Global Health Threats: Global Warming in Perspective

Indur M. Goklany, Ph.D.

ABSTRACT

Some authorities have claimed that global warming is one of the most—if not the most—important public health threat of this century. They do not, however, support this assertion by comparative analysis of the relative magnitude and severity of various health threats. Such an analysis, presented here, shows that other global health threats outrank global warming at present, and are likely to continue to do so through the foreseeable future, even under the warmest scenario developed by the UN Intergovernmental Panel on Climate Change (IPCC).

Exaggerated and unsupported claims about the importance of global warming risk skewing the world's public health priorities away from real, urgent health problems. Policies curbing global warming would, moreover, increase energy prices and reduce its usage, retarding both economic development and advances in human well-being. That would slow advances in society's adaptive capacity to deal not only with the effects of global warming, but all other sources of adversity. Through the foreseeable future, global health would be advanced farther, faster, more surely, and more economically if efforts are focused not on reducing greenhouse gas emissions, but on reducing vulnerability to today's urgent health problems that may be exacerbated by global warming, while increasing adaptive capacity, particularly of developing countries, through economic development.

Introduction

Several influential policymakers have declared that climate change is one of the defining challenges of this century.[1,2] In their wake, even august publications such as *The Lancet* have taken the position that "climate change is the biggest global health threat of the 21st century."[3] Such assertions have serious implications for allocation of fiscal and human resources to address global public health problems. Societal resources devoted to curb carbon dioxide and other greenhouse gas emissions will be unavailable for other—and as will be shown—more urgent tasks including vector control, developing safer water supplies or installing sanitation facilities in developing countries, or for cancer research or drug development in developed countries. Additionally, reduction in wealth due to higher energy costs and lower energy usage could have serious consequences, not only for society's public health,[4] but also for its continued ability to adapt to present or future health threats.[5]

Assertions that global warming outranks other public health threats are not based upon comparative analysis of the magnitude, severity, and manageability of various health threats vying for the dubious title of the most important threat. But, absent any such analysis, how can one determine the risk ranking?

This article undertakes such an analysis. It draws upon analysis of global mortality and burden of disease attributed to 26 risk factors, including global warming,[6] presented by the World Health Organization (WHO) in the *World Health Report 2002*,[7] and *Comparative Quantification of Health Risks*.[8] For future risks, it uses results from the British government-sponsored "Fast Track Assessments" (FTAs) of the global impacts of global warming.[9,10]

The FTAs share many authors with the IPCC's latest (2007) assessment.[11] For example, the FTA lead author on hunger,[12] Professor Martin Parry, co-chaired IPCC Work Group 2 while it prepared the IPCC's latest (2007) assessment. More than half the burden of disease attributed by the World Health Organization to global warming in 2000 was derived from an earlier version of the FTAs' hunger study.[10-13,14] Similarly, the authors of the FTA's water resources and coastal flooding studies were also lead authors of corresponding chapters in the same IPCC report.

I will, for argument's sake, consider "the foreseeable future" to extend to 2085, since the FTAs provide estimates for that year, although to quote a paper commissioned for the Stern Review, "changes in socioeconomic systems cannot be projected semi-realistically for more than 5–10 years at a time."[15]

A note on terminology: In most public discourse the term "climate change" is synonymous with "global warming." For the sake of accuracy, this paper uses "global warming" rather than "climate change" when the change under discussion is warming.

Comparing Present-Day Health Risks

Table 1 presents rankings of 26 risk factors, including global warming, for the year 2000, based on both global mortality and

Table 1. Ranking of 26 Risk Factors Based on DALYs and Mortality for 2000.[7,16]

Risk factor	DALYs	Rank	Risk factor	Total Mortality	Rank
	(000)			(000)	
Underweight	137,801	1	Blood pressure	7,141	1
Unsafe sex	91,869	2	Tobacco	4,907	2
Blood pressure	64,270	3	Cholesterol	4,415	3
Tobacco	59,081	4	Underweight	3,748	4
Alcohol	58,323	5	Unsafe sex	2,886	5
Unsafe water, sanitation and hygiene	54,158	6	Low fruit and vegetable intake	2,726	6
Cholesterol	40,437	7	Overweight	2,591	7
Indoor smoke from solid fuels	38,539	8	Physical inactivity	1,922	8
Iron deficiency	35,057	9	Alcohol	1,804	9
Overweight	33,415	10	Unsafe water, sanitation and hygiene	1,730	10
Zinc deficiency	28,034	11	Indoor smoke from solid fuels	1,619	11
Low fruit and vegetable intake	26,662	12	Iron deficiency	841	12
Vitamin A deficiency	26,638	13	Urban air pollution	799	13
Physical inactivity	19,092	14	Zinc deficiency	789	14
Risk factors for injury	13,125	15	Vitamin A deficiency	778	15
Lead exposure	12,926	16	Unsafe health care injections	501	16
Illicit drugs	11,218	17	Risk factors for injury	310	17
Unsafe health care injections	10,461	18	Airborne particulates	243	18
Lack of contraception	8,814	19	Lead exposure	234	19
Childhood sexual abuse	8,235	20	Illicit drugs	204	20
Urban air pollution	7,865	21	**Global warming**	**154**	**21**
Global warming	**5,517**	**22**	Lack of contraception	149	22
Noise	4,151	23	Carcinogens	146	23
Airborne particulates	3,038	24	Childhood sexual abuse	79	24
Carcinogens	1,421	25	Ergonomic stressors	0	25
Ergonomic stressors	818	26	Noise	0	26
TOTAL for the 26 factors	**800,965**			**40,719**	
TOTAL from all causes	**1,472,392**			**55,693**	

burden of disease.[7,13,16] These factors cumulatively accounted for 73% of the global mortality, and 54% of global disability adjusted life years lost (DALYs) in 2000.[7] The latter (DALYs) is the measure of burden of disease employed in the WHO reports.

