NOVEMBER
2007

The Age of Consequences:
The Foreign Policy and National Security Implications of Global Climate Change

By Kurt M. Campbell, Jay Gulledge, J.R. McNeill, John Podesta, Peter Ogden, Leon Fuerth, R. James Woolsey, Alexander T.J. Lennon, Julianne Smith, Richard Weitz, and Derek Mix

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CSIS
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Center for a New American Security

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
NOV 2007		**00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Age of Consequences: The Foreign Policy and National Security Implications of Global Climate Change	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Center for a New American Security (CNAS),1301 Pennsylvania Avenue, NW,Suite 403,Washington,DC,20004**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**124**	

Acknowledgements

This report was edited by Sharon Burke, Jim Miller, Whitney Parker, and Christine Parthemore of the Center for a New American Security (CNAS) as well as Richard Weitz, Hudson Institute. Additional copy-editing was provided by Vinca LaFleur, CSIS. Billy Sountornsorn of CNAS, as always, supplied creative insights.

Cover Image
Earth going down the drain (1992)

Page 2 Image
Polar Bear (Ursus maritimus), hauling out on the ice floe, Water Bay, Canada

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"The Romans did in these instances what all prudent princes ought to do, who have to regard not only present troubles, but also future ones, *for which they must prepare with every energy, because, when foreseen, it is easy to remedy them; but if you wait until they approach, the medicine is no longer in time because the malady has become incurable; for it happens in this, as the physicians say it happens in hectic fever, that in the beginning of the malady it is easy to cure but difficult to detect, but in the course of time, not having been either detected or treated in the beginning, it becomes easy to detect but difficult to cure. Thus it happens in affairs of state, for when the evils that arise have been foreseen (which it is only given to a wise man to see), they can be quickly redressed, but when, through not having been foreseen, they have been permitted to grow in a way that every one can see them, there is no longer a remedy."*

— Niccolo Machiavelli, Chapter 3, The Prince,in a discussion of the foreign policy of the Roman Republic

LOCATION: Kangerlussuaq, Greenland — Ice boulders ejected and left behind after lake overflow.

EXECUTIVE SUMMARY

In August 2007, a Russian adventurer descended 4,300 meters under the thinning ice of the North Pole to plant a titanium flag, claiming some 1.2 million square kilometers of the Arctic for mother Russia. Not to be outdone, the Prime Minister of Canada stated his intention to boost his nation's military presence in the Arctic, with the stakes raised by the recent discovery that the icy Northwest Passage has become navigable for the first time in recorded history. Across the globe, the spreading desertification in the Darfur region has been compounding the tensions between nomadic herders and agrarian farmers, providing the environmental backdrop for genocide. In Bangladesh, one of the most densely populated countries in the world, the risk of coastal flooding is growing and could leave some 30 million people searching for higher ground in a nation already plagued by political violence and a growing trend toward Islamist extremism. Neighboring India is already building a wall along its border with Bangladesh. More hopefully, the award of the 2007 Nobel Peace Prize to Vice President Al Gore and the Intergovernmental Panel on Climate Change is a clear recognition that global warming poses not only environmental hazards but profound risks to planetary peace and stability as well.

Although the consequences of global climate change may seem to be the stuff of Hollywood—some imagined, dystopian future—the melting ice of the Arctic, the spreading deserts of Africa, and the swamping of low lying lands are all too real. We already live in an "age of consequences,"[1] one that will increasingly be defined by the intersection of climate change and the security of nations.

For the past year a diverse group of experts, under the direction and leadership of the Center for Strategic and International Studies (CSIS) and the Center for a New American Security (CNAS), met regularly to start a new conversation to consider the potential future foreign policy and national security implications of climate change. The group consisted of nationally recognized leaders in the fields of climate science, foreign policy, political science, oceanography, history, and national security, including Nobel Laureate Thomas Schelling, Pew Center Senior Scientist Jay Gulledge, National Academy of Sciences President Ralph Cicerone, American Meteorological Society Fellow Bob Correll, Woods Hole Oceanographic Institute Senior Scientist Terrence Joyce and former Vice President Richard Pittenger, Climate Institute Chief Scientist Mike MacCracken, Georgetown University Professor John McNeill, former CIA Director James Woolsey, former Chief of Staff to the President John Podesta, and former National Security Advisor to the Vice President Leon Fuerth. Our eclectic group occasionally struggled to "speak the same language," but a shared sense of purpose helped us develop a common vocabulary and mutual respect.

The mandate of the exercise was, on its face, very straightforward: employ the best available evidence and climate models, and imagine three future worlds that fall within the range of scientific plausibility. As climate scientist Jay Gulledge explains in Chapter II, projections about the effects of climate change have tended to focus on the most *probable* outcome based on mathematical modeling of what

we know about the global climate. With climate science, however, the level of uncertainty has always been very high. Indeed, the scientific community has been shocked at how fast some effects of global warming are unfolding,[2] which suggests that many of the estimates considered most probable have been too conservative. When building climate scenarios in order to anticipate the future, therefore, there is a very strong case for looking at the full range of what is *plausible*.

Such scenario planning is more than a creative writing exercise; it is a tool used successfully by businesses and governments all over the world to anticipate future events and plan more wisely in the present. These particular scenarios aim not to speculate centuries into the future, as some scientific models do, but to consider possible developments using a reasonable timeframe for making acquisition decisions or judgments about larger geopolitical trends. In national security planning, it generally can take about 30 years to design a weapons system and bring it to the battlefield, so it is important to anticipate future threat environments. It is no less important to anticipate and prepare for the challenges we may face in the future as a result of climate change.

The three scenarios we develop in this study are based on *expected, severe,* and *catastrophic* climate cases. The first scenario projects the effects in the next 30 years with the *expected* level of climate change. The *severe* scenario, which posits that the climate responds much more strongly to continued carbon loading over the next few decades than predicted by current scientific models, foresees profound and potentially destabilizing global effects over the course of the next generation or more. Finally, the *catastrophic* scenario is characterized by a devastating "tipping point" in the climate system, perhaps 50 or 100 years hence. In this future world, global climate conditions have changed radically, including the rapid loss of the land-based polar ice sheets, an associated dramatic rise in global sea levels, and the destruction beyond repair of the existing natural order.

For each of the three plausible climate scenarios, we asked a national security expert to consider the projected environmental effects of global warming and map out the possible consequences for peace and stability. Further, we enlisted a historian of science to consider whether there was anything to learn from the experience of earlier civilizations confronted with rampant disease, flooding, or other forms of natural disaster. Each climate scenario was carefully constructed and the three corresponding national security futures were thoroughly debated and discussed by the group.

Below is a synthesis and summary of some of the key findings from the various chapters, discussions, and presentations that have emerged over the course of the last several months. This is by no means an exhaustive list but is meant to provide a clear distillation of our key findings:

- **The *expected* climate change scenario considered in this report, with an average global temperature increase of 1.3°C by 2040, can be reasonably taken as a basis for national planning.** As Podesta and Ogden write in Chapter III, the environmental effects in this scenario are "the least we ought to prepare for." National security implications include: heightened internal and cross-border tensions caused by large-scale migrations; conflict sparked by resource scarcity, particularly in the weak and failing states of Africa; increased disease proliferation, which will have economic consequences; and some geopolitical reordering as nations adjust to shifts in resources and prevalence of disease. Across the board, the ways in which societies react to climate change will refract through underlying social, political, and economic factors.

- **In the case of *severe* climate change, corresponding to an average increase in global temperature of 2.6°C by 2040, massive nonlinear events in the global environment give rise to massive nonlinear societal events.** In this scenario, addressed in Chapter IV, nations around the world will be overwhelmed by the scale of change and pernicious challenges, such as pandemic disease. The internal cohesion of nations will be under great stress, including in the United States, both as a result of a dramatic rise in migration and changes in agricultural patterns and water availability. The flooding of coastal communities around the world, especially in the Netherlands, the United States, South Asia, and China, has the potential to challenge regional and even national identities. Armed conflict between nations over resources, such as the Nile and its tributaries, is likely and nuclear war is possible. The social consequences range from increased religious fervor to outright chaos. In this scenario, climate change provokes a permanent shift in the relationship of humankind to nature.

- **The *catastrophic* scenario, with average global temperatures increasing by 5.6°C by 2100, finds strong and surprising intersections between the two great security threats of the day — global climate change and international terrorism waged by Islamist extremists.** This catastrophic scenario would pose almost inconceivable challenges as human society struggled to adapt. It is by far the most difficult future to visualize without straining credulity. The scenario notes that understanding climate change in light of the other great threat of our age, terrorism, can be illuminating. Although distinct in nature, both threats are linked to energy use in the industrialized world, and, indeed, the solutions to both depend on transforming the world's energy economy — America's energy economy in particular. The security community must come to grips with these linkages, because dealing with only one of these threats in isolation is likely to exacerbate the other, while dealing with them together can provide important synergies.

- **Historical comparisons from previous civilizations and national experiences of such natural phenomena as floods, earthquakes, and disease may be of help in understanding how societies will deal with unchecked climate change.** In the past, natural disasters generally have been either localized, abrupt, or both, making it difficult to directly compare the worldwide effects of prolonged climate change to historical case studies. No precedent exists for a disaster of this magnitude — one that affects entire civilizations in multiple ways simultaneously. Nonetheless, the historical record can be instructive; human beings have reacted to crisis in fairly consistent ways. Natural disasters have tended to be divisive and sometimes unifying, provoke social and even international conflict, inflame religious turbulence, focus anger against migrants or minorities, and direct wrath toward governments for their actions or inaction. People have reacted with strategies of resistance and resilience — from flood control to simply moving away. Droughts and epidemic disease have generally exacted the heaviest toll — both in demographic and economic terms — and both are expected effects of future climate change. Indeed, even though global warming is unprecedented, many of its effects will be experienced as local and regional phenomena, suggesting that past human behavior may well be predictive of the future.

- **Poor and underdeveloped areas are likely to have fewer resources and less stamina to deal with climate change — in even its very modest and early manifestations.** The impact on rainfall, desertification, pestilence, and storm intensity has already been felt in much of Africa, parts of Central Asia, and throughout Central and South America. Some of the nations and people of these regions lack the resilience to deal with

modest — let alone profound — disturbances to local conditions. In contrast, wealthier societies have more resources, incentives, and capabilities to deploy, to offset, or to mitigate at least some of the more modest consequences of climate change. It would be a mistake, however, to assume that climate change will not be a problem for affluent countries, including the United States. Such nations may also face dire conditions such as permanent agricultural disruptions, endemic disease, ferocious storm patterns, deep droughts, the disappearance of vast tracks of coastal land, and the collapse of ocean fisheries, which could well trigger a profound loss of confidence in the most advanced and richest states.

- **Perhaps the most worrisome problems associated with rising temperatures and sea levels are from large-scale migrations of people — both inside nations and across existing national borders.** In all three scenarios it was projected that rising sea levels in Central America, South Asia, and Southeast Asia and the associated disappearance of low lying coastal lands could conceivably lead to massive migrations — potentially involving hundreds of millions of people. These dramatic movements of people and the possible disruptions involved could easily trigger major security concerns and spike regional tensions. In some scenarios, the number of people forced to move in the coming decades could dwarf previous historical migrations. The more severe scenarios suggest the prospect of perhaps billions of people over the medium or longer term being forced to relocate. The possibility of such a significant portion of humanity on the move, forced to relocate, poses an enormous challenge even if played out over the course of decades.

- **The term "global climate change" is misleading in that many of the effects will vary dramatically from region to region.** Changes in ocean currents, atmospheric conditions, and cumulative rainfall will vary across different geographies, making it difficult to predict truly global outcomes. Most localities will likely experience rising temperatures, but some places might see temperature declines due to the complexities of local climate processes. Changes across the board are unlikely to be gradual and predictable and more likely to be uneven and abrupt. Certain ecosystems — such as polar ice regions and tropical rainforests — are much more susceptible to even modest changes in local temperatures. And these regions are particularly important when it comes to both regulating and triggering conditions associated with climate change. Global climate change involves the entire planet but it will play out very differently with varying levels of intensity and significance in different regions — a key observation of the group.

- **A few countries may benefit from climate change in the short term, but there will be no "winners."** Any location on Earth is potentially vulnerable to the cascading and reinforcing negative effects of global climate change. While growing seasons might lengthen in some areas, or frozen seaways might open to new maritime traffic in others, the negative offsetting consequences — such as a collapse of ocean systems and their fisheries — could easily negate any perceived local or national advantages. Unchecked global climate change will disrupt a dynamic ecological equilibrium in ways that are difficult to predict. The new ecosystem is likely to be unstable and in continual flux for decades or longer. Today's "winner" could be tomorrow's big-time loser.

- **Climate change effects will aggravate existing international crises and problems.** Although a shared sense of threat can in some cases promote national innovation and reform as well as induce cooperation among governments, the scenario authors found that climate change is likely to worsen existing tensions, especially over natural resources, and possibly lead to conflict. Indeed,

this magnifying of existing problems by climate change is already taking place, from desertification in Darfur, to water shortages in the Middle East, to disruptions of monsoons in South Asia and attendant struggles over land and water use. These and other effects are likely to increase and intensify in the years ahead.

- **We lack rigorously tested data or reliable modeling to determine with any sense of certainty the ultimate path and pace of temperature increase or sea level rise associated with climate change in the decades ahead.** Our group found that, generally speaking, most scientific predictions in the overall arena of climate change over the last two decades, when compared with ultimate outcomes, have been consistently below what has actually transpired. There are perhaps many reasons for this tendency—an innate scientific caution, an incomplete data set, a tendency for scientists to steer away from controversy, persistent efforts by some to discredit climate "alarmists," to name but a few—but the result has been a relatively consistent underestimation of the increase in global climate and ice melting. This tendency should provide some context when examining current predictions of future climate parameters.

- **Any future international agreement to limit carbon emissions will have considerable geopolitical as well as economic consequences.** For instance, China's role in such an arrangement could significantly affect the international community's perception of its willingness and capacity to serve as a "responsible stakeholder." The added strategic significance of low-carbon fuels in a carbon-constrained world, meanwhile, could bolster the position of a natural gas-rich country such as Russia. Such a new correlation of energy related power might conceivably lead to a diminished role and significance of the Middle East in global politics. In addition, major proliferation challenges would ensue from a vast expansion in the use of nuclear power. The emergence of alternative energy sources, especially biofuels, could also create new regions of strategic significance.

