these environmentally harmful practices. Promoting democratically responsive institutions could be an important element in reducing societal vulnerability to extreme weather events (e.g., Ascher 1999).

Addressing poverty and health

Many factors that increase societal vulnerability to extreme weather, particularly in the developing world, will not be solved without a concurrent focus on alleviating poverty and improving public health (e.g., Sachs 1999, Bloom and Canning 2000). Poor people frequently build homes through the informal housing sector, making building codes and land use restrictions meaningless. They often settle on marginal lands such as steep slopes and flood-prone areas. Poverty is also a factor in environmental degradation practices such as deforestation. Vulnerability reduction has clear links with economic development and public health.

A broader base for energy policy

Recognising that climate impacts are best addressed through adaptation rather than prevention need not undercut the goals of increased energy efficiency and reduced greenhouse gas emissions. Rather, such a change in justification might move debate beyond the gridlock caused by the focus on global warming onto issues more amenable to political and practical progress. For instance, pollution, congestion, subsidies, political stability, and revenue lost to inefficiency each provides a compelling reason for increased energy efficiency (cf. Brunner and Klein 1999). There existed a powerful argument for energy efficiency before global climate change became an issue. Many of these arguments remain current today.

CONCLUSION

The analysis presented in this paper raises the possibility that policy makers should focus less on long-term predictions about the future of the climate as a basis for valuing the reduced impacts of various energy policies and more on providing information that decision makers at the scale of impact can use to reduce present and expected vulnerabilities to climate (cf. Sarewitz et al. 2000). This shift in focus means that research will have to look at society's vulnerability to *climate* rather than only *climate change*.

The alternative approach suggested here means that adaptation will occupy a considerably larger role in climate policy - a role reflected not simply in words, but in resource allocation decisions. One of the implications of this change for policy will be that scientific uncertainty need not stand in the way of effective "action" because the measures proposed make sense under any future climate scenario. Another implication is that there is not a single worldwide solution to the problem of climate change. Rather, there is a large portfolio of responses that allow for learning based on experience and evaluation based on success in addressing actual impacts and vulnerability.

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