The methodology used in the WHO reports to estimate mortality (and burden of disease) from global warming in Table 1 essentially is to assign fractions of deaths occurring from real causes (e.g., diarrhea and malaria) to hypothesized underlying risk factors (e.g., global warming).[13] Thus, malnutrition (hunger) accounted for 52% of the DALYs attributed to global warming; diarrhea (from food and water-borne disease), 26%; malaria, 18%; flooding, 3%.[13, p 1607] In addition to 154,000 deaths in 2000 from diarrhea, malaria, dengue, flooding, and malnutrition assumed to result from climate change (global warming),[7] the study from which this estimate was obtained added 12,000 deaths from presumed climate-change-induced cardiovascular disease.[13] This estimate of 166,000 deaths in 2000 attributable to global warming was also the basis for the estimate provided in a 2005 review article in *Nature*,[17] which was then picked up and repeated in various influential publications.

But *all* of these estimates are inherently uncertain, not least because, as noted by the researchers who developed them:

> [C]limate change occurs against a background of substantial natural climate variability, and its health effects are confounded by simultaneous changes in many other influences on population health…. Empirical observation of the health consequences of long-term climate change, followed by formulation, testing and then modification of hypotheses would therefore require long time-series (probably several decades) of careful monitoring. *While this process may accord with the canons of empirical science, it would not provide the timely information needed to inform current policy decisions on GHG emission abatement, so as to offset possible health consequences in the future* [emphasis added].[13, p 1546]

That is, the analysis was guided more by the need to satisfy a policy agenda than rigorous scientific methodology. As a result, as the above quotation implicitly acknowledges, the estimates for global warming are based on, at best, poorly validated models.

Table 1 indicates that in 2000, global warming ranked below the top 20 global threats to public health—behind much more mundane problems such as hunger (underweight), unsafe water and poor sanitation, vitamin A deficiency, poor nutritional intake, and indoor air pollution.

The estimates for global warming effectively assume that one-third of the mortality (or 2,000 deaths) from floods in the year 2000 were from global warming. To put this number in context, EM-DAT, the International Emergency Disaster database, indicates that in 2000, hydrological, meteorological, and climatological disasters (i.e., droughts, extreme temperatures, floods, wet mass movement, storms and wildfires) claimed 9,500 lives globally, of which 6,000 were due to floods.[18] Thus even if one attributes all 9,500 deaths from extreme events to global warming (ignoring natural weather and climate variability) and assumes that one death translates into 100 DALYs—yet another overestimate since the global average life expectancy is 69 years[19]—global warming would not advance in rank. In fact, if one assumes, arbitrarily, that mortality and DALYs attributed to global warming are underestimated by 100%, it would still not rank among the top 15 health threats.

It should also be noted that because deaths (and burden of disease) from malaria are parceled among a variety of risk factors, malaria itself does not appear in Table 1. Thus a casual reader could jump to the erroneous conclusion that malaria should be nowhere on the list of global health priorities, and that global warming currently outranks malaria as a global health problem. But in fact, there were 1.1 million deaths due to malaria in 2000, with an estimated global burden of disease of 40.2 million DALYs.[7] Thus, had mortality from malaria not been "cannibalized," malaria, with seven times as many deaths and burden of disease, would on its own have ranked far ahead of global warming on Table 1. Specifically, it would have ranked 12th and 7th, depending on whether one uses mortality or the burden of disease as the criterion.

Comparing Health Risks Through the Foreseeable Future

Although global warming does not rank high on the list of global public health problems based on present-day (2000) data, its impacts could conceivably outweigh that of other factors in the foreseeable future.

To check this, I will estimate the contribution of global warming to global mortality for various climate-sensitive threats—specifically hunger (which contributes to underweight), malaria, and extreme events—in the year 2085 for four IPCC scenarios. These scenarios, from the warmest to the coolest, are labeled as A1FI, A2, B2 and B1. Their 1990–2085 globally averaged temperature increases are estimated to be 4.0 °C, 3.3 °C, 2.4 °C, and 2.1 °C, respectively.[9] The Lancet Commission, echoing others, has suggested that "we…urgently need to generate evidence and projection on health effects and adaptation for a more severe (3–4 °C) rise in temperature."[3, p. 1694]

For hunger and malaria, which together accounted for 70% of the global burden of disease attributed to global warming in Table 1, I use mortality estimates developed previously[20] from the results of the global populations at risk (PARs) of hunger and malaria in 1990 (the base year) and 2085 (the foreseeable future) from the relevant Fast Track Assessments (FTAs).[9,10] Note that since malaria accounts for about 75% of the global burden of disease from vector-borne diseases, it is a good surrogate for the latter.[21] The estimates for hunger and malaria, shown in Table 2, assume that global mortality for each threat is proportional to its global PAR, and that this relationship is constant between 1990 and 2085. Estimates of mortality for 1990 are based on various WHO publications.[20]

For extreme events, I use the same methodology as in the above except that I employ the change in PAR of coastal flooding from 1990 to 2085 provided in the relevant FTA[22] as a surrogate for the change in PAR of *all* extreme weather and climate events over this period. Also, instead of using the EM-DAT's mortality figure of 8,000 from extreme events in 1990, from an abundance of caution I use 24,800, which is the average annual mortality for 1986–1995 from such events (after accounting for differences in global population from the 1990 level). The 10-year average is used so that mortality from global warming for 2085 is not inadvertently biased downward because of the relatively low mortality from such events in 1990.