- **The scale of the potential consequences associated with climate change—particularly in more dire and distant scenarios—made it difficult to grasp the extent and magnitude of the possible changes ahead.** Even among our creative and determined group of seasoned observers, it was extraordinarily challenging to contemplate revolutionary global change of this magnitude. Global temperature increases of more than 3°C and sea level rises measured in meters (a potential future examined in scenario three) pose such a dramatically new global paradigm that it is virtually impossible to contemplate all the aspects of national and international life that would be inevitably affected. As one participant noted, "unchecked climate change equals the world depicted by Mad Max, only hotter, with no beaches, and perhaps with even more chaos." While such a characterization may seem extreme, a careful and thorough examination of all the many potential consequences associated with global climate change is profoundly disquieting. The collapse and chaos associated with extreme climate change futures would destabilize virtually every aspect of modern life. The only comparable experience for many in the group was considering what the aftermath of a U.S.-Soviet nuclear exchange might have entailed during the height of the Cold War.

- **At a definitional level, a narrow interpretation of the term "national security" may be woefully inadequate to convey the ways in which state authorities might break down in a worst case climate change scenario.** It is clearly the case that dramatic migrations and movements of people (among other worrisome effects) will trigger deep insecurity in some communities, but it is far from clear whether these anxieties will trigger a traditional national security response. It is conceivable

that under certain scenarios a well-armed nation experiencing the ravages of environmental effects brought on by climate change might covet the more mild and fertile territory of another country and contemplate seizing that land by force. While this kind of scenario should not be ignored, there is a broader and more likely range of potential problems, including disease, uncontrolled migration, and crop failure, that are more likely to overwhelm the traditional instruments of national security (the military in particular) and other elements of state power and authority rather than cause them to be used in the manner described above.

In the course of writing this study we found inescapable, overriding conclusions. In the coming decade the United States faces an ominous set of challenges for this and the next generation of foreign policy and national security practitioners. These include reversing the decline in America's global standing, rebuilding the nation's armed forces, finding a responsible way out from Iraq while maintaining American influence in the wider region, persevering in Afghanistan, working toward greater energy security, re-conceptualizing the struggle against violent extremists, restoring public trust in all manner of government functions, preparing to cope with either naturally occurring or manmade pathogens, and quelling the fear that threatens to cripple our foreign policy—just to name a few. Regrettably, to this already daunting list we absolutely must add dealing responsibly with global climate change. Our group found that, left unaddressed, climate change may come to represent as great or a greater foreign policy and national security challenge than any problem from the preceding list. And, almost certainly, overarching global climate change will complicate many of these other issues.

This report makes clear that we are already living in an age of consequences when it comes to climate change and its impact on national security, both broadly and narrowly defined. The overall experience of these working groups helped underscore how much needs to be done on a sustained basis in this emerging field of exploration. While more work clearly needs to be done on the overall science of carbon loading and its impact on climate change, we already know enough to appreciate that the cascading consequences of unchecked climate change are to include a range of security problems that will have dire global consequences. This study aims to illuminate how some of these security concerns might manifest themselves in a future warming—and worrisome—world.

LOCATION: South Georgia — King Penguins at the beach in the cold windy rain, against the high snow mountains.

THE METHODOLOGICAL APPROACH OF THIS STUDY AND PREVIOUS RESEARCH ON THE IMPACTS OF CLIMATE CHANGE

By Kurt M. Campbell and Richard Weitz

Although the consequences of global climate change may seem to be the stuff of Hollywood—some imagined, dystopian future—the melting ice of the Arctic, the swamping of low lying lands, and the spreading deserts of Africa are all too real. We already live in an age of consequences, one that will increasingly be defined by the intersection of climate change and the security of nations. This point was fundamentally underscored by the awarding of the 2007 Nobel Peace Prize to former Vice President Al Gore and the Intergovernmental Panel on Climate Change, a recognition that climate change carries with it not only environmental threats, but threats to the very peace and stability of the planet.

In spite of the demands of this age, the body of literature looking at the actual implications of climate change is relatively small. We hope this study will make an important contribution to the understanding of what might well turn out to be the single most significant challenge confronting the United States—and, indeed, human civilization. We approached the task with humility: understanding the scope and the scale of climate change is not easy. It is even harder to come up with credible ideas and options for managing and mitigating the effects of global warming.

For the past year a diverse group of experts, under the direction and leadership of the Center for a New American Security (CNAS) and the Center for Strategic and International Studies (CSIS), met regularly to start a new conversation about security and climate change and consider the potential future foreign policy and national security implications. Our collaboration engaged, for the first time, climate scientists and national security specialists in a lengthy dialogue on the security implications of future climate change. Our eclectic group occasionally struggled to "speak the same language," but a shared sense of purpose helped us develop a common vocabulary and mutual respect.

A distinguished group of nationally recognized leaders were identified and recruited from the fields of climate science, foreign policy, political science, oceanography, history, and national security to take part in this endeavor. Members of the group included: Nobel Laureate Thomas Schelling; Pew Center Senior Scientist Jay Gulledge; National Academy of Sciences President Ralph Cicerone; American Meteorological Society Fellow Bob Correll; Woods Hole Oceanographic Institute Senior Scientist Terrence Joyce and former Vice President Richard Pittenger; Climate Institute Chief Scientist Mike MacCracken; John McNeill of Georgetown University; former CIA Director James Woolsey; former Chief of Staff to the President John Podesta; former National Security Advisor to the Vice President Leon Fuerth; Jessica Bailey, Sustainable Development Program Officer at the Rockefeller Brothers Fund; Rand Beers, President of Valley Forge Initiative; General Counsel Sherri Goodman of the Center for Naval Analysis; CNAS Senior Fellow Derek Chollet; President of the Pew Center on Global Climate Change Eileen Claussen; Gayle Smith, Senior Fellow at the Center for American Progress; Daniel Poneman, Principal of The Scowcroft Group; Senior Fellow Susan Rice of The Brookings Institution; and Principal of The Albright Group Wendy Sherman.

The mandate of the exercise was, on its face, very straightforward: employ the best available evidence and climate models, and imagine three future worlds that fall within the range of scientific plausibility. Such scenario planning is more than a creative writing exercise: it is a tool used successfully by businesses and governments all over the world to anticipate future events and plan more wisely in the present. The scenarios in this report use the timeframe of a national security planner: 30 years, the time it takes to take major military platforms from the drawing board to the battlefield. The exception is the catastrophic scenario, which extends out beyond fifty years to a century from now.

The three scenarios are based on *expected, severe,* and *catastrophic* climate cases. The first scenario projects the effects in the next 30 years with the expected level of climate change. The *severe* scenario, which posits that the climate responds much more strongly to continued carbon loading over the next few decades than predicted by current scientific models, foresees profound and potentially destabilizing global effects over the course of the next generation or more. Finally, the *catastrophic* scenario is characterized by a devastating "tipping point" in the climate system, perhaps 50 or 100 years hence. In this future world, global climate conditions have changed radically, including the rapid loss of the land-based polar ice sheets, an associated dramatic rise in global sea levels, and the destruction of the existing natural order.

For each of these three future climate scenarios, we asked a national security expert to speculate about what the likely consequences for peace and stability might conceivably be of the environmental conditions proposed. Further, we enlisted a historian of science to consider whether there was anything to learn from the experience of earlier civilizations confronted with rampant disease, flooding, or some other form of national disaster. Each climate scenario was carefully constructed and the three corresponding national security futures were thoroughly debated and discussed by the group.

Although the intersection of climate change and national security has yet to be fully mapped, scholars and strategists certainly have explored this territory in recent years. We felt it was important to begin this study by looking at this literature, in order to understand how we both build on and depart from the existing intellectual framework.

Foundations of the Debate

The literature of global warming and national security has centered on a foundational debate: are climate change and other ecological developments comparable to traditional security threats, or are they not? Thomas F. Homer-Dixon, a professor who studies the link between environment and conflict, helped to launch this debate with a pair of articles in *International Security* in 1991 and 1994. He discussed various contingencies in which widespread environmental changes could lead to international and intranational conflict and concluded that global warming would not have a major independent impact on international security issues. For at least the next few decades, he wrote, climate change would likely generate conflict of this scale only in conjunction with several other social, political, and environmental variables. He maintained that non-environmental variables such as weak political institutions, illegitimate or contested governments, and ethnic group ties must be present for environmental scarcity to cause conflict among or within states.[3] Soon after, Marc A. Levy argued against expanding the traditional definition of national security to encompass environmental issues and maintained that climate change, ozone depletion, and other global ecological changes are best addressed in the environmental realm.[4]

More recently, the literature has charted a more direct relationship between climate change and conflict, and specifically, conflict stemming from resource shortages. "Climate policy, in short, equals security and peace politics," wrote Hermann Ott in 2001. "Water and food shortages, rising sea levels and generally changing patterns of precipitation will lead to mass migrations and a considerable increase in low- and high- intensity warfare in many parts of the southern world."[5] Scholars at a June 2004 roundtable conference in Washington, D.C. voiced a similar assessment: "By threatening human livelihoods and contributing to social and economic inequities, environmental problems exacerbate proximate causes of conflict such as migration, relative deprivation, tense ethnic divisions, poor governance, and declining economic productivity."[6] And the High-Level Panel on Threats, Challenges, and Change appointed by former UN Secretary General Kofi Annan warned in 2004 of a vicious cycle of poverty, disease, environmental degradation, and civil violence.[7] Another group of scholars recently stated:

> Natural resources are at the core of a number of conflicts. Non-renewable resources such as oil and minerals fuel geopolitical rivalries, clashes with indigenous peoples, and sometimes finance civil wars. Disputes also arise over renewable natural resources such as water, arable land, and forests. The effects of environmental breakdown often reinforce social and economic inequities or deepen ethnic and political fault lines.[8]

According to another assessment, conflicts over natural resources have contributed to wars in Kuwait, Columbia, Afghanistan, and the Democratic Republic of Congo, and have sustained insurgencies in Angola, Sierra Leone, and elsewhere.[9]

There are disagreements, however, about the relationship between natural resources and war. Daniel Deudney, for example, wrote that fighting to obtain scarce resources is normally irrational since cheaper solutions to access problems exist, including conservation, trade, and substitution. For this reason, actors will often cooperate in the collective management of natural resources to avoid the costs of fighting.[10] Indra de Soysa argued that abundance is more likely to provoke conflict than scarcity, given that potential adversaries may target resources as a war aim or as a way to finance military actions.[11]

The Case of Water

As noted in the historical survey in the next section of this report, there is a long record of states dealing with scarcity of water. Given that history, it's not surprising that much has been written on the subject, including the relationship between access to water and conflict. This body of literature is important, both because water scarcity is predicted to be one consequence of global warming and because it affects our understanding of the climate change debate.

The historical record shows that water scarcity has resulted in both conflict and cooperation. The Environmental Change and Security Program at the Smithsonian Institution's Woodrow Wilson Center highlighted this dichotomy that environmental challenges such as climate change can threaten or bolster human security. "These factors can contribute to conflict or exacerbate other causes such as poverty, migration, and infectious diseases," the group stated. "However, managing environmental issues and natural resources can also build confidence and contribute to peace by facilitating cooperation across lines of tension."[12]

In 1991, Joyce Starr published a landmark article in *Foreign Policy* titled "Water Wars." The author warned that water shortages threatened conflict throughout much of North Africa and the Middle East.[13] Many related articles and studies about armed clashes and other conflicts surrounding access to water followed. Peter Gleick's 2000 chronology, for example, identifies water as a factor in at least 42 violent conflicts that have occurred worldwide since the beginning of the last century. However, Gleick's chronology includes cases in which adversaries have employed water as a means of attack, such as when they bomb dams or poison wells.[14] Other scholars have identified as few as seven cases of acute, water-related, transboundary conflicts—with exchanges of fire occurring in only four of them, including two between Israel and Syria.[15]

There are also "water wars" skeptics. One report claimed that the last time parties fought a military conflict expressly over water could be when the Mesopotamian cities of Lagash and Umma battled each other 4,500 years ago.[16] Noting that governments have signed thousands of international agreements regarding water issues, Sandra Postel and Aaron Wolf wrote that, in the case of water, "the history of cooperation, creativity and ingenuity is infinitely more rich than that of acute conflict."[17]

Scholars involved with the "Basins at Risk" project at Oregon State University—which studies developments relating to the Nile, Mekong, Euphrates, Amu Darya, Syr Darya, and Ganges—concluded that water scarcity does not increase the likelihood of interstate conflicts. Nevertheless, they maintain that tensions surrounding shared river basins can characterize relations between nations and undermine cooperation in other areas. As a result, governments may be more likely to turn to unilateral development projects, such as dams, that control water flow across international borders. Under favorable conditions, however, dialogue over water can promote cooperation and prevent conflict. For example, discussions between India and Pakistan over the Indus River led to the resumption of talks over other bilateral concerns. In other cases, transboundary water agreements and institutions have proven resilient even in the face of conflicts over other issues—as shown by the relationship between Israel and Jordan, the Mekong Committee, and the Indus River Commission.

This absence of a clear link between conflict and water may explain why some analysts are reluctant to systematically link environmental issues to national security more broadly.