The individual and cumulative mortality estimates based on the above methodology and sources are presented in Table 2 for hunger, malaria, and extreme events for four IPCC scenarios. The table provides estimates for (a) mortality that would occur in the absence of any post-1990 global warming, (b) increases in mortality in 2085 due to any unmitigated global warming, and (c) the sum of the two (i.e., total mortality). For simplicity, this table only provides upper-bound estimates for the additional mortality due to global warming and total mortality in 2085.

The assumption of an invariant relationship between mortality and PAR from 1990 to 2085 ignores any increases in adaptive capacity due to either (a) higher levels of future economic development that have been built into the IPCC emissions and climate change scenarios or (b) secular, i.e., time-dependant, technological change.[5, 23] These increases in adaptive capacity should attenuate mortality in 2085 relative to PAR. Hence, mortality estimates provided in Table 2 for 2085 are probably overestimates, but for any scenario the degree of overestimation for each risk factor—hunger, malaria and extreme events—is probably the same for mortality with or without global warming. The wealthiest scenario probably has the largest overestimates, because it is likely to have the highest adaptive capacity, *ceteris paribus*.

This table shows that annual global mortality from extreme events could increase from 25,000 in 1990 to 111,000–873,000 in 2085. Such increases, were they to occur, would not square with historical experience. EM-DAT data indicate that from 1900–1909 to 1997–2006, the aggregate global mortality rate from all extreme weather events declined by 95%, owing largely to society's increased adaptive capacity because of a variety of interrelated factors, namely, greater wealth, increases in technological options, and greater access to and availability of human and social capital.[24] These factors acting in concert enabled—among other things—sturdier housing, early warning systems, and better meteorological forecasts.

Greater energy use allowed for better-insulated clothing and housing—most insulating material is made from petrochemicals—and temperature-controlled inhabited spaces in the home, at work, and elsewhere, regardless of what the weather might have been outdoors. Greater energy use also enabled improved transportation systems to evacuate populations at risk; supply and provision stricken areas with food and medicine faster; raise global availability of food through use of energy-intensive fertilizers, pesticides, and irrigation; and move food from surplus areas to deficit areas through trade and—in times of disasters—aid.[20, 25]

If one assumes that technological developments between 1990 to 2085 will parallel the historical experience from 1900–1909 to 1997–2006, then estimated mortality in 2085 from extreme weather events could be about one-twentieth of the estimate furnished in Table 2. That is, it could be more in the range of 4,900–43,700. Nevertheless, this paper uses, for the sake of argument, the implausibly high upper-bound estimates provided in Table 2 in order to estimate an upper bound for the contribution of global warming to mortality from the three listed risk factors.

Table 2 indicates that, despite the inflated estimates of the mortality due to global warming in 2085, its contribution to total mortality from hunger, malaria, and extreme events will not exceed 7% for the B1 (coolest) scenario and 13% for the A1FI (warmest) scenario. These upper-bound estimates would be smaller and more plausible had they incorporated reductions in disaster damages that should be expected to occur due to secular (time-dependent) technological advances and economic growth assumed in the IPCC scenarios.

This table also indicates that total mortality in 2085 for hunger, malaria, and extreme events is lower under the warmest scenario than under the A2 (poorest) and B2 scenarios. There are two reasons for this. First, the latter two scenarios are projected to have higher populations in 2085 (14.2 and 10.2 billion, respectively, versus 7.9 billion).[9,20] This would be consistent with assumptions regarding the level of economic development for these scenarios in 2085—because a richer world should ultimately have a lower population, based on the world's experience in the 20th century.[5] Second, the FTA estimates for the populations at risk for hunger and extreme events account for some, but not all, increases in adaptive capacity due to economic growth that is assumed under the various scenarios.[23]

For hunger specifically, the FTA food and hunger analysis allows for some secular increases in agricultural productivity, increases in crop yield with economic growth due to greater application of fertilizer and irrigation as developing countries become wealthier, decreases in hunger due to economic growth, and for some adaptive responses at the farm level to deal with global warming. However, as that study itself acknowledged, these adaptive responses are based on currently available (1990s) technologies, not on technologies that would be available in 2085, nor any technologies developed to specifically cope with the negative impacts of global warming (were they to become evident) or to take advantage of any beneficial impacts.[14, p 57] For malaria, mortality estimates are based on an FTA study that assumed no change in adaptive capacity from 1990 to 2085.[10, 23]

Note also that mortality in 2085 from the three risk factors considered in Table 2 is approximately the same for the warmest-but-richest (A1FI) and coolest (B1) scenarios. However, mortality for the richest-but-warmest scenario has most likely been overestimated relative to the coolest scenario. First, populations for these two scenarios are assumed to be identical. But as noted, this contradicts historical experience that over the long haul wealthier nations generally have lower population growth rates.[3,5] Second, a fuller accounting of increases in adaptive capacity between 1990 and 2085 due to higher economic development would likely have reduced the mortality estimate for the A1FI scenario more than it would have for the B1 scenario, particularly for malaria, for which—as already noted—future changes in adaptive capacity were ignored.[5,23]

Table 2. Mortality in 2085 from Hunger, Malaria, and Extreme Events[17, 20, 22]

	1990	2085 Scenarios			
	Baseline	**A1FI**	**A2**	**B2**	**B1**
Population in 2085 (billions)		7.9	14.2	10.2	7.9
Global temp change (°C) in 2085		4.0	3.3	2.4	2.1
Mortality in absence of global warming (thousands)					
Hunger	3,240	407	2,976	904	349
Extreme events	25	7	184	87	12
Malaria	1,120	1,657	2,977	2,143	1,657
(Subtotal)	***4,385***	***2,072***	***6,137***	***3,134***	***2,018***
Upper-bound estimate for change in mortality due to global warming (thousands)					
Hunger	0	109	-35	19	39
Extreme events	0	104	689	164	85
Malaria	0	95	96	44	26
(Subtotal)	***0***	***308***	***750***	***228***	***150***
Total mortality	**4,385**	**2,380**	**6,887**	**3,362**	**2,168**

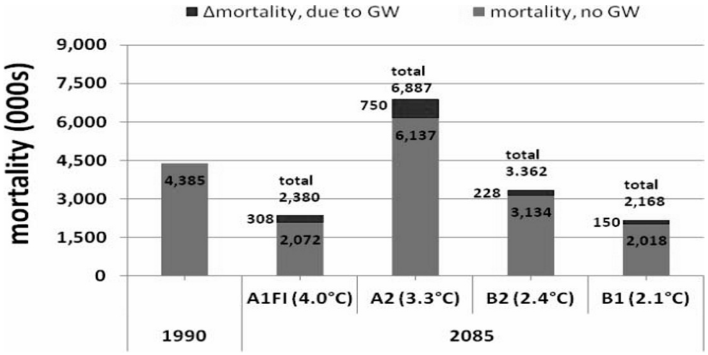

Figure 1 . Deaths in 2085 Due to Hunger, Malaria and Extreme Events, with and without Global Warming. Only *upper bound* estimates are shown for mortality due to global warming. Average global temperature increase from 1990-2085 for each scenario is shown below the relevant bar. Source: Table 2.

Results for the warmest scenario are plotted in Figure 1. Thus, although global warming could become a greater public health threat in the foreseeable future, it will, nevertheless, remain a much smaller threat than other non-global-warming-related threats.

Note that the above estimates do not explicitly consider changes in mortality due to reduced cold stress from any warming that may occur in the future. In many areas, average daily mortality is substantially higher in cold months than in warm months.

Figure 2 shows the average daily deaths per month for the U.S., based on data from 2001–2007. It shows that on average, there were 7,200 daily deaths from December through March for the U.S., compared to 6,400 during the rest of the year.[26, 27] This translates into 95,000 "excess" deaths during the cold months. The same pattern is evident in England and Wales, where excess winter mortality for the 10 winters from 1997/1998 to 2007/2008 fluctuated between 23,000 and 48,000, with 25,300 excess winter deaths for the latest (2007/2008) winter for which data are available (as of this writing). [28] The EU,[29] Japan,[30] and Shanghai, China[31] also have more deaths in winter than in other months. Even for São Paolo, Brazil, which is at the Tropic of Capricorn, Gouveia et al. found a 2.6% increase in all-cause mortality per degree increase in temperature above 20 °C for the elderly, but a 5.5% increase per degree drop below 20 °C, after adjusting for confounding factors such as air pollution; the relationships for children were similar, but somewhat weaker for adults.[32] Finally, it is worth noting that Deschenes and Moretti estimate that 8%–15% of the total gains in life expectancy in the U.S. population from 1970 to 2000 may be because of continuing migration from the cold Northeastern states to the warmer Southern states.[33]

For the future, Tol estimates that net mortality from cardiovascular disease (from heat and cold stress) and respiratory disease (due to heat stress) may decline by half a million in 2050, and 1.5 million in 2200 because reductions in mortality due to lower cold temperatures would more than offset increases due to hotter weather.[34] Similarly, Kovats estimates that through the 2050s, global warming would reduce net mortality in Europe.[35] Bosello et al., however, have a mixed result. Their estimates indicate that net mortality from cardiovascular and respiratory diseases should decline by 850,000 worldwide in 2050 for a 1 °C temperature increase from 1997 to 2050; however, they also estimate an increase in the burden of disease of 4.2 million (based on additional years spent in a diseased condition).[36]

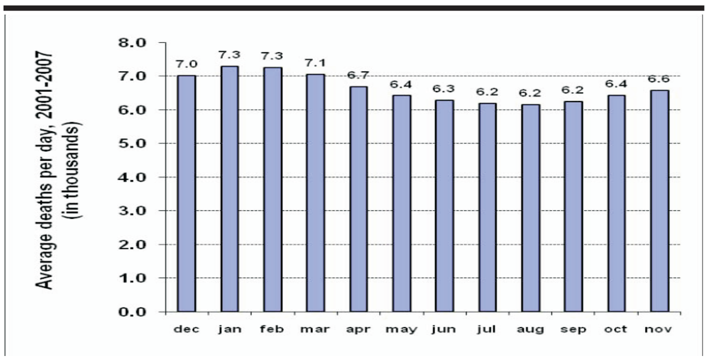

Figure 2: Average Daily Deaths for Each Month, United States, 2001-2007[26, 27]

All this indicates that for many areas, claims that global warming would increase net mortality should be viewed with skepticism unless there is specific—and accurate—accounting for changes in mortality that would result from increases in year-round temperature that might occur not only because of greater warming during the summer months, but lesser cooling in the winter months.