The Climate Skeptics

The climate change-conflict nexus has its fair share of skeptics. Many observers remain unconvinced that climate change, whether due to manmade or natural causes, represents an urgent security threat requiring major changes in national foreign and defense policies.[18] For example, some researchers from the Hart-Rudman Commission, which was charged in the late 1990s with speculating on 21st century threats to American security, downplayed the potential danger from climate change. The commission's summary paper posits that, while there will always be natural disasters and environmentally induced refugees, "There is doubt, however, about the severity of future trends, depending on how one reads the pace, depth, and source of climate change."[19]

Similarly, Ben Lieberman observed that temperatures have risen and fallen many times in the past and that current changes fall within this historic range of natural variability. He asserted that the recent warming trend has not proven especially harmful to human beings or the Earth's other inhabitants, who he maintains are much more resilient to changes in temperature than is generally assumed.[20]

For this reason, Lieberman and other analysts still consider global warming as solely an environmental concern; in their assessment the security implications of climate change remain speculative. In addition, they observe that none of the consequences forecast in the authoritative reports of the IPCC represent immediate security threats. Instead, they argue, the United Nations could contribute to international security more effectively in other ways, such as by strengthening its peacekeeping operations.[21] Participants in the Copenhagen Consensus process likewise questioned the value of devoting scarce resources to the potential threats of global climate change at a time when other threats to human life appear more certain.[22]

Climate as a Threat

There are strong voices on the other side of the argument, as well. For example, according to the December 2000 *Global Trends 2015* report from the National Intelligence Council, "Some existing agreements, even when implemented, will not be able by 2015 to reverse the targeted environmental damage they were designed to address…Global warming will challenge the international community."[23]

Other analysts expressed much more direct national security concerns, including the possibility of a link between climate change and terrorism. Writing just before the attacks of September 11, 2001, Elizabeth Chalecki maintained that as natural resources become more scarce and vulnerable, they become increasingly attractive terrorist targets. In her words, "The destruction of a natural resource can now cause more deaths, property damage, political chaos, and other adverse effects than it would have in any previous decade."[24] Chalecki defined environmental terrorism as "the unlawful use of force against *in situ* environmental resources so as to deprive populations of their benefit(s) and/or destroy other property,"[25] and warned of the ease with which they can be perpetrated and their long-lasting effects. Chalecki also distinguished between the use of environmental resources as a terrorist tool and the potential for natural resources to become a target of terrorism. In the former scenario, the resource is used as a delivery vehicle to carry a destructive agent to a human population. In the latter case, resources are targeted for their own sake, with nearby communities suffering collateral damage. In Chalecki's assessment, water sites, crops, and oil facilities have properties that make them especially attractive and vulnerable to environmental terrorists.[26]

Since September 11, 2001, the relationship between environmental developments and terrorism has become even more prominent. In a 2005 article titled *Climate Change Poses Greater Security Threat than Terrorism,* Janet Sawin asserted

that transformations in the climate will disrupt global water supplies and agricultural activities. Sawin stated that the resulting drought and famine will lead some people to turn to extralegal organizations and terrorist groups that can provide for their basic needs better than existing economic and political institutions.[27]

Others have maintained that global climate change represents a more serious threat than terrorism, regardless of how it impacts the latter phenomenon. For example, Gregory Foster called "focusing our thinking and our actions on identifying and eradicating the underlying causes of insecurity, thereby curing the disease rather than treating the symptoms," a strategic imperative, on par with establishing new regional security regimes and better civil-military integration. As he describes, "Environmental degradation and climate change take us much farther along the path to ultimate causes than terrorism ever could, especially if we acknowledge that the social, political, economic, and military conditions we prefer to deal with and attribute violence to may mask disaffection and unrest more deeply attributable to an environmentally degraded quality of life."[28]

Climate change rather than the perennial issues of globalization, nuclear proliferation, and the Iraq War dominated this year's World Economic Forum meeting of the world's political and business leaders in Davos, Switzerland.[29] In explaining why he chose to discuss climate change at Davos, British Conservative Party Leader David Cameron explained: "There is a consensus…that says we need to take action to prevent it, rather than just mitigate its effects. But, at the same time, politicians have a duty to prepare for its consequences in terms of domestic and international security." Cameron and others cite the example of Darfur as a "climate change conflict," where resource shortages have contributed to the unresolved dispute while drawing international pressure to alleviate the human suffering and quell refugee flows.[30]

An Array of Scenarios and Models

The most extreme vision of the possible near-term disruptive effects of global climate on international affairs appears in *An Abrupt Climate Change Scenario and Its Implications for United States National Security* by Peter Schwartz and Doug Randall.[31] This October 2003 report, commissioned by the Office of Net Assessment of the Department of Defense, gained widespread attention after it was profiled in *Fortune* magazine.[32] (The film *The Day After Tomorrow* subsequently popularized an even more abrupt-transition scenario.) The authors deliberately aimed for "imagining the unthinkable" by describing an extremely unlikely scenario in which the world experiences an abrupt and vast change in its climate over the next two decades then speculating how nations might respond. For example, Schwartz and Randall suggested that the resulting shortages in food, water, and energy supplies would "de-stabilize the geo-political environment, leading to skirmishes, battles, and even war" between countries seeking to defend their existing resource stocks and those less fortunate states compelled to seize assets from others for their survival. Other potentially disruptive security developments featured in this scenario included mass population movements, civil wars, and accelerated nuclear proliferation.

Notwithstanding the goal of Schwartz and Randall to break with conventional assessments of the pace of climate change, their recommendations are surprisingly conventional: improving the predictive power of climate models, creating vulnerability metrics for countries at risk, identifying robust hedging strategies to ensure reliable access to food and water, and rehearsing adaptive responses to climate change. Their one novel suggestion—exploring geo-engineering options to regulate the climate (such as perhaps deliberately adding GHG neutralizing agents to the atmosphere)—has not garnered much support given the risks involved.

The implausibility of the study's contingency, moreover, appears to have made national security planners cautious about accepting the authors' scientific analysis or policy recommendations. For this reason, this report's analysis adheres to the general scientific consensus that such an abrupt change in the world's climate will not occur before the next century.

Although he does not focus on the international consequences of global climate change, James Lovelock—the originator of the Gaia hypothesis, which posits that the Earth naturally regulates its climate and chemistry to support life—predicted that within a few decades large regions of the planet will become uninhabitable to human beings and other species. In such a scenario, human civilization itself could well collapse as people abandon many modern practices and relocate to the few remaining habitable regions at the extreme northern and southern hemispheres.[33]

Essam El Hinnawi first coined the term "environmental refugee" in 1985 to refer to people forced to leave their homes, temporarily or permanently, due to environmental threats to their existence or quality of life.[34] Since one-third of the world's population resides within 60 kilometers of a coastline, the widespread sea level rises predicted by scientific models of global warming could create millions of additional environmental refugees (their current number is estimated at around 25 million people).[35] A recent working paper made available by the World Bank argues that over the course of the 21st century sea level rise due to climate change could displace hundreds of millions of people residing in developing countries.[36] Christian Aid fears that climate change could deprive as many as 1 billion people of their homes between now and 2050.[37]

Relocating is a common response to environmental threats. For example, Rafael Reuveny counted 38 cases of mass environmental migration in human history. In his analysis land degradation played a role in 27 of these cases, drought in 19, deforestation in 17, water scarcity in 15, floods in nine, storms in seven, and famine in five cases.[38] Reuveny also described four ways in which this environmental migration can contribute to conflict. First, violent competition can ensue between natives and migrants over local resources, especially under conditions of scarcity or when property rights are already loosely defined. Second, the arrival of migrants of a different ethnic background than the natives can threaten to shift the locality's ethnic balance, a prospect the natives may resist. Third, people in both the original and the new host country can seek to use the migrants as a foreign policy tool, especially to destabilize the other country. Fourth, the migration can exacerbate already existing conflicts over issues such as land rights, resulting in an escalation of these disputes. Reuveny concluded that the likelihood of conflict is greater if the host country is underdeveloped and if the affected communities have large income disparities.[39]

What Can Be Done?

Whatever the possible international distribution of climate change effects, there is a general consensus about the need for multilateral cooperation. In the October 2006 *Review on the Economics of Climate Change,* former World Bank economist Nicholas Stern maintained that, while the near-term costs of stabilizing the concentration of greenhouse gases in the atmosphere are significant but manageable (approximately 1 percent of global GDP), any major delay in responding would result in substantially higher aggregate costs, amounting to an estimated loss of up to 20 percent of the world's GDP. One of the report's key assessments is that all countries can contribute to combating climate change while still achieving economic growth. In particular, the Stern review urged a multi-dimensional international response involving: expanded use of carbon emissions trading arrangements;

increased cooperation in developing and sharing low-carbon technologies, curbing deforestation, and greater support for adaptation measures.[40]

At the end of March 2007, the U.S. Army War College sponsored a two-day conference at the Triangle Institute for Security Studies on "The National Security Implications of Global Climate Change." Participants included civilian strategists and active duty and former military officers, who explored a range of issues potentially linking climate change to international security. A major goal of the meeting was to assess how the military could mitigate climate change, assist in efforts to adapt to climate change, and prepare for the security challenges that might ensue from climate change. The attendees stressed that any effective response to climate change-related security problems likely would require multi-agency cooperation, especially for domestic emergency management, and typically multinational action.[41]

In April 2007, the Center for Naval Analysis (CNA) Corporation issued a landmark report that attracted major attention in the national security community because of its advisory board of former senior U.S. military officers.[42] The authors recognized that much scientific uncertainty regarding climate change persists, but urged "moving beyond the argument of cause and effect" since observed climate change was already occurring and presenting challenges to national security planners. According to the report, "The chaos that results can be an incubator of civil strife, genocide, and the growth of terrorism." The authors warn that these developments could contribute to state failure, interstate conflicts, or other security problems in many geographic regions that could require a response by an already overburdened U.S. military. Transformations in the environment resulting from climate change could also complicate regular U.S. military operations. Hurricanes and rising sea levels could threaten U.S. military facilities, extremely hot or cold weather could disrupt U.S. military operations, and allied militaries might offer less support for joint missions if they also have to respond to environmental threats. The board affirmed that, as military officers, they had long recognized the need to assess the risks of low probability events if the consequences could prove sufficiently severe.

In the face of these challenges, the CNA panel recommended that the United States adjust its national security and national defense strategies to account for the possible consequences of climate change.[43] For example, the Department of Defense should conduct an impact assessment of how rising sea levels, extreme weather events, and other effects of climate change might affect U.S. military installations over the next three to four decades. They also cautioned that extreme environmental conditions degrade weapons systems and military personnel. Beyond the military dimension, the panel members urged that the U.S. government seek to enhance the resilience of the international community against climate-related threats by strengthening the governance, healthcare, and disaster prevention and relief capabilities of foreign countries. They noted that the recent creation of U.S. Africa Command (AFRICOM) seems to serve such a purpose. The authors also recommended that the United States help limit climate change through unilateral and multilateral measures, with the Department of Defense contributing through more efficient energy use and other measures.

Conclusion

In a 2007 *New York Times* op-ed Thomas Homer-Dixon offered his own assessment of the last few decades of research on the relationship between climate change and violent conflict. His conclusion: "Climate stress may well represent a challenge to international security just as dangerous — and more intractable — than the arms race between the United States and the Soviet Union during the

Cold War or the proliferation of nuclear weapons among rogue states today…It's time to put climate change on the world's security agenda."[44]

Indeed, in early 2007, the group responsible for setting the "Doomsday Clock," a depiction of the risks of imminent worldwide catastrophe, cited the threat of climate change as one reason for moving its minute hand two minutes closer to midnight.[45] The risk that such catastrophe may lie at this intersection of climate change and national security is not as well understood as it should be, despite decades of exploration of the relationship between climate change and conflict. We hope that this collaborative effort offers a strong foundation for its continued, high-priority exploration.

The Age of Consequences:
The Foreign Policy and National Security Implications of Global Climate Change

LOCATION: West Germany — Silhouette of the Neurath Power Plant.

By J.R. McNeill[46]

It is prudent, both intellectually and practically, to accept that the atmosphere and oceans are indeed warming, as the evidence tells us, and that this trend will accelerate in the decades ahead. While we do not and cannot know just how much warming will occur how fast, we can safely say that the rapidity of warming currently, and in all likelihood over the next decades, has few precedents in the history of the Earth and none in the history of civilization. This is true regardless of which of the three versions of the future offered in this report one prefers.

No instrumental records exist for prior episodes of climate change. The proxy evidence used for the reconstruction of climate history—palynology, foraminifera, oxygen isotopes, and other tools—can give a good but not precise idea of past temperature and precipitation patterns.

The Earth's climate has never been static. For the past 2.7 million years, it has shown a pattern of alternating long ice ages and shorter interglacials, governed by cycles in the Earth's orbit around the sun. The last ice age was at its height around 20,000 years ago. Its end (c. 11,000-6,000 years ago) was probably crucial for human history as it coincided with the emergence of agriculture in multiple locations. After that bout of warming—generally much slower than what we have witnessed in the last 100 years but not without sudden lurches now and again—global climate changed only modestly and slowly until the industrial age.[47] While our Paleolithic ancestors did have to cope with rapid climate change from time to time, when they did so the Earth had fewer people (or hominids) than Chicago has today, and they were accustomed to migrating with their scant possessions as a matter of course. Their response to adverse climate change (as to much else) was to walk elsewhere. Since the emergence of agriculture, sedentarism, civilization, and the settlement of all habitable parts of the globe, the Paleolithic response has become more and more impractical. Thus, while there are

analogues in Earth's history for the climate change now under way, there are none in human history. We have entered uncharted terrain.

Buffers, Resilience, and Nature's Shocks

As a species, we've enjoyed a run of luck in the Holocene. In the last 10,000 years, while migration as a response to adversity has become progressively less viable, warming and cooling trends and attendant sea level fluctuations were small. Even the Little Ice Age, c. 1300–1850, amounted to a cooling (in Europe, where the data are best) of about 0.5°C. It made harvest failures more frequent in northern Europe, and probably contributed to the extinction of the tiny Greenland Norse settlement in the early 15th century. In lower latitudes, the Little Ice Age probably featured desiccation and more frequent droughts—a much more disruptive experience than mild cooling or warming. But as nature's surprises go, the climate change of the Little Ice Age was modest.[48]

In the past, nature's shocks and stresses challenged all societies. In recent millennia, the most dangerous of these included epidemics, droughts, floods, earthquakes, and volcanic eruptions. Warming, cooling, and sea level changes were far down the list. Broadly speaking, these challenges came in two varieties: short, sharp shocks with durations of days, weeks, or a year or two; and long, slow stresses that played out over decades or centuries, and were often invisible to people at the time. In terms of demographic losses, epidemics were by far the most serious.[49]

Table 1 ranks the demographic seriousness of nature's shocks in very rough terms. The mortality figures, given only as an order of magnitude, represent the maximum, meaning 95 to 99 percent of such incidents would kill fewer people. So for example, while there may have been a flood or even 10 floods that killed more than 1 million people, this represents the worst that floods have ever done to humankind.

Table 1

Approximate Maximum Mortality Levels from Nature's Shocks	
Volcanic Eruptions	10^4
Earthquakes	10^5
Floods	10^6
Droughts	10^7
Epidemics	10^8

The worst epidemics have killed 30 million to 100 million people, even if one counts the bubonic plague pandemic of the 14th century as a single epidemic. The most recent epidemic on such a scale, the 1918 to 1919 influenza, killed perhaps 40 million (about 2 percent of the global population). The ongoing AIDS pandemic has so far killed 25 million to 30 million, about 0.5 percent of the current population.[50] Such pandemics are mercifully rare, but epidemics that affected regions or single cities were not, and they routinely killed 5 to 10 percent or even more of the affected population.