Population at Risk of Water Stress

A frequently raised concern regarding global warming is the potential increase in water stress.[3,11]

Figure 2 provides estimates of the global PAR of water stress in 2085 from the FTA water resources analysis undertaken by Arnell.[37] Remarkably, it indicates that global warming would *reduce* the net global PAR of water stress. This occurs because warming should increase average global precipitation, and although some areas may receive less precipitation, other, more populated areas are, serendipitously, projected to receive more.

This finding apparently clashes with the information provided in the IPCC's latest assessment of the impacts of global warming. The "Summary for Policy Makers" that accompanies that report states that "hundreds of millions [would be] exposed to increased water stress."[11, p 16] This message has been disseminated around the world via numerous channels.[3] Unfortunately, it neglects to inform readers about how many people might experience *reduced* water stress.

Tracing the origin of the above IPCC statement on water stress to its original source, one is led to the results in Arnell's Table 10 (reproduced in Appendix A) that were generated for the year 2085 by the UK Hadley Centre's "coupled atmosphere-ocean general circulation model," version 3, or HadCM3 for short.[37] But this table also indicates that according to HadCM3, water stress would decline for a greater number of people. Moreover, Arnell's Table 9 shows a *decline* in net global PAR for water stress due to global warming under the same HadCM3 runs (Appendix A). Oki and Kanae's review of studies of the global freshwater impacts of global warming indicates that other studies also support this result, that is, global warming would reduce the *net* population under water stress through most of the 21st century.[38]

Figure 3 reinforces the finding from Table 2 that factors unrelated to global warming would, in aggregate, be more adverse for human well-being than global warming through the foreseeable future.

One may choose to overlook the many assumptions made above that would inflate the health impacts of global warming and argue against adopting the analyses represented in Figures 2 and 3, on the basis of the claim that carbon dioxide emissions have grown more rapidly than had been anticipated by the IPCC's scenarios. Reinforcing highly publicized claims that "climate change is worse than we thought,"[39] the Lancet Commission, for example, asserts that "Work done after the IPCC 2007…found that CO_2 emissions growth rate increased from 1.3% to 3.3% every year, suggesting that the current carbon cycle is generating more severe climate change sooner than expected."[3 p 1701] Indeed, it is true that the spectacular economic growth of China and India was beyond most expectations in the 1990s, when the IPCC scenarios were formulated. But emissions increases are not the same as global warming. The relevant question is whether global temperatures and sea levels have risen more rapidly than anticipated in the IPCC (2007) assessment.

The IPCC assessment estimated that if emissions stayed within the range of the IPCC scenarios, then global average temperature should increase 0.2°C per decade in the near term.[40] Therefore, higher CO_2 emissions should, if anything, result in higher temperature increases. But neither the satellite[41] nor surface temperature data[42] show significant global warming since 2000, let alone an increase at a rate greater than 0.2 ºC per decade. The trend for the temperature anomaly (base period 1979-1998) for the lower troposphere using Remote Sensing System's satellite data is essentially flat from January 2000 through April 2009, with an R^2 of 0.0006.[41] The trend line for the surface temperature anomaly (base period 1961-1990) from January 2000 through March 2009 using data from the UK's Hadley Centre is essentially flat, with an R^2 of 0.0003.[42] Of equal importance is the fact that ocean heat content has not increased significantly in recent years,[43, 44] and sea level rise has slowed since 2003.[45]

Admittedly, these empirical trends are based on short-term trends, but so is the claim that we should be more concerned because of a (short-term) increase in CO_2 emissions. More importantly, the divergence over the most recent decade between the IPCC's projected temperature increase and the lack of upward trend in global temperature, sea level, and ocean heat content at a time of unprecedented increases in CO_2 emissions, although short term in origin, suggests that the sensitivity of climate to CO_2 emissions may have been overestimated in the models relied upon by the IPCC for its projections of future warming and its impacts, or that natural variability may be a larger influence on climate than acknowledged by the IPCC, or both.

Policy Implications

So how should we deal with global warming in the context of other more significant health threats?

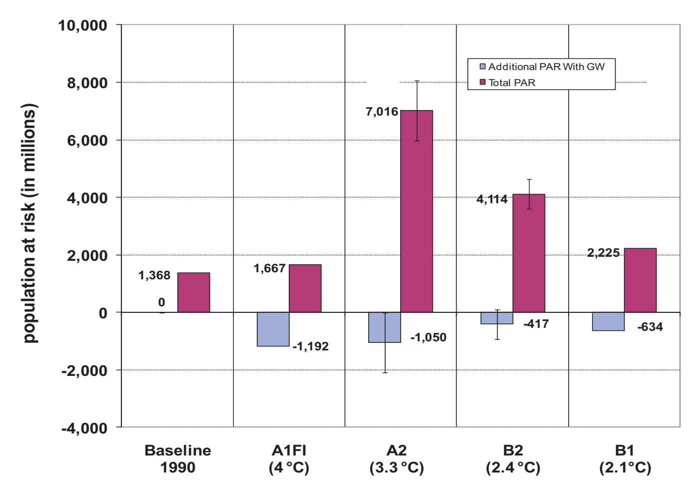

Figure 3. Population at Risk (PAR) from Water Stress in 2085, with and without Global Warming.[20, 37] The vertical bars indicate the PARs based on the mid-point estimates of several model runs, while the vertical lines indicate the range of estimates.

Figures 1 and 2 show that even if it was possible to "roll climate back to 1990 levels" through drastic emissions reductions, it would at most reduce mortality from hunger, malaria, and extreme events in 2085 by 13% under the warmest (A1FI/4°C) scenario, while *adding* a net 1.2 billion people to global PAR of water stress. Such a rollback, even if it were technologically feasible, would have an astronomical cost in terms of economic and social well-being.

On the other hand, one could focus on reducing vulnerability to today's climate-sensitive global health problems that might be exacerbated by global warming. That would target 100% of the mortality (compared to a maximum of 13% for emission reductions) while allowing society to benefit from positive impacts of global warming on water stress even as it tries to reduce its negatives. This approach—labeled "focused adaptation"[20]—can, for instance, consist of measures identified by the U.N. Millennium Project (UNMP) that would, as part of the push to achieve the Millennium Development Goals (MDGs), reduce malaria by 75% at a cost of $3 billion a year.[46] Such measures include improving antenatal care for expectant mothers in vulnerable areas, developing a malaria vaccine, indoor residual spraying with DDT, insecticide-treated bed nets, and otherwise improving public health services.[20] These measures are generic—they would be equally effective whether the malaria was caused by global warming or, as seems more likely, another factor.[47] By contrast, the maximum reduction in malaria mortality that could be obtained in 2085 from emissions reduction is 5% (under the warmest scenario) (see Table 1) were climate to be rolled back to its 1990 level (at an astronomical cost, given present technology).[20]

With respect to hunger, focused adaptation could include measures to develop crops that would do better in poor climatic or soil conditions (drought, waterlogging, high salinity, or acidity) that could be exacerbated by global warming, and under the higher CO_2 and temperature conditions that might prevail in the future.[20] The UNMP estimates that the MDG of a 50% reduction in hunger could cost an additional $12-15 billion per year.[48] Table 1 shows that reducing emission reductions and "rolling climate back to its 1990 level" would, however, reduce hunger by no more than 21%.

Another approach to advancing human well-being while addressing health threats would be to broadly advance adaptive capacity, particularly of developing countries, by reducing poverty through economic development, for example by adherence to the MDGs. Such development would address the fundamental reason why such countries are most vulnerable to global warming, namely, they lack the resources—both economic and human—to deploy the technologies to cope with, or take advantage of, its impacts.[3, p 1694; 5, 23]

A comparison of the two adaptive approaches—focused adaptation and economic development—with primary mitigation of global warming, based on work undertaken by the UNMP and the IPCC, indicates that either adaptive approach will, for a fraction of the cost of any significant emission reductions, deliver greater benefits for human health and well-being.[20] These greater benefits would also be delivered faster because any benefits from emission reductions would necessarily be delayed by the climate system's inertia. No less important, they would accrue to humanity with greater certainty because while the reality of hunger, malaria, and extreme events is uncontested, the contribution of global warming to these problems is, at best, uncertain, as discussed in the foregoing and elsewhere.[20,47]

Yet another benefit of the adaptive approaches is that they allow societies to take advantage of the positive consequences of higher carbon dioxide concentrations and global warming (e.g., higher crop productivity due to carbon fertilization, longer growing seasons in some areas, or lower water stress in some heavily populated areas), whereas mitigation indiscriminately reduces both the positive and the negative impacts associated with global warming. Essentially the adaptive approaches are scalpels compared to mitigation, which is necessarily a meat axe.

Conclusion

Even on the basis of speculative analysis that tends to systematically overestimate the threat posed by global warming, it is currently outranked by numerous other health threats, and will continue to be outranked through the foreseeable future. Exaggerated claims about the importance of global warming seriously risk misplacing priorities in the world's efforts to improve public health. Equally importantly, policies to curb global warming would, by increasing the price of energy and reducing its usage worldwide, retard the economic development that is central to the fight against poverty. Thereby, such policies would tend to perpetuate the diseases and problems associated with poverty (such as hunger, malaria, diarrhea, and other water related afflictions), slow advances in society's adaptive capacity, and retard improvements in human well-being .[5,20]

Since global warming would mostly amplify existing health risks,[3,20] addressing the underlying health risks (e.g., hunger and malaria) would also address any additional health risks attributable to global warming. Accordingly, global health and well-being would, through the foreseeable future, be advanced farther, faster, more surely and more economically through efforts focused on (a) reducing vulnerability to today's urgent health problems that may be exacerbated by global warming, or (b) increasing adaptive capacity, especially of developing countries, through economic development rather than on (c) quixotic, and most likely counterproductive, efforts to reduce energy usage.

Indur M. Goklany, Ph.D. is an author and a researcher who has been associated with the Intergovernmental Panel on Climate Change since its inception in 1988 as an author, expert reviewer, and U.S. delegate to that organization. Contact: 8726 Old Courthouse Rd., Vienna, VA 22182, igoklany@verizon.net.

Disclaimer: The author works for the U.S. federal government. The views expressed in this paper, which was written on the author's own time, are his alone and not those of the U.S. government. No funding was received for writing this paper. There are no conflicts of interest.