Droughts at their worst killed a few million. The long history of drought is notably fuzzy, and whether or not deaths ought to be laid at drought's door is often unclear, especially for the deeper past. In the 20th century, where the uncertainties are smaller, the deadliest droughts occurred in China from 1928 to 1931, in 1936, and in 1941, with 2 million to 5 million deaths on each occasion, generally through starvation. The famous Sahelian droughts of 1967 to 1973 and again in the early 1980s each killed about 1 million people. In all probability some of the drought-induced Indian famines of the 19th century killed more, but the figures are in dispute.[51]

Floods too could kill thousands, even millions, although flood control and evacuation procedures have made a large difference in flood mortality. Since 1953, the annual average of deaths in floods in India, the country most afflicted by floods, is about 1,500. The worst flood in recent Chinese

history, on the Yangtze in 1954, killed 30,000 people. Yangtze floods of 1931, perhaps the most costly ever, killed 1 million to 4 million, and those on the Hwang He in 1887 perhaps 1 million to 2 million. The great North Sea floods of December 1953 killed some 2,400 in the Netherlands, whereas earlier floods, in 1212, had killed 60,000. A 1342 flood in central Europe, which caused half of all the soil erosion over German lands in the past millennium, probably drowned hundreds of thousands of people.[52] In 1927, the worst flood in U.S. history (until Katrina) killed 243 people along the lower Mississippi River.[53]

Of the many thousands of deadly earthquakes, only 10 have killed more than 100,000 people. The worst occurred in China in 1566, killing perhaps 800,000. The recent tsunami of December 2004, created by an earthquake, killed 284,000, while the 2005 earthquake in Pakistan killed about 79,000. The San Francisco earthquake of 1906, the worst in U.S. history, killed about 3,000.[54]

Of the countless volcanic eruptions, only six are likely to have killed more than 10,000 people. The worst case, Tambora (Indonesia) in 1815, took 92,000 lives; Krakatau (1882) cost 36,000. The famous eruption of Mt. Vesuvius in AD 79 killed about 3,600, while the worst in U.S. history, Mt. St. Helens in 1980, killed 57.

With the exception of the richer parts of the world since 1919, every generation everywhere lived with the likelihood of devastatingly lethal epidemic, flood, drought, and other sorts of natural risks.[55]

As a result, all societies had to build resilience to nature's shocks. They did not, by and large, intentionally build resilience or resistance to nature's slow-acting stresses, such as desiccation or soil salinization, because these progressed too slowly to cause alarm and normally too slowly to be noticed from one generation to the next. But resistance and resilience to the easily observable short, sharp shocks was, always and everywhere, an important priority.

Resistance and resilience are not the same thing. Resistance to flood, for example, can take the form of the construction of seawalls and dikes, as the Dutch have done for 600 years to keep the North Sea at bay. Resilience to flood means the capacity to recover as quickly and easily as possible, which might take the form of leaving a river floodplain uninhabited, used only for seasonal pasture, as was done along the Rhine until its canalization (which began in 1815).

Societies built resistance to nature's shocks as a conscious enterprise. In regions of the world prone to drought, they developed water-storage infrastructure such as cisterns. In flood-prone regions, they built homes on stilts. Cities developed quarantine routines to try to prevent epidemics. By the 18th century, the Chinese Qing dynasty had constructed an elaborate system of state granaries intended to prevent famine from whatever cause (the Aztecs had done this on a smaller scale in the 15th century). By the 19th century, richer societies undertook to control river floods with dikes, dams, and canalization.[56] Since the 1880s, public health services have made major efforts—by and large crowned by success—to prevent epidemics through sanitation reforms and vaccination regimes. Otherwise there would not be 6.3 billion people today.

There have always been limits to the degree to which resistance can be built. Preventing volcanic eruptions remains impossible and stopping lava flows implausibly expensive. Flood control is feasible but only within limits, which occasionally are overwhelmed, as in the Mississippi basin in 1927 and 1993 and most recently in New Orleans in 2005. Moreover, as the Mississippi and New Orleans floods show, societal faith in the

infrastructure of resistance can undermine resilience: the opportunity cost of leaving a floodplain unoccupied seems excessive if one trusts the levees and dikes.

Resilience, on the other hand, has to date proved in abundant supply: our species has survived countless shocks and now covers the globe as never before. In our earliest years, as noted above, resilience consisted mainly of mobility, the ability to escape the worst of a natural shock through migration, and to start afresh in a new landscape. Until recent decades, this remained an option for millions of pastoralists and the few remaining hunting/foraging populations. As recently as 1912–15, when severe droughts affected the West African Sahel, millions of people adapted by migrating southward—a feasible response because in those days West Africa had about one-eighth the population it carries today, and there were no effective border control regimes to inhibit migration. For the great majority of our historical experience, mobility was the solution to nature's shocks. Today it is severely restricted.

A second source of resilience in times past was simplicity combined with fertility. Societies with minimal infrastructure lose little except people in experiencing natural disasters, and new people are easily created. Rebuilding a city in the aftermath of a flood or earthquake requires much more in the way of knowledge, investment, coordination, and cooperation than does rebuilding a patchwork of fields and villages. Most peasant societies prior to the 20th century maintained a stock of unmarried young people who, in the wake of deadly catastrophe, would stampede into marriage and within a year sharply raise birth rates. This was not a conscious strategy, but a result of custom and economic preferences. Nonetheless it provided resilience in the form of the ability to ramp up fertility quickly and jump start demographic recovery.[57]

For many centuries societies have also created more conscious mechanisms to improve resilience. Storing food in state warehouses to cope with dearth or famine is a strategy intermittently practiced since ancient times, and brought to a high level of reliability by the Qing dynasty in 18th century China.[58] Transportation infrastructure, although built for other reasons, also provided resilience in that it both allowed faster evacuations from affected zones and also quicker rescue and relief. Societies with extensive and dense road and/or canal networks, for example, eliminated famine by the end of the 18th century, while those without remained vulnerable.

Organized relief efforts also improved resilience in modern history. The practice of maintaining contingency funds against disasters is probably nearly as old as money and treasuries. Providing government funds internationally for disaster victims dates back at least to a great Jamaican hurricane of 1783 and a Venezuelan earthquake of 1812. Standing international bodies devoted to disaster relief probably began no earlier than 1863, with the founding of the Red Cross (which until the late 1940s concerned itself almost entirely with victims of war, rather than nature's shocks).[59] The total effect of such efforts and organizations upon societal resilience has to date been modest, but they have eased the suffering of millions.

In the last two or three centuries, as societies have grown less simple and as mobility has become less feasible as a societal response, resistance and resilience have come to take more bureaucratic and technological forms; for example, granaries, seawalls, and international relief organizations. Since 1950 or so, the ability to evacuate millions and to bring large quantities of food and other supplies, quickly and over great distances, has improved immensely. As a result, modern famines have mainly been an artifact of war and totalitarian politics, rather than a result of environmental factors.[60] Ironically, the logistical capacity to do

such things was in large part developed to meet the military requirements of global war, especially in World War II.

As a consequence disease, droughts, floods, and earthquakes that a century or more ago might have killed millions more recently would only kill thousands. This extraordinary ability to mitigate disaster has hinged on the comparative stability of international politics since 1945. This relative stability provided an opportunity for what we might call "regimes of resilience" to develop. However, the rapid population growth that allowed these resilience regimes to flourish (rapid population growth promoted quick demographic recovery after disasters) may actually prove counterproductive. Resilience in the face of drought or similar shock can be harder to maintain in more crowded circumstances, as can resistance to disease.

Vulnerability to shock consisted of several components. First and most obviously, the intensity and duration of natural shocks often made all the difference between survival and catastrophe. Societies that could withstand one drought per year with only hunger could not withstand two without starvation. Second and equally obviously, some societies had, by design or accident, less in the way of buffers or resilience than others. A society that had few or no domestic animals, for example, could not survive a harvest failure as reliably as could a society that could eat its animals one by one. Societies that had poor transport infrastructure could not import food as readily or cheaply as could others with good roads, canals, or (eventually) railroads. Nor could the isolated receive government or charitable assistance as easily, if it was in the offing. Societies such as early 20th century rural China, which used nearly every available acre as farmland and preserved very little in the way of woodlands or wetlands, proved more vulnerable to flood than did others that (by accident or design) kept land in reserve. Societies without active and able public health systems suffered more from epidemics than did those that had such systems.

Less obvious, perhaps, were differences in levels of ecological ignorance. Populations that have lived in one environment for several generations gradually acquire, and usually take pains to transmit, knowledge of how to survive and prosper within the limits of their environment. They also gradually form a sense of the boundary conditions to be expected and know from oral tradition that they must be prepared for adversities—locust invasions, prolonged drought, and so forth—beyond their own personal experience. Populations present for dozens of generations normally had exquisite ecological knowledge and knew where to find edible plants to see them through famine, where to find underground water when there was none on the land's surface, and so forth. Such knowledge contributed materially to resilience.

Conversely, in many instances, especially in the last two centuries (because of cheap transportation and more long-distance migration), many populations found themselves operating experimentally in new environments. This was true of the British and Irish settlers in Australia after 1788, who inevitably misunderstood antipodean ecology and often paid a price for it.[61] It was true of the American farmers on the southern plains, almost all of whom came from more humid climes, who during the 1930s drought naturally presumed that the moister years of 1915 to 1930 were normal. They were ignorant of the cyclic drought patterns of the plains and inadvertently turned a routine drought into an epic Dust Bowl. Ecological ignorance also lay behind the failures of the Soviet Virgin Lands scheme of the 1950s, in which Premier Nikita Khrushchev ordered an area of dry Siberian steppe land the size of California to be planted to wheat, only to see within a few years disastrous drought, dust storms, and harvest failure.

Societal and Political Reverberations

Natural shocks regularly took a demographic toll. But it is worth emphasizing that the great majority of floods, drought, epidemics, and so on had only local or regional effects and killed small numbers of people. This was true in the distant past because the human population was small. It has been true in the past 50 years partly because of luck (nothing really bad has come up since the influenza pandemic of 1918–19) and partly because public health systems, disaster management systems, and so forth have grown remarkably (albeit imperfectly) effective. In terms of demographic losses from natural shocks, the worst era came between 1300 and 1920.

Interestingly, heightened mortality was not the only source of demographic decline connected to natural shocks. When young people's expectations for the future were lowered and their faith shaken, they tended to postpone marriage, either of their own will or because their elders required it. Moreover, married people, in such dark times, found ways to restrict their fertility. Consequently, for the duration of most disasters, and in the wake of those that were especially disheartening, not only did more people than usual die, but fewer than usual were born. Wars and severe economic depressions produced this effect too. Its magnitude varied tremendously, with the degree of discouragement and the availability of knowledge and means for contraception.

Normally, if disaster was followed by good fortunes, exuberant fertility made up for the losses within a few years. In some cases, however, reproductive slowdowns and strikes lasted decades. This appears to have been the case with the native populations of the Americas during and after the relentless epidemics of the 16th and 17th centuries.

The economic effects of natural shocks, unlike the demographic ones, have tended to grow and grow. But that is mainly for cheerful reasons: the world economy is now so large that there is much more at risk. Global GNP grew 15-fold in the 20th century, and more than four-fold in per capita terms.[62] The direct effects of damage to property depended on where disasters occurred. None were worse, in monetary terms, than the Kobe earthquake of 1995, whose costs may have topped $200 billion, and 2005's Hurricane Katrina, whose costs are put variously between $25 billion and $100 billion. The Indian Ocean tsunami of 2004 led to about $10 billion in direct economic losses.

The Kobe earthquake mangled a densely populated and built-up part of Japan, the country's industrial heartland. It killed 4,571 people and knocked down more than 67,000 buildings. The monetary costs came to about 2.5 percent of Japan's 1995 GNP, and led to the failure of financial institutions such as Barings Bank that were deeply invested in the Japanese property market (Japanese property often carried no earthquake insurance).[63]

While storms and earthquakes often had locally devastating economic effects, droughts by and large did not. In the United States, estimated federal expenditures on droughts averaged half a billion dollars between 1953 and 1988. Federal costs rose from the 1950s to the 1980s, but even the worst case, the 1987–89 drought years, did not much exceed $2 billion per year. This is far more than the federal government provided for drought relief during the Dust Bowl decade of the 1930s.[64]

Although droughts were relatively less expensive overall, costs from discrete natural shocks rose rapidly. In the 1950s, the American total came to roughly $4 billion per annum on average. In 2003 that had swollen to $65 billion, and in 2004 to $145 billion, according to Munich Re, the world's biggest reinsurance firm. About two-thirds of the costs incurred came from floods and storms. The mass migration into flood-prone regions since 1930, and the consequent creation of housing stock and infrastructure, chiefly accounts for the

tremendous rise in the cost of floods and storms. Florida's Broward Country, a regular hurricane victim, had 20,000 people in 1930, and 1.6 million by 2000.[65]

Although the costs from nature's shocks rose rapidly—and locally could have devastating effects for a decade or more—none in modern history, not even the 1918-19 influenza, had durable economic consequences that changed the affairs of nations. One could not make that claim for the 1346 to 1350 plague pandemic, which is credited with helping to end feudalism in Western Europe by raising the negotiating power of laborers. But this event was of unique intensity (it killed perhaps one-third of Europe's population).

A final consideration with respect to the economic implications of nature's shocks is the possibility of Schumpeterian "creative destruction." The Austrian economist had in mind business cycle crashes and disruptive innovations when he coined this phrase in 1942 to refer to a phenomenon in which bankruptcies eliminated inefficient enterprises, freeing up resources for more efficient use. Taking the response to the plague pandemic in Europe as an inspiration, it is possible to imagine that in the long run, brutal destruction of existing infrastructure and plant could clear the way for a new generation of more efficient investment. This optimistic perspective, it must be said, assumes a shock is followed by a time of stability and other favorable conditions. While the great Lisbon earthquake of 1755 cleared the way for a more economically rational city plan in subsequent years, it is anything but clear that, for example, post-Katrina New Orleans will feature more economically efficient plant and infrastructure—although the opportunity surely exists.[66] In any event, recurrent shocks would prohibit creative destruction even if other circumstances were favorable.

Political and social effects of nature's shocks defy quantitative measure, and all conclusions about them are tentative and subject to dispute. Nevertheless, some generalizations seem reliable.

First, nature's shocks in the past have proven both socially divisive and unifying at the same time. This is easily visible in the Katrina disaster, in which looting was widespread and citizens preyed upon one another in various disturbing ways. Moreover, the challenges of responding to a disaster on that scale exacerbated political and social cleavages, as various officials and groups blamed one another for mismanagement (not without cause). At the same time, however, citizens throughout the United States donated money, materials, and labor in solidarity with the Katrina victims. So did populations in dozens of countries overseas. Such paradoxical responses are probably the norm.

Second, social conflict on some scale was routine during and after disasters. Societies with little in the way of safety net—say Ethiopia in the 1970s and 1980s—easily succumbed to banditry, ethnic and religious violence, and even outright civil war under the stress of acute drought.[67] Restraint and civility can quickly perish when confronted with imperious necessity. This much has been obvious to observers since Thucydides's analysis of the Corcyran Revolution.