Acknowledgements: I am grateful to Dr. Jane Orient and two anonymous referees whose comments and criticisms have vastly improved this paper. Any remaining errors and shortcomings, however, are my responsibility.

References

1 McNicoll T. The President's Passion Play. *Newsweek,* Feb 18, 2008. Available at: www.newsweek.com/id/109547. Accessed Jul 9, 2009.

2 Rosenthal E. U.N. Chief Seeks More Climate Change Leadership. *New York Times*, Nov 18, 2007.

3 Lancet and University College London Institute for Global Health Commission (The Commission). Managing the health effects of climate change. *Lancet* 2009;373:1693-1733.

4 Brenner, MH. Commentary: Economic growth is the basis of mortality rate decline in the 20th century—experience of the United States 1901–2000. *Int J Epidemiol* 2005;34:1214-1221.

5 Goklany, IM. Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development. *Mitigation and Adaptation Strategies for Global Change* 2007. doi:10.1007/s11027-007-9098-1.

6 World Health Organization. *Risk factors*. Available at: www.who.int/healthinfo/global_burden_disease/risk_factors/en/index.html. Accessed May 15, 2009.

7 World Health Organization. *World Health Report 2002—Statistical Annex*. Available at: http://www.who.int/whr/2002/annex/en/index.html. Accessed May 15, 2009.

Appendix A: Tables 9 and 10 from Arnell[37] (reprinted with permission)

Table 9
Numbers of people (millions) moving into and out of the water-stressed category

2025	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR	2055	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR	2085	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR
Become stressed																				
A1	126						A1	280						A1	380					
A2	115–216	206	119	121	67	175	A2	342–423	293	983	302	262	431	A2	493–565	718	756	494	99	788
B1	123						B1	261						B1	235					
B2	131–209	119	298	201	53	105	B2	136–140	147	156	185	56	476	B2	247–396	177	445	325	187	417
Stop being stressed																				
A1	71						A1	1168						A1	1573					
A2	58–823	818	875	729	163	787	A2	191–1375	1493	1048	301	385	601	A2	522–2663	1820	976	2589	1202	1742
B1	637						B1	907						B1	870					
B2	98–609	697	685	755	624	666	B2	857–1048	1369	754	820	85	1219	B2	293–1184	1474	899	994	206	1197

Water-stressed watersheds have less than 1000 m^3/capita/year.

Table 10
Numbers of people (millions) with an increase or decrease in water stress

2025	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR	2055	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR	2085	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR
Increase in stress																				
A1	829						A1	1136						A1	1256					
A2	615–1661	679	915	500	891	736	A2	1620–1973	1092	2761	2165	1978	1805	A2	2583–3210	2429	4518	2845	1560	3416
B1	395						B1	988						B1	1135					
B2	508–592	557	1183	594	374	601	B2	1020–1157	885	1030	1142	670	1538	B2	1196–1535	909	1817	1533	867	2015
Decrease in stress																				
2025	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR	2055	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR	2085	HadCM3	ECHAM4	CGCM2	CSIRO	GFDL	CCSR
A1	649						A1	2364						A1	1818					
A2	1385–1893	2423	1583	1675	1140	1539	A2	2804–3813	4286	2604	1805	2595	3167	A2	4688–5375	6005	3372	4099	4671	4460
B1	1819						B1	2359						B1	1732					
B2	1651–1937	2202	1261	1488	1721	1612	B2	2407–2623	3138	1788	2087	2154	2508	B2	2791–3099	3460	2473	2358	2610	2317

Water-stressed watersheds have less than 1000 m^3/capita/year.

[8] World Health Organization. *Comparative Quantification of Health Risks*. Geneva: World Health Organization; 2004. Available at: www.who.int/healthinfo/global_burden_disease/cra/en/index.html. Accessed Aug 17, 2009.

[9] Parry ML, ed. Special issue: an assessment of the global effects of climate change under SRES emissions and socio-economic scenarios. *Global Environ Change* 2004;14:1-99.

[10] Arnell NW, et al. The consequences of CO_2 stabilization for the impacts of climate change. *Climatic Change* 2002;53:413-446.

[11] Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, eds. *Climate Change 2007: Impacts, Adaptation, and Vulnerabilit*y. Cambridge University Press; 2007.

[12] Parry ML, Rosenzweig C, Iglesias I, Livermore M, Fischer G. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environ Change* 2004;14(1):53–67.

[13] McMichael AJ, Campbell-Lendrum D, Kovats S, et al. Global climate change. In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors.* Geneva: World Health Organization; 2004:1543–1649.

[14] Parry M, Rosenzweig C, Iglesias A, Fischer G, Livermore M. Climate change and world food security: a new assessment. *Global Environ Change: Human and Policy Dimensions* 1999;9:S51-S67.

[15] Lorenzoni I, Adger WN. Critique of treatments of adaptation costs in PAGE and FUND models. In: Warren, R, Hope C, Mastrandrea MD, et al. *Spotlighting Impacts Functions in Integrated Assessment: Research Report Prepared for the Stern Review on the Economics of Climate Change.* Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK. Working Paper 91; September 2006:74**.**

[16] Goklany IM. Climate change is not the biggest global health threat of the 21st century. *Lancet* 2009 (in press).

[17] Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005;438:310-317.

[18] *EM-DAT: The OFDA/CRED International Disaster Database*. Université Catholique de Louvain, Brussels, Belgium. Available at: www.emdat.be/Database/AdvanceSearch/emdat_chooser.php. Accessed May 17, 2009.

[19] World Bank. *World Development Indicators 2008*. Available at: http://ddp-ext.worldbank.org/ext/DDPQQ/member.do?method=getMembers&userid=1&queryId=135. Accessed Jul 9, 2009.

[20] Goklany IM. Is climate change the "defining challenge of our age"? *Energy & Environment* 2009;20(3):279-302.

[21] IPCC [Intergovernmental Panel on Climate Change] (2001a). *Climate Change 2001: Impacts, Vulnerability, and Adaptation*. Cambridge: Cambridge University Press; 2001:463.

[22] Nicholls RJ. Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. *Global Environ Change* 2004;14(1):69-86.

[23] Goklany IM. Is a richer-but-warmer world better than poorer-but-cooler worlds? *Energy & Environment* 2007;18:1023-1048.

[24] Goklany IM. Death and death rates due to extreme weather events: global and U.S. trends, 1900-2006. In: *The Civil Society Report on Climate Change*. London: International Policy Press; 2007. Available at: www.csccc.info/reports/report_23.pdf. Accessed May 20, 2009.

[25] Goklany, IM. *The Improving State of the World: Why We're Living Longer, Healthier, More Comfortable Lives on a Cleaner Planet.* Washington, D.C.: Cato Institute; 2007.

[26] National Center for Health Statistics. Data Warehouse. Available at www.cdc.gov/nchs/datawh/statab/unpubd/mortabs/gmwkIV_10.htm. Accessed Dec 22, 2008.

[27] National Vital Statistics Reports. Available at: www.cdc.gov/nchs/products/pubs/pubd/nvsr/nvsr.htm. Accessed Dec 22, 2008.

[28] Office of National Statistics. Winter mortality: excess winter mortality remains low. Available at: www.statistics.gov.uk/cci/nugget.asp?id=574. Accessed Dec 24, 2008.

[29] Healy JD. Excess winter mortality in Europe: a cross country analysis identifying key risk factors. *J Epidemiol Community Health* 2003;57:784-789.

[30] Nakaji S, Parodi S, Fontana V, et al. Seasonal changes in mortality rates from main causes of death in Japan (1970-1999). *Eur J Epidemiol* 2004;19:905-913.

[31] Kan H-D, Jia J, Chen, B-H. Temperature and daily mortality in Shanghai: a time-series study. *Biomed Environ Sci* 2003;16:133-139.

[32] Gouveia N, Hajat S, Armstrong B. Socioeconomic differentials in the temperature–mortality relationship in São Paulo, Brazil. *Int J Epidemiol* 2003;32:390-397.

[33] Deschenes O, Moretti E. *Extreme Weather Events, Mortality and Migration.* National Bureau of Economic Research Working Paper No. W13227. Social Science Research Network. Available at: http://ssrn.com/abstract=998010.

[34] Tol RSJ. New estimates of the damage costs of climate change, Part II: dynamic estimates. *Environ Resource Economics* 2002;21(1):135-160.

[35] Kovats S. Estimates of temperature-related mortality due to climate change in Europe. *Epidemiology* 2004;15:S95–S96.

[36] Bosello F, Roson R, Tol RSJ. Economy-wide estimates of the implications of climate change: human health. *Ecological Economics* 2006;58:579-591.

[37] Arnell NW. Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environ Change* 2004;14:31-52.

[38] Oki T, Kanae S. Global hydrological cycles and world water resources. *Science* 2006;313:1068-1072.

[39] Public Broadcasting Service. *California and the American Dream, Building Healthy Communities*; 2006. Available at: www.pbs.org/california/programfeature.html. Accessed Jul 3, 2009.

[40] IPCC. *Climate Change 2007: The Physical Science Basis*. Cambridge: Cambridge University Press; 2007:12.

[41] Remote Sensing Systems. *Description of MSU and AMSU Data Products. RSS version 3.2, TLT*. Available at: www.ssmi.com/msu/msu_data_description.html. Accessed May 16, 2009.

[42] Met Office Hadley Centre for Climate Change. *Met Office Hadley Centre Observations Datasets 2009*. www.cru.uea.ac.uk/cru/data/temperature/hadcrut3gl.txt. Accessed May 16, 2009.

[43] Dickey JO, Marcus SL, Willis JK. Ocean cooling: Constraints from changes in Earth's dynamic oblateness (J 2) and altimetry. *Geophys Res Lett* 2008;35,L18608. doi:10.1029/2008GL035115.

[44] Levitus S, Antonov JI, Boyer TP, et al. Global ocean heat content 1955–2008 in light of recently revealed instrumentation problems. *Geophys Res Lett* 2009;36,L07608. doi:10.1029/2008GL037155, figure S11.

[45] University of Colorado. *Sea Level Rise*. Available at: http://sealevel.colorado.edu/. Accessed May 16 2009.

[46] Task Force on HIV/AIDS, Malaria, TB, and Access to Essential Medicines, Working Group on Malaria. *Coming to Grips with Malaria in the New Millennium.* London: EarthScan and UN Millennium Project; 2005.

[47] Reiter P. Global warming and malaria: knowing the horse before hitching the cart. *Malaria J 2008;*7(Suppl 1):S3. doi:10.1186/1475-2875-7-S1-S3.

[48] Task Force on Hunger. *Halving Hunger: It Can Be Done*. London: EarthScan and UN Millennium Project; 2005.