Third, political reaction to shocks often took the form of scapegoating minorities or foreigners. The Black Death in Europe intensified persecution of Jews, who were accused of poisoning wells and causing the pestilence. This played some role in encouraging Jewish migration to Eastern Europe in the 14th century.[68] After the great 1923 Kanto earthquake in Japan, which killed some 130,000 to 150,000 people, vigilante mobs together with army and police units attacked Tokyo's Korean

community, then about 30,000 strong, and killed perhaps 6,000. Many Japanese believed rumors that Koreans had set fires and poisoned water supplies in the earthquake's aftermath.[69]

Fourth, in the wake of disasters government authorities frequently attracted popular wrath either for neglect or for intrusive efforts to minimize or prevent damage. This is by and large a modern phenomenon, a reflection of the state's assumption of responsibility for public health and order. The cholera epidemics in 19th century Europe intensified divisions within society and contributed to the revolutionary spirit of the 1830 to 1871 era. Cholera was a fearsome scourge that killed quickly and seemed to come out of nowhere (it was communicated by a bacillus that thrives in warm water and came from South Asia). Urban populations with unsanitary water were especially victimized, which in the context of the times fueled the widespread belief that the upper classes or the state were systematically poisoning the poor. Government efforts at quarantines, compulsory hospitalization, and *cordons sanitaires* provoked riots and attacks on state officials. While popular reactions to cholera and to state efforts to control it in France cannot be said to have caused the revolutions of 1830 or 1848, they surely contributed to the distrust of authorities and class antagonisms that underlay these uprisings.[70] Echoes lasted as late as the 1910–11 cholera epidemic in Apulia, Italy, to which the authorities reacted by encouraging pogroms against gypsies and forcibly detaining and isolating the sick. Italians responded by rioting and killing medical officials, which led the state to call in the army.[71]

In the course of the 19th and early 20th centuries, states took more and more responsibility for public health. Compulsory inoculation against smallpox, pioneered by George Washington in the Continental Army—he probably would have lost the Revolutionary War without this step[72]—set an example that inspired much imitation once vaccines were developed against commonplace diseases. Popular resistance still factored in, however. In Rio de Janeiro, for example, poor neighborhoods revolted against public health campaigns involving smallpox vaccination and mosquito control as a measure against yellow fever from 1904 to 1905.[73]

In colonial contexts this sort of political turmoil as a reaction to government efforts to check epidemics or other natural disasters was often still more pronounced, and rumors of deliberate biological warfare more frequent. In colonial Mexico, for example, droughts often preceded peasant uprisings, not merely because drought meant hunger, but also because at such times the distribution of irrigation water seemed especially unfair, whereas in times of plentiful rainfall it mattered less.[74] Efforts to control outbreaks of sleeping sickness in colonial East Africa, which involved resettlement schemes, quarantine of livestock, and other intrusive measures, regularly provoked local rebellions against British rule.[75] Along the coast of what is now southeastern Ghana, in West Africa, coastal erosion which the colonial government declined to address helped push the local population into political resistance to colonial rule.[76] British efforts to improve public health in colonial India, and especially to contain the many epidemics of the years 1890 to 1921, frequently ran afoul of local sensibilities and aroused ire that easily translated into political resistance.[77] In the right social and political circumstances, natural shocks, and perceptions of official reactions to them, could precipitate resistance and rebellion.

In one sense, this was nothing new. In most pre-colonial African societies, and in imperial China (before 1911) as well, populations normally believed that proper ecological functioning, meaning the absence of floods, droughts, epidemics and so forth, depended on a proper relationship between their rulers and heavenly powers. Natural shocks, therefore, represented a breakdown in

that relationship and an inevitable loss of moral authority for rulers. Floods and droughts were taken to mean rulers had lost their efficacy—lost the mandate of heaven in Chinese parlance—and thus no longer were owed obedience. This obviously invited political turmoil.

In the 19th and 20th centuries, when national governments increasingly sought and took responsibility for disease control, flood control, drought relief, and so forth, they inadvertently put themselves in the vulnerable position of the Chinese emperors. If natural shocks were not properly managed—in some instances if they were not prevented—the blame lay with the state. Legitimacy became hostage to the whims of nature. So while states improved their capacity to deal with nature's shocks, they were held to ever higher standards, expected to cope effectively with them, but not to intrude too deeply upon citizen's lives and lifestyles. At times rulers invited trouble by encouraging lofty expectations. France's Emperor Napoleon III in 1857 addressed parliament with the great Alpine floods of 1856 as well as the revolutions of 1848 on his mind: "By my honor, I promise that rivers, like revolution, will return to their beds and remain unable to rise during my reign."[78] Such boasts did nothing to enhance his moral authority.

The political significance of nature's shocks normally played out on local or national scales and touched international politics only indirectly. When they did affect international politics, they exhibited the same paradoxical power to bring nations together and to push them into conflict.

Since at least the 18th century, natural disasters have occasionally provoked outpourings of sympathy, both among populations and among states. A notable recent example came in August and September 1999, when earthquakes hit first Izmit in Turkey and then a suburb of Athens, Greece. The Greek government was the first to come to the aid of Turkish earthquake victims, and weeks later the Turks reciprocated. Ordinary Greeks and Turks donated money and supplies to help earthquake victims in the other country. This came against a background of long enmity between the governments and populations, and helped considerably in defusing a long-simmering rivalry and reorienting politics across the Aegean. In this case, of course, political conditions had to be right for a rapprochement before earthquake diplomacy could yield such results.

Epidemics, while providing plenty of opportunity for mutual recrimination, probably brought states together more often than they drove them apart. The obvious rewards to international cooperation in disease control put the incentives clearly in favor of harmonized actions wherever possible, and against giving vent to frustrations with inadequate measures taken by neighboring states. Since the establishment of the International Red Cross, the World Health Organization, and other such entities—whether global or regional in scope—the multinational integration of disease control efforts has become routine and rarely the occasion for conflict. One exception to this rule is the position taken by Thabo Mbeki and some other South Africans on HIV/AIDS, which they sometimes attributed to malevolence on the part of Americans and Europeans.[79] Even this, however, did not fundamentally affect relations between South Africa and the West.

Sometimes, of course, nature's shocks exacerbate international or intersocietal conflicts. Earthquakes, hurricanes, and volcanic eruptions have rarely if ever had this effect because they are so localized in their damage. Droughts are another matter. The greatest revolt in the history of Spanish America, that of Tupac Amaru in the Andes from 1780 to 82, coincided with one of the worst droughts of the millennium, a result of a powerful El Niño. Thousands of desperate peasants rallied to his standard, which in better times would have appealed to far fewer. In another dramatic case,

recent drought in southern Africa in the decade between 1820 and 1830, converted routine competition for grazing land and food into systemic conquests of the weak by the strong. The *mfecane* ('crushing') created a torrent of refugees throughout southern Africa and resulted in the formation of powerful new states, such as the Zulu kingdom.[80] Drought was also a spur to the slave-raiding that fed the Atlantic slave trade between 1550 and 1850: when food was scarce, one of the few ways to get it was to capture people and trade them for food from afar. Indeed progressive desiccation—secular climate change—in the West African Sahel drove mounted slave raiders deeper and deeper into West Africa in the years after 1600.

Throughout the semi-arid zones of the world, where drought was a regular risk, pastoralists and cultivators often uneasily shared frontier zones. Droughts, locust plagues, or any natural shock created desperation and drove otherwise peaceful communities to attack their neighbors; and weakness born of drought (or some other shock) aroused the cupidity of nearby peoples or states. The most common format for such violence was attacks by pastoralists upon settled villages, a common pattern in world history in semi-arid areas from Manchuria to Senegal. Such attacks of course also took place without the provocation of drought, but drought made them more frequent. In medieval times in northern Syria and Iraq environmental shocks of one sort or another came once every five or six years on average, and often brought political violence in their wakes. Villagers had every reason to support a strong state in hopes of keeping pastoralists in check.[82]

While drought was probably the most politically dangerous of all nature's shocks in the deeper past, in the last 100 years water management schemes have often blunted its impact. Moreover, violent political conflict has become more often the affair of urban-based states rather than pastoral tribes and confederacies, and such states have found it imprudent to go to war to resolve problems created by drought. Even the potentially divisive cases of international river basins such as the Indus, the Mekong, or the Nile have so far been the subject of successful diplomacy rather than military conflict. While observers in recent decades have often foreseen "water wars," in these and other contexts, it has yet to happen, and indeed it has not happened for several millennia, if ever.[83] The historical record suggests that with well-organized states, the probability of warfare arising from drought-induced water shortage is low; the risk rises in the presence of weak states within which those components of society most aggrieved by drought are less constrained in their responses.

Before departing the subject of political reverberations from nature's shocks it is worth considering whether or not there is an analogue to Schumpeterian creative destruction in the political realm. Can natural shocks shake a society and state out of harmful complacencies and create the political will to undertake needed reforms? Can they discredit the least efficient parts of the political apparatus so thoroughly as to create new space for the more efficient? Perhaps, if conditions already exist for reformism, and if the gales of destruction are not so powerful as to destroy the state entirely. The Dust Bowl in the United States, for example, gave rise to a useful reform in the creation of the Soil Conservation Service, which has helped prevent the recurrence of catastrophic erosion on the scale of the 1930s, despite droughts in subsequent decades that were equally or more severe. The 1755 earthquake in Lisbon provided the Marques de Pombal with an opportunity to push through fundamental reforms in Portugal. The bubonic plague that harrowed Russia in the 1770s and the cholera epidemics of 19th century Europe both led to major reform efforts in municipal and national governments. Disappointing responses to hurricanes in 19th century Cuba had similar effects.[84] This may amount to a small silver lining in the dark cloud of

natural disaster, in the same way that losing a war or undergoing economic depression served as spurs for reform—provided something survived to be reformed.

Religious turbulence has long been a normal social reaction to nature's shocks. Throughout history most people understood plagues, hurricanes, droughts, and so forth as divinely ordained or the work of evil people with supernatural powers. Hence extraordinary natural shocks often brought heightened religiosity, either in the form of more intense devotion to traditional religions or more defections to innovative religions or cults. The rise of the Lotus Sect (Nichiren Buddhism) in Japan was abetted by a great earthquake in Kamakura, among Japan's chief Buddhist centers, in 1257. The recurrent bubonic plague epidemics in Europe after 1348 gave rise to all manner of eccentric religious practices, most famously a sect of self-flagellants who when not occupied murdering Jews and clergymen wandered about renting their flesh in imitation of Jesus' sufferings. The Neapolitan cult of San Gennaro derives from the experience of 1631 when Naples avoided harm in a great eruption of Mt. Vesuvius. The New Madrid earthquakes of 1811–12, following on serious floods in the Ohio and Mississippi basins, helped the prophet Tecumseh—who allegedly predicted the earthquakes—rally Native Americans to his religious war against the United States (which incidentally helped maintain Canada as an independent entity). It also prompted many white Americans to experiment with eccentric religious doctrines.[85] The severe drought of 1991 to 1992 in Zimbabwe, often called the worst in living memory, gave rise to at least three charismatic religious movements as Zimbabweans found divine explanations for their misfortunes more satisfying than hypotheses about perturbations in the Intertropical Convergence Zone.[86]

There is rarely a shortage of people charismatic and persuasive enough to make a convincing case (for those ready to be convinced) that any extraordinary event is a sign that religious reform is needed. It would be interesting to know whether the Katrina disaster brought an upsurge in religiosity along the Gulf Coast. In any case, if the future holds more serious extreme weather events it seems likely that the most extreme will generate new forms of religion and intensified commitment to old ones.

Conclusion

So can history help us with global warming? The answer, perhaps, is yes and no. Yes in the sense that in the long record of human history there have been certain consistencies in how human beings handle environmental disasters. From conflict, to coming together, to scapegoating migrants or minority groups, to religious zeal, it is clear what to expect from most people. The answer also has to be no, however, given that past disasters occurred on a relatively limited or discrete scale, particularly in recent years. There is no precedent in human history for a global disaster that affects whole societies in multiple ways at many different locations all at once. It is very difficult to predict how the past might inform the present and the future when it comes to climate change as a global phenomenon. But the effects of climate change will play out simultaneously on several scales, and some of its likeliest consequences – enhanced drought and flood for example—will in the future, as in the past, be felt locally and regionally rather than globally. Thus the more one unpacks the concept of climate change into its components, the more the record of the past becomes relevant to imagining the future.

The Age of Consequences:
The Foreign Policy and National Security Implications of Global Climate Change

LOCATION: The Amazon — A deforestation scene.

By Jay Gulledge[87]

AUTHOR'S NOTE: The scenarios outlined in this section are not predictions of future conditions and should not be read or cited as such.

Overview

This chapter reviews projected climate change impacts over the next 30 to 100 years and outlines three increasingly severe climate change scenarios that cover a plausible range of impact severity. These scenarios, based on current scientific understanding and uncertainty regarding past and future climate change, guide assessments in later chapters of potential security consequences of climate change impacts. The general approach is to settle on three different levels of global average temperature change for each scenario, and then extract relevant projected impacts from the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change and other peer-reviewed sources. We focus particularly on changes in freshwater resources, food production, extreme weather events, sea level rise, and the overturning circulation of the North Atlantic Ocean.

As the purpose of this project is to assess potential security risks of future climate change, the primary criterion for the climate impacts scenarios outlined here is *plausibility* rather than *probability*. Rather than asking, *What is the most likely climate-driven outcome?*, we ask, *What potential climate-driven outcomes are plausible, given current scientific understanding?* Recent observations indicate that projections from climate models have been too conservative; the effects of climate change are unfolding faster and more dramatically than expected. Given the uncertainty in calculating climate change, and the fact that existing estimates may be biased low at this time, plausibility is an important measure of future impacts. Under this umbrella of plausibility, potential changes that the IPCC or other assessments may characterize as improbable are considered plausible here if significant uncertainty persists regarding their probability; collapse of the North Atlantic overturning circulation is an example. Because projections of sea level rise remain particularly

uncertain, direct consultation with experts and the author's professional judgment inform the sea level rise scenarios outlined here.

Scenario-based Approach

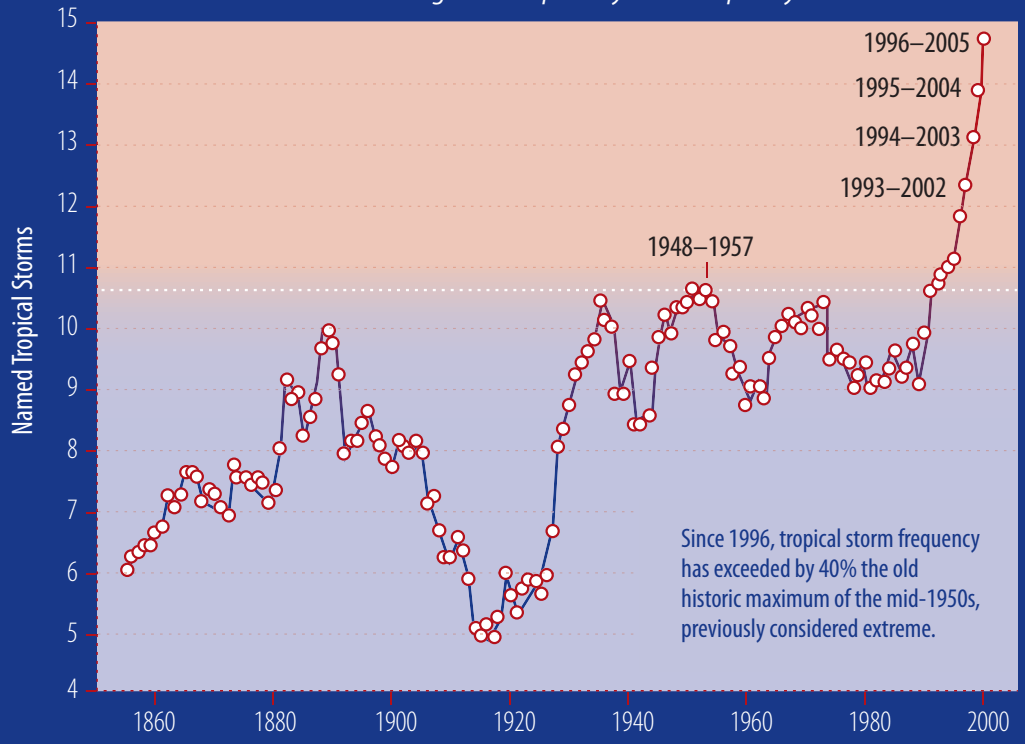
According to the IPCC, a *scenario* is "a coherent, internally consistent and plausible description of a possible future state of the world. Scenarios are not predictions or forecasts but are alternative images without ascribed likelihoods of how the future might unfold."[88] In this volume we develop a group of three impacts scenarios: *expected, severe,* and *catastrophic*. Although guided in general by the IPCC AR4 and other authoritative sources, these impacts scenarios are unique to this study and were created specifically for its purposes.

The IPCC uses independent scenarios of man made greenhouse gas emissions called SRES scenarios[89] in its assessment process. The SRES scenarios make assumptions about future population growth, economic and infrastructure development, and energy policy that result in plausible, alternative pathways of future greenhouse gas emissions. In the IPCC assessments and other studies, greenhouse gas emissions from alternative SRES emission scenarios are used to drive climate models, which in turn produce alternative projections of future climate conditions. As described below, the SRES A1B emission scenario is used in our study solely to derive levels of temperature change for each of our three impacts scenarios. We then extract impacts from published studies (primarily the AR4) based on those levels of temperature change, regardless of which emission scenarios were used to drive climate models in those studies.

A caveat of this approach is that different SRES emission scenarios assume different demographic trends, such as total population, population living near coastlines, and level of economic and technological development in developing countries. These differences alter estimates of population sizes affected by climate impacts, particularly sea level rise, food availability, and water scarcity. To address this caveat, in some cases we present a range of estimates provided in the published literature based on a variety of emission scenarios for a given temperature change. From the perspective of risk assessment, the upper ends of such ranges are most relevant.

In any assessment of climate change, it is essential to distinguish between a *prediction* and a *projection*. A *projection* describes an outcome that is deemed plausible, often subjectively, in the context of current uncertainties,[90] whereas a prediction describes the statistically most probable outcome based on the best current knowledge.[91] As described by Michael MacCracken, "a projection specifically allows for significant changes in the set of [determinants] that might influence the [future climate], creating 'if this, then that' types of statements."[92] The greater the degree of uncertainty surrounding determinants of future climate conditions, such as future man made greenhouse gas emissions, the less certain a prediction can be and the more important projections become for risk assessment. This is why the IPCC uses several alternative SRES emission scenarios in assessing future climate change. In keeping with the purpose of our study, our scenarios outline plausible impacts projections and should not be taken to be or cited as predictions of future conditions.

Figure 1: Tropical Cyclone Frequency in the North Atlantic



The running 10-year average of annual frequency shows a dramatic and abrupt increase above the previous maximum observed in the mid-1950s, previously considered extreme. DATA SOURCE: The Atlantic Hurricane Database Re-analysis Project; http://www.aoml.noaa.gov/hrd/data_sub/ re_anal.html.

Box 1:
Two Myths About Climate Change

MYTH 1: Future climate change will be smooth and gradual. The history of climate reveals that climate change occurs in fits and starts, with abrupt and sometimes dramatic changes rather than gradually over time.[93] This basic tendency implies that surprising changes are likely in the future even if average climate change is projected accurately.[94] Hypothetically, a projection of 1 meter of sea level rise over one century could prove correct, but it could occur in several quick pulses with relatively static periods in between. This type of change is more difficult to prepare for than gradual change, as large-scale public works projects intended to adapt to such a change are likely to require several decades to complete. Surprises from abrupt climate change may therefore increase the burden of climate impacts beyond what is expected, with unforeseen security implications.

MYTH 2: Impacts will be moderate in industrialized nations. Many people have the impression that developed nations will not experience serious climate change impacts. In fact, the United States, southern Europe, and Australia are likely to be among the most physically impacted regions. By virtue of its large size and varied geography, the United States already experiences a wide range of severe climate-related impacts, including droughts, heat waves, flash floods, and hurricanes, all of which are likely to be exacerbated by climate change.[95] According to the IPCC, the western United States, southern Europe, and southern Australia will experience progressively more severe and persistent drought, heat waves, and wildfires in future decades as a result of climate change.[96] The United States is also one of the most susceptible countries to future sea level rise, with the largest number of coastal cities and two agricultural river deltas near or below sea level. The United States and coastal countries of the European Union are likely to experience some of the greatest losses of coastal wetlands.[97]

The misconception that climate change impacts will spare the industrialized world may stem from confusion between the concepts of impacts and vulnerability. Vulnerability measures the ability of a population to withstand impacts, but low vulnerability does not imply low impacts. Because of greater infrastructure and wealth, the United States may be more capable of devoting resources to preparing for, adapting to, and recovering from climate change impacts than developing countries with similar exposure to climate change. Because it will be severely impacted, the United States will need to divert great financial and material resources toward coping with climate change. Severe climate change impacts in wealthy nations portend diversion of foreign aid to domestic projects, generating greater potential for environmental refugees to migrate to wealthy countries.

Underlying Assumptions in the Three Climate Impacts Scenarios

As a basis for outlining future climate change impacts, we derive temperature change projections based on the SRES A1B emission scenario defined by the IPCC,[98] with upward temperature adjustments for our two more extreme scenarios. It is a medium-range emission scenario that considers continued growth of man made greenhouse gas emissions under rapid economic growth, technological development, and ongoing efficiency improvements, but with significant continued reliance on fossil fuels. Atmospheric carbon dioxide (CO_2) rises to a concentration of about 700 parts per million (ppm)—2.5 times the preindustrial concentration of 280 ppm—by the end of the 21st century, which the AR4 projects would be associated with a global surface temperature increase of 1.7 to 4.4°C, with a best estimate of 2.8°C.[99] Although SRES scenarios assume that society takes no actions to limit climate change, it is possible for society to enact policies that would limit emissions significantly below the level of the A1B projection.[100]

The climate impacts summarized here are based largely on IPCC model projections. An unavoidable caveat of this approach is that the regional projections are continental or subcontinental in scale and impacts are generally described in aggregate. How climate in any specific location might deviate from the subcontinental average is less certain; distinct consequences of climate change for particular locales might not be available from existing scientific literature. As a result, assessing the security implications of climate change requires assumptions regarding the impacts that may occur in a given geopolitical arena. Although this report is no exception, we strive to constrain such assumptions based on cues from large-scale regional projections provided by the IPCC and other peer-reviewed scientific publications.

Two of the impacts scenarios outlined here project changes to the year 2040. Although we choose a particular emission scenario as a reference case, temperature increases based on the various emission scenarios examined by the IPCC do not diverge significantly by the year 2040, as past emissions dominate temperature forcing over this short time frame. Uncertainty in the temperature outcome on this time frame is related less to greenhouse gas emissions than to uncertainty about physical climate sensitivity to greenhouse gas forcing and the response of individual climate components (e.g., ice sheets, sea level, or storm systems) to a given degree of warming.[101] Over the longer time frame (about one century) of the most severe scenario, divergence of different emissions scenarios is significant and A1B emerges as a mid-range projection of temperature change, which we adjust in scenario three to account for potential underestimation as described below.

Climate Scenario 1: Expected Climate Change

This scenario provides the basis for the chapter in this report by Podesta and Ogden on the expected consequences of climate change for national and international security over the next 30 years. It accepts the temperature change projected in the AR4 for emission scenario A1B (table 1). Attendant impacts described for this temperature change are also accepted, except for sea level rise, which is assessed separately as described below. The AR4 projects impacts for the 2020s, 2050s, and 2080s. Where relevant, scenario one assumes that impacts intermediate to those described for the 2020s and 2050s represent impacts 30 years from the present.

Climate Scenario 2: Severe Climate Change

This scenario provides the basis for the chapter in this volume by Fuerth on severe consequences of climate change for national and international security over the next 30 years. It assumes that the AR4 projections of both warming and attendant impacts are systematically biased low. Multiple

lines of evidence support this assumption,[102] and it is therefore important to consider from a risk perspective. For instance, the models used to project future warming either omit or do not account for uncertainty in potentially important positive feedbacks that could amplify warming (e.g., release of greenhouse gases from thawing permafrost, reduced ocean and terrestrial CO2 removal from the atmosphere), and there is some evidence that such feedbacks may already be occurring in response to the present warming trend.[103] Hence, climate models may underestimate the degree of warming from a given amount of greenhouse gases emitted to the atmosphere by human activities alone. Additionally, recent observations of climate system responses to warming (e.g., changes in global ice cover, sea level rise, tropical storm activity) suggest that IPCC models underestimate the responsiveness of some aspects of the climate system to a given amount of warming.[104] On these premises, the second scenario assumes that omitted positive feedbacks occur quickly and amplify warming strongly, and that the climate system components respond more strongly to warming than predicted. As a result, impacts accrue at twice the rate projected for emission scenario A1B (table 2).

Based on current understanding of physical inertia in the climate system, a doubling of the rate of warming seems highly unlikely on the 30-year time scale. Bearing in mind, however, that the IPCC projections show only average change with a smooth evolution over time and have tended to underestimate climate system response to warming already realized, a combination of underestimated change and abrupt episodes could plausibly result in an unexpectedly large and rapid warming in a matter of a few decades, as outlined in scenario two. Moreover, a recent study aimed at quantifying the uncertainty surrounding model projections of future temperature found greater than a one-in-twenty chance that warming could exceed 2°C relative to 1990 by 2040 for the highest SRES emission scenario.[105] This level of warming is not greatly different from projected in scenario two.

Climate Scenario 3: Catastrophic Climate Change

This scenario provides the basis for the chapter in this report by Woolsey on *catastrophic* consequences of climate change for national and international security through the end of the 21st century. Based on current scientific understanding of climate change, we assume that abrupt, large-scale climate events cannot plausibly occur in the next three decades, but could plausibly do so over the course of this century. To examine the consequences of such events, scenario three extends the rapid warming and attendant accelerated impacts associated with scenario two to the end of the 21st century, leading to assumed rapid loss of polar land ice, abrupt 2 meter sea level rise, and collapse of the Atlantic meridional overturning circulation (MOC). We therefore assume warming that is double the best estimate of modeled surface warming under emission scenario A1B for the year 2100 (Table 2). Although doubling an IPCC projection is arbitrary, the result (5.6°C warming by 2095 relative to 1990) compares well with the upper-end projection of a group of models that incorporated carbon cycle feedbacks and therefore simulated higher atmospheric CO_2 growth rates than did the IPCC models.[106] When adjusted to account for changes in non-CO_2 greenhouse gases and atmospheric particulates, the models including carbon cycle feedbacks produced an upper-end projection of 5.6°C in 2100 relative to 2000. These models still did not incorporate all possible positive feedbacks, such as increased greenhouse gas emissions from thawing permafrost, so our most extreme warming scenario could potentially prove conservative. Even so there is little utility in assuming higher projected temperatures, as impacts have generally not been assessed for 21st century warming greater than 5°C.[107]

Sea Level Rise

The values shown in Table 2 for average global sea level rise relative to 1990 were obtained as described in this section. Given that 10 percent of the world's population currently lives in low-lying coastal zones and that this proportion is growing,[108] sea level rise is an important aspect of future climate change impacts. Unfortunately, current methods of projecting sea level are insufficient to provide either a best estimate or an upper limit for sea level rise over the current century.[109] The range of sea level rise projected for the 21st century in the AR4 explicitly omits any estimate of accelerating ice flow into the ocean from the Greenland and Antarctic Ice Sheets, yet recent observations indicate that ice flow is already accelerating on parts of these ice sheets.[110] IPCC sea level projections also assume that melt ponds on the surface of ice sheets refreeze on the ice sheet rather than draining to the ocean, whereas recent observations and theoretical assessment suggest that an unknown fraction of this melt water finds its way into the ocean.[111] These ice sheets represent the largest potential source of future sea level rise, and omitting ice sheet dynamics and melt point drainage likely systematically biases the IPCC projections low. For the IPCC, this omission was perhaps unavoidable because current knowledge of ice sheet dynamics simply does not permit the process to be modeled. For our purposes, such an omission is unacceptable as it would lead to an unrealistically low upper limit. We therefore depart from the AR4 to assess plausible upper limits to sea level rise.

The IPCC's model projections for sea level rise from the 2001 Third Assessment Report (TAR)[112] were higher than the latest projections of the AR4.[113] Stefan Rahmstorf et al. demonstrated that observed sea level rise for the period 1990 to 2006 tracks the upper uncertainty bound of the TAR projections, and therefore exceeds all AR4 model projections for sea level rise during the same period.[114] For scenario one, therefore, we adopt the upper bound of projected sea level rise in the TAR. This approach yields a sea level rise for scenario one of 23 cm in the year 2040 relative to 1990. (Note that all IPCC scenarios of 21st century sea level rise are relative to global average sea level in 1990.)

For scenarios two and three, temperature change was derived by doubling the corresponding temperature change in an IPCC projection. Both of these scenarios assume that the rate of change was underestimated in the AR4 but that the basic mechanisms of change were qualitatively correct. Given that the largest uncertainty with regard to sea level rise rests on which of two mechanisms—thermal ocean water expansion or freshwater contributions from land-based ice sheets—will dominate future sea level rise, we must ask whether the assumption we made for temperature response also holds for sea level response. To assess to what extent and by what means 21st century sea level rise can be constrained at the upper end, the author surveyed nine leading climatologists with relevant expertise.[115] This is an accepted approach for assessing climate change when fundamental uncertainties hamper model-based estimates.[116] All of the experts agreed that at least 1 meter of sea level rise by the end of the 21st century was plausible, and at least three felt that 2 meters were plausible. In recent writings, ocean physicist Stefan Rahmstorf opined that more than one meter of sea level rise could not be ruled out,[117] and climate physicist James Hansen expressed confidence that sea level rise would be measured in meters rather than centimeters.[118]

Until sound mechanistic models are available to estimate ice sheet contributions to sea level rise, past sea level rise may be our best guide to the future.[119] During warming at the end of the last ice age sea level rise was dominated by the retreat of land-based ice sheets and occurred at an average rate of 1 to 2 meters per century for several thousand years.[120] There is no question, therefore,

that large ice sheets can contribute to sea level rise at much higher rates than those projected by the IPCC; the question is rather a matter of timing. Traditionally, long lag times have been assumed for ice sheet response to warming, but this assumption is now receiving greater scrutiny.[121] The warmest point of the last interglacial period, around 125,000 years ago, was about 1°C warmer than the present global average temperature for only a few centuries, yet saw an average sea level 4 to 6 meters higher than at present.[122] Thus, it seems plausible that approximately 2 meters above present sea level could have been contributed from ice sheets within a century or two;[123] the modern warming trend has already been under way for nearly a century.[124]

Based on expert input and the writings of Rahmstorf and Hansen, this author judges that 2 meters is a plausible upper bound for the increase in sea level during the during the 21st century under a scenario of rapid warming and ice sheet-dominated sea level rise, as assumed in scenario three. The choice of any given number remains largely arbitrary, a sentiment expressed by several of the experts interviewed for this project. However, 2 meters corresponds to mapping programs available for assessing potential coastline inundation at 1 meter vertical resolution, and is therefore convenient for impact assessment in addition to being plausible. Furthermore, 2 meters is not far off from a doubling of the upper bound of the 2001 IPCC sea level rise projection of 0.88 meters for 2100.[125] In scenario three, therefore, we adopt 2 meters for projected sea level rise at the end of the 21st century relative to 1990.

To obtain a projection of sea level rise for scenario two, we use the projection of the 2001 IPCC report as a scaling function.[126] The upper end of the projection is about 0.23 meters in 2040 and 0.88 meters in 2100, giving a ratio of 0.26. Multiplying this ratio by the posited rise of 2 meters per century yields a sea level rise projection of 0.52 meters for the year 2040 relative to 1990 in scenario two.

As stated previously, these sea level rise scenarios are not predictions and should not be taken as such or used in ways other than are consistent with the purpose and intent of this project. It is also important to keep in mind that regardless of how high the sea rises by the end of this century, many more centuries will pass before sea level equilibrates with the change in temperature. Sustained warming of about 3°C would eventually eliminate the Greenland Ice Sheet in future centuries, ultimately raising sea level by 6 meters; contributions from Antarctica would increase the total even more.

Table 2

Projections of Global Average Surface Warming and Sea Level Rise Relative to 1990

Climate Scenario	Start	End	Warming	Basis for Warming	Sea Level
1 (Expected)	1990	2040	1.3°C	model average for A1B emission scenario in 2040	0.23 m
2 (Severe)*	1990	2040	2.6°C	double the model average for A1B in 2040	0.52 m
3 (Catastrophic)*	1990	2100	5.6°C	double the model average for A1B in 2100	2.00 m

*Projections for scenarios 2 and 3 are unique to this study and are meaningful only the context of this study.

Summaries of the Three Scenarios

This section provides brief summaries of the three climate scenarios. More detail on regional changes and the impacts of sea level rise follow.

Climate Scenario 1: Expected Climate Change

The average change obtained in IPCC projections based on the SRES emission scenario is realized without abrupt changes or other great surprises. By 2040 average global temperature rises 1.3°C above the 1990 average. Warming is greater over land masses and increases from low to high latitudes. Generally, the most damaging local impacts occur at low latitudes because of ecosystem sensitivity to altered climate and high human vulnerability in developing countries, and in the Arctic because of particularly large temperature changes at high northern latitudes. Global mean sea level increases by 0.23 meters, causing damage to the most vulnerable coastal wetlands with associated negative impacts on local fisheries, seawater intrusion into groundwater supplies in low-lying coastal areas and small islands, and elevated storm surge and tsunami heights, damaging unprotected coastlines. Many of the affected areas have large, vulnerable populations requiring international assistance to cope with or escape the effects of sea level rise. Marine fisheries and agricultural zones shift poleward in response to warming, in some cases moving across international boundaries. The North Atlantic MOC is not affected significantly.

Regionally, the most significant climate impacts occur in the southwestern United States, Central America, sub-Saharan Africa, the Mediterranean region, the mega-deltas of South and East Asia, the tropical Andes, and small tropical islands of the Pacific and Indian Oceans. The largest and most widespread impacts relate to reductions in water availability and increases in the intensity and frequency of extreme weather events. The Mediterranean region, sub-Saharan Africa, northern Mexico, and the southwestern United States experience more frequent and longer-lasting drought and associated extreme heat events, in addition to forest loss from increased insect damage and wildfires.

Overall, northern mid-latitudes see a mix of benefits and damages. Benefits include reduced cost of winter heating, decreased mortality and injury from cold exposure, and increased agricultural and forest productivity in wetter regions because of longer growing seasons, CO_2 fertilization, and fewer freezes. Negative consequences include higher cost of summer cooling, more heavy rainfall events, more heat-related death and illness, and more intense storms with associated flooding, wind damage, and loss of life, property, and infrastructure.

Climate Scenario 2: Severe Climate Change

Average global surface temperature rises at an unexpectedly rapid rate to 2.6°C above 1990 levels by 2040, with larger warming over land masses and at high latitudes. Dynamical changes in polar ice sheets (i.e., changes in the rate of ice flow into the sea) accelerate rapidly, resulting in 0.52 meters of global mean sea level rise. Based on these observations and an improved understanding of ice sheet dynamics, climate scientists by this time express high confidence that the Greenland and West Antarctic Ice Sheets have become unstable and that 4 to 6 meters of sea level rise are now inevitable over the next few centuries. Water availability decreases strongly in the most affected regions at lower latitudes (dry tropics and subtropics), affecting about 2 billion people worldwide. The North Atlantic MOC slows significantly, with consequences for marine ecosystem productivity and fisheries. Crop yields decline significantly in the fertile river deltas because of sea level rise and damage from increased storm surges. Agriculture becomes nonviable in the dry subtropics, where irrigation becomes exceptionally difficult because of low water availability and increased soil salinization resulting from more rapid evaporation of water from irrigated fields. Arid regions at low

latitudes expand, taking previously marginally productive croplands out of production. North Atlantic fisheries are affected by significant slowing of the North Atlantic MOC. Globally, there is widespread coral bleaching, ocean acidification, substantial loss of coastal nursery wetlands, and warming and drying of tributaries that serve as breeding grounds for anadromous fish (i.e., ocean-dwelling fish that breed in freshwater, e.g., salmon). Because of a dramatic decrease in the extent of Arctic sea ice, the Arctic marine ecosystem is dramatically altered and the Arctic Ocean is navigable for much of the year. Developing nations at lower latitudes are affected most severely because of climate sensitivity and low adaptive capacity. Industrialized nations to the north experience clear net harm and must divert greater proportions of their wealth to adapting to climate change at home.

Climate Scenario 3: Catastrophic Climate Change

Between 2040 and 2100 the impacts associated with climate scenario two progress and large-scale singular events of abrupt climate change occur. The average global temperature rises to 5.6°C above 1990 levels with larger warming over land masses and at higher latitudes. Because of continued acceleration of dynamical polar ice sheet changes global mean sea level rises by 2 meters relative to 1990, rendering low-lying coastal regions uninhabitable, including many large coastal cities. The large fertile deltas of the world become largely uncultivable because of inundation and more frequent and higher storm surges that reach farther inland. The North Atlantic MOC stops at mid-century, generating large-scale collapse of North Atlantic marine ecosystems and associated fisheries. Northwestern Europe experiences colder winters, shorter growing seasons, and reduced crop yields relative to the 20th century.

Outside of northwestern Europe and the northern North Atlantic Ocean, the MOC collapse increases average temperatures in most regions and reorganizes precipitation patterns in unpredictable ways, hampering water resource planning around the world and drying out existing grain-exporting regions. Southern Europe and the Mediterranean region remain warmer than the 20th century average and continue to experience hotter, drier summers with more heat waves, more frequent and larger wildfires, and lower crop yields. Agriculture in the traditional breadbaskets is severely compromised by alternating persistent drought and extreme storm events that bring irregular severe flooding. Crops are physiologically stressed by temperatures and grow more slowly even when conditions are otherwise favorable. Even in many regions with increased precipitation, summertime soil moisture is reduced by increased evaporation. Breadbasket-like climates shift strongly northward into formerly sub-arctic regions with traditionally small human populations and little infrastructure, including roads and utilities, but extreme year-to-year climate variability in these regions makes sustainable agricultural difficult on the scale needed to feed the world population.

Mountain glaciers are virtually gone and annual snow pack dramatically reduced in regions where large human populations traditionally relied on glaciers and annual snowfall for water supply and storage, including Central Asia, the Andes, Europe, and western North America. Arid regions expand rapidly, overtaking regions that traditionally received sufficient annual rainfall to support dense populations. The dry subtropics, including the Mediterranean region, much of Central Asia, northern Mexico, much of South America, and the southwestern United States are no longer inhabitable. Not only is the area requiring remote water sources for habitability dramatically larger than in 1990, but such remote sources are much less available because mountain glaciers and snowlines

have retreated dramatically as well. Half of the world's human population experiences persistent water scarcity.

Locally devastating weather events are the norm for coastal and mid-latitude continental locations, where tropical and mid-latitude storm activity and associated wind and flood damage becomes much more intense and occurs annually, leading to frequent losses of life, property, and infrastructure in many countries every year. Whereas water availability and loss of food security disproportionately affect poor countries at lower latitudes, extreme weather events are more or less evenly distributed, with perhaps greater frequency at mid-latitudes because of stronger extratropical storm systems, including severe winter storms.

General Patterns of Projected Climate Change

This section reviews general patterns of climate change as projected by the IPCC Fourth Assessment Report (AR4). The purpose is to provide a general template of regional patterns of climate impacts at subcontinental scales, over which to lay the generalities described for the three scenarios above. Unless otherwise indicated the results described in this section are extracted from chapters 10 and 11 of the Contribution of Working Group I to the AR4,[128] which present projections of future climate change based on modeling experiments using mostly aggregated results of up to 21 different global circulation models. Changes are presented as averages of all the models used in an analysis.

Temperature

All models in the AR4 show global surface warming in proportion to the amount of man made greenhouse gases released to the atmosphere. For the A1B emission scenario, average global surface warming relative to 1990 is about 1.3°C in 2040 and 2.8°C in 2100. It is essential to put these global averages into geographic context, as changes are far from uniform globally. Temperature over land, particularly in continental interiors, warms about twice as much as the global average, as surface temperatures rise more slowly over the oceans. High northern latitudes also warm about twice as fast as the global average. Moreover, the average change in any given location is not a smooth increase over time. Rather, it is associated with larger extremes, leading to generally fewer freezes, higher incidence of hot days and nights, and more heat-related impacts, such as heat waves, droughts, and wildfires. Larger warming at high northern latitudes leads to faster thawing of permafrost, with consequent infrastructure damage (e.g., collapsed roads and buildings, coastal erosion) and feedbacks that amplify climate change (e.g., CH_4 and CO_2 release from thawed organic soils).[129] There are also seasonal differences, with winter temperatures rising more rapidly than summer temperatures, especially at higher latitudes. Wintertime warming in the Arctic over the 21st century is projected to be three to four times greater than the global wintertime average warming, resulting in much faster loss of ice cover and associated impacts (e.g., faster sea level rise). More regional detail is provided in Box 2.

Precipitation

Under the A1B scenario, global average precipitation increases by 2 percent in 2040 and 5.5 percent in 2100. Because some regions experience substantially decreased precipitation, a global change of a few percent translates into changes greater than 20 percent for particular areas. Both extreme drought and extreme rainfall events are therefore expected to become more frequent as a result of this intensification of the global water cycle. Increased precipitation generally prevails in the tropics and at high latitudes, particularly over the tropical Pacific and Indian Oceans during the northern hemisphere winter and over South and Southeast Asia during the northern hemisphere summer. Decreased precipitation prevails in the

subtropics and mid-latitudes, with particularly strong decreases in southern North America and Central America, southern South America (parts of Chile and Argentina), southern Europe and the Mediterranean region in general (including parts of the Middle East), and in northern and southern Africa. Central America experiences the largest decline in summer precipitation. The main areas projected to experience greater drought are the Mediterranean region, Central America, Australia and New Zealand, and southwestern North America.[130]

Decreases in precipitation and related water resources are projected to affect several important rain-fed agricultural regions, particularly in South and East Asia, in Australia, and in northern Europe. Although monsoon rainfall is projected to increase in South and Southeast Asia, this extra rain may not provide benefits as rain is already plentiful at this time of year. However, the added rainfall will likely increase damage from flooding. Notably, a decrease in summer precipitation is projected for Amazonia, where the world's largest complex of wet tropical forest depends on high year-round precipitation.[131]

Two important correlates of precipitation are annual runoff (i.e., surface water flow) and soil moisture. These parameters are critical to water supply for consumption and irrigation and to the ability of soil to support crop production. Soil moisture generally corresponds with precipitation, but declines in some areas where precipitation increases because warmer temperatures lead to greater evaporation. The biggest changes in soil moisture include a strong increase in a narrow band of equatorial Africa and a moderate increase in a band extending from northern and eastern Europe and into Central Asia. Soil drying is more widespread and decreases by 10 percent or greater over much of the United States, Mexico and Central America, southern Europe and the Mediterranean basin in general (including parts of the Middle East), southern Africa, the Tibetan Plateau, and across much of northern Asia.

Runoff follows a pattern very similar to precipitation, with increases in high northern latitudes and parts of the tropics, including Central, South, and Southeast Asia, tropical eastern Africa, the northern Andes and the east-central region of South America around Uruguay, and extreme southern Brazil. The strongest decreases occur in the southwestern United States, Central America, the Mediterranean region (including southern Europe, northern Africa, and the Middle East), southern Africa, and northeastern South America, including Amazonia.

Box 2:
Summary of IPCC Findings for Regional Climate Projections[132]

The following summaries, excerpted from the Executive Summary of Chapter 11 of the Contribution of Working Group I to the Fourth Assessment Report, detail robust findings on projected regional change over the 21st century. These changes are assessed as likely (greater than 66 percent likelihood) to very likely (greater than 90 percent likelihood) taking into account the uncertainties in climate sensitivity and SRES emission trajectories of the B1, A1B, and B2 scenario range.

AFRICA. Warming is very likely to be larger than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics. Annual rainfall is likely to decrease in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached. Rainfall in southern Africa is likely to decrease in much of the winter rainfall region and western margins. There is likely to be an increase in annual mean rainfall in East Africa. It is unclear how rainfall in the Sahel, the Guinean Coast, and the southern Sahara will evolve.

MEDITERRANEAN AND EUROPE. Annual mean temperatures in Europe are likely to increase more than the global mean. Seasonally, the largest warming is likely to be in northern Europe in winter and in the Mediterranean area in summer. Minimum winter temperatures are likely to increase more than the average in northern Europe. Maximum summer temperatures are likely to increase more than the average in southern and central Europe. Annual precipitation is very likely to increase in most of northern Europe and decrease in most of the Mediterranean area. In central Europe, precipitation is likely to increase in winter but decrease in summer. Extremes of daily precipitation are very likely to increase in northern Europe. The annual number of precipitation days is very likely to decrease in the Mediterranean area. Risk of summer drought is likely to increase in central Europe and in the Mediterranean area. The duration of the snow season is very likely to shorten, and snow depth is likely to decrease in most of Europe.

ASIA. Warming is likely to be well above the global mean in Central Asia, the Tibetan Plateau and northern Asia, above the global mean in East Asia and South Asia, and similar to the global mean in Southeast Asia. Precipitation in boreal winter is very likely to increase in northern Asia and the Tibetan Plateau, and likely to increase in eastern Asia and the southern parts of Southeast Asia. Precipitation in summer is likely to increase in northern Asia, East Asia, South Asia, and most of Southeast Asia, but is likely to decrease in Central Asia. It is very likely that heat waves/hot spells in summer will be of longer duration, more intense, and more frequent in East Asia. Fewer very cold days are very likely in East Asia and South Asia. There is very likely to be an increase in the frequency of intense precipitation events in parts of South Asia, and in East Asia. Extreme rainfall and winds associated with tropical cyclones are likely to increase in East Asia, Southeast Asia, and South Asia.

NORTH AMERICA. The annual mean warming is likely to exceed the global mean warming in most areas. Seasonally, warming is likely to be largest in winter in northern regions and in summer in the southwest. Minimum winter temperatures are likely to increase more than the average in northern North America. Maximum summer temperatures are likely to increase more than the average in the southwest. Annual mean precipitation is very likely to increase in Canada and the northeast United States, and likely to decrease in the southwest. In southern Canada, precipitation is likely to increase in winter and spring but decrease in summer. Snow season length and snow depth are very likely to decrease in most of North America except in the northernmost part of Canada where maximum snow depth is likely to increase.

CENTRAL AND SOUTH AMERICA. The annual mean warming is likely to be similar to the global mean warming in southern South America but larger than the global mean warming on the rest of the continent. Annual precipitation is likely to decrease in most of Central America and in the southern Andes, although changes in atmospheric circulation may induce large local variability in precipitation response in mountainous areas. Winter precipitation in Tierra del Fuego and summer precipitation in southeastern South America is likely to increase. It is uncertain how annual and seasonal mean rainfall will change over northern South America, including the Amazon forest. However, there is qualitative consistency among the simulations in some areas (rainfall increasing in Ecuador and northern Peru, and decreasing at the northern tip of the continent and in southern northeast Brazil).

AUSTRALIA AND NEW ZEALAND. Warming is likely to be larger than that of the surrounding oceans, but comparable to the global mean. The warming is less in the south, especially in winter, with the warming in the South Island of New Zealand likely to remain less than the global mean. Precipitation is likely to decrease in southern Australia in winter and spring. Precipitation is very likely to decrease in southwestern Australia in winter. Precipitation is likely to increase in the west of the South Island of New Zealand. Changes in rainfall in northern and central Australia are uncertain. Increased mean wind speed is likely across the South Island of New Zealand, particularly in winter. Increased frequency of extreme high daily temperatures in Australia and New Zealand, and a decrease in the frequency of cold extremes is very likely. Extremes of daily precipitation are very likely to increase, except possibly in areas of significant decrease in mean rainfall (southern Australia in winter and spring). Increased risk of drought in southern areas of Australia is likely.

POLAR REGIONS. The Arctic is very likely to warm during this century more than the global mean. Warming is projected to be largest in winter and smallest in summer. Annual arctic precipitation is very likely to increase. It is very likely that the relative precipitation increase will be largest in winter and smallest in summer. Arctic sea ice is very likely to decrease in its extent and thickness. It is uncertain how the Arctic Ocean circulation will change. The Antarctic is likely to warm and the precipitation is likely to increase over the continent. It is uncertain to what extent the frequency of extreme temperature and precipitation events will change in the polar regions.

SMALL ISLANDS. Sea levels are likely to rise on average during the century around the small islands of the Caribbean Sea, Indian Ocean, and northern and southern Pacific Oceans. The rise will likely not be geographically uniform but large deviations among models make regional estimates across the Caribbean, Indian, and Pacific Oceans uncertain. All Caribbean, Indian Ocean, and North and South Pacific islands are very likely to warm during this century. The warming is likely to be somewhat smaller than the global annual mean. Summer rainfall in the Caribbean is likely to decrease in the vicinity of the Greater Antilles but changes elsewhere and in winter are uncertain. Annual rainfall is likely to increase in the northern Indian Ocean with increases likely in the vicinity of the Seychelles in December, January, and February, and in the vicinity of the Maldives in June, July, and August, while decreases are likely in the vicinity of Mauritius in June, July, and August. Annual rainfall is likely to increase in the equatorial Pacific, while decreases are projected by most models for just east of French Polynesia in December, January, and February.

Regional Sensitivity to Climate Change

A given change in climate such as a degree of warming or a 10 percent change in precipitation does not affect all regions the same way. It may be useful, therefore, to examine how sensitive different regions might be to changes in temperature or precipitation. From a security perspective it would then be useful to compare regional sensitivity to the distribution of global population density and to regions that are important for crop production.

There is a striking correspondence between the global distributions of human population density and land that is currently suitable for producing rain-fed crops. This pattern holds for the United States even though extensive irrigation augments precipitation to increase crop yields, implying that rainfall remains the primary determinant of agricultural production and population density.

Some regions experience a very stable climate, and natural and human systems have developed around this stability; in such regions even a small change may generate significant impacts. For instance, in wet tropical systems moderate decreases in precipitation may lead to the collapse of productive rainforests.[133] Alternatively, settlements and infrastructure in wet tropical regions may be damaged by increased flooding from small increases in precipitation during the rainy season. Semi-arid regions that are already marginal for supporting natural and human systems may be rendered uninhabitable by small decreases in precipitation or runoff. In contrast, regions with historically large climate variability require larger changes of future climate to move natural and human systems beyond the bounds of the climate extremes to which they have adapted. For instance, in spite of great natural climate variability, the Arctic is expected to be heavily impacted by climate change because the degree of warming is projected to be large compared to the global average and much larger than in the tropics.

The areas most sensitive to a combination of projected temperature and precipitation change relative to natural variability are in tropical Central and South America, tropical and southern Africa, Southeast Asia, and the polar regions. The Mediterranean region, China, and the western United States show intermediate levels of sensitivity.[134] Marginal agricultural lands generally show intermediate to high climate sensitivity, including in the southwestern United States, Central America, sub-Saharan Africa, southern Europe, Central Asia, including the Middle East, and eastern China. Most of these regions also bear large human populations. Also of note, the most affected region of South America completely covers the Amazonian rainforest, which is projected to become relatively drier. Reduced productivity of this forest would have strong feedbacks on global climate by releasing carbon to the atmosphere and would result in massive loss of biodiversity, including economically important species.[135]

Extreme Weather Events

In general, the IPCC projects an increased incidence of extreme weather events.[136] Droughts, flash floods, heat waves, and wildfires are all projected to occur more frequently and to become more intense in regions where such events are already common. Intense tropical and mid-latitude storms with heavier precipitation and higher wind speeds are also projected. There is evidence that many of these events already occur more frequently and have become more intense.[137] Projections indicate fewer cold spells and a decrease in the frequency of low-intensity storms. As a consequence, the total number of storms decreases globally even as the number of intense storms increases.

Precipitation and drought. In general, the IPCC projects that a larger fraction of total precipitation will fall during extreme events, especially in the moist tropics and in mid and high latitudes where increased mean precipitation is projected. Regionally, extremes are expected to increase more

than the means. Even in areas projected to become drier, the average intensity of precipitation may increase because of longer dry spells and greater accumulation of atmospheric moisture between events. This portends increased incidence and duration of drought, punctuated by extreme precipitation, which may be either rainfall or snowfall, depending on latitude and season. In general, the risk of drought is expected to increase during summers in the continental interiors.

Some tropical and subtropical regions experience monsoons, distinct rainy seasons during which prevailing winds transport atmospheric moisture from the tropical oceans. The Asian, African, and Australian monsoons are projected to bring increased rainfall to certain regions of these continents. Because this rain falls during what is already the rainy season, it may cause more flooding without bringing additional benefits. In Mexico and Central America, the monsoon is projected to bring less precipitation to the region, contributing to the increased drought generally projected for the region.

Heat waves. Hotter temperature extremes and more frequent, more intense, and longer-lasting heat waves are robust projections of the models examined by the IPCC, portending increased heat-related illness and mortality. Growing seasons will also become longer because of earlier spring warming and later fall cooling, but crops will face greater heat stress and associated drought during the growing season. Cold spells will become less frequent, causing fewer deaths and economic losses associated with cold weather.

Tropical cyclones and mid-latitude storms. Projected patterns of change are similar for both tropical cyclones, including typhoons and hurricanes, and extratropical cyclones (i.e., mid-latitude storms). Tropical storms may become less frequent overall, yet are expected to reach higher peak wind speeds and bring greater precipitation on average. The decrease in frequency is likely to result from fewer weak tropical storms, whereas intense tropical storms may become more frequent with warming. Similarly, mid-latitude storms may become less frequent in most regions yet more intense, with more damaging winds and greater precipitation. Intensification of winter mid-latitude storms may bring more frequent severe snow storms, such as those experienced in the north-central United States in February and March of 2007. Near coasts, both tropical and mid-latitude storms will increase wave heights and storm surge heights, increasing the incidence of severe coastal flooding (see *Abrupt Sea Level Rise* below).

Regions affected by tropical storms, including typhoons and hurricanes, include: all three coasts of the United States; all of Mexico and Central America; the Caribbean islands; East, Southeast, and South Asia; and many South Pacific and Indian Ocean islands. Although tropical storms are very rare in the South Atlantic, in 2004 Hurricane Catarina became the only hurricane to strike Brazil in recorded history.[138] Similarly, it is unusual for tropical storms to make landfall in Europe, yet in 2005 the remnants of Hurricane Vince became the first tropical storm on record to make landfall on the Iberian Peninsula.[139] In June 2007 Cyclone Gonu, the first category five hurricane documented in the Arabian Sea, temporarily halted shipping through the Strait of Hormuz, the primary artery for exporting Persian Gulf oil.[140] Whether such historical aberrations are related to global warming remains unknown, but they illustrate that much is left to learn about how and why climate extremes are already changing and what such changes portend for society in coming decades. Extreme weather events exceeding historical precedents should be expected as a general consequence of climate change.

Singular, Abrupt Events

With the assumptions of scenario three, the probability and consequences of abrupt events move beyond the bounds of the assumptions of the IPCC projections. This departure is necessary as the potential consequences of large-scale abrupt events are of particular concern, yet the science for projecting and assessing them remains significantly underdeveloped.[141] To assess the consequences of such events, therefore, we draw upon the author's own assessment of a few particularly informative but uncertain studies.

Collapse of the Atlantic meridional overturning circulation. The Gulf Stream and the North Atlantic Current are part of the Atlantic meridional overturning circulation (MOC; also known as the thermohaline circulation or the ocean conveyor belt). These currents transport warm tropical surface water from the equatorial North Atlantic Ocean northward along the east coast of North America and then eastward toward northern Europe (Gulf Stream). From here, the water flows north toward southern Greenland and the North Sea (North Atlantic current). Throughout this journey, the surface water cools and consequently becomes denser, eventually causing it to sink in the far North Atlantic near Greenland and flow southward at depth, driving the overturning circulation and sustaining continued transport of heat from the equator northward. This ocean transport of heat may warm the climate of northwestern Europe by several degrees. Global warming is thought to present a risk of shutting down the MOC by warming and freshening northern North Atlantic surface water (through Arctic ice melt, increased Arctic river runoff, and increased precipitation over the North Atlantic), thus decreasing the water's density and reducing its tendency to sink.[142]

Collapse of the MOC has often been described as a "low probability, high impact" event. In fact, however, there is tremendous variation among models and expert judgment regarding the probability of such an event.[143] Likewise, there has been little investigation of the potential consequences of such an event and it remains unclear whether it would indeed be of great consequence.[144] It is therefore all the more important not to regard the scenario outlined here as a prediction. Our purpose is to explore the possibility that collapse of the MOC could have a large impact, as such an outcome is widely considered plausible, if improbable.[145]

According to the IPCC, models that accurately represent past and current climate project a slowing of the Atlantic MOC of up to 60 percent, but none indicates a complete shutdown during the 21st century. As a result, the IPCC places the likelihood of a shutdown of the MOC during the 21st century at not more than 10 percent.[146] In the IPCC models, slowing of the MOC of up to 60 percent does not produce a cooling of Europe, as the warming effect of increasing atmospheric greenhouse gases outweighs the cooling effect of the slowing MOC. If, however, the rate of warming and loss of polar ice has been underestimated, as assumed in scenario three, then the chance of a collapse during this century could be considerably higher. Should an abrupt shutdown occur, a cooling of the North Atlantic region, including northwestern Europe, is more likely.[147] We therefore consider the potential consequences of Atlantic MOC collapse in scenario three.

As it is not possible to estimate the timing of MOC collapse for a given degree of warming, we arbitrarily assume a collapse during the 2050s, with attendant impacts occurring in subsequent decades of the 21st century (and beyond). This approach is similar to that of N.W. Arnell, who simulated a shutdown of the Atlantic MOC in a global circulation model in the year 2055 and followed its subsequent effects on water resources, energy use, human health, agriculture, and settlement and infrastructure.[148] Because there are few studies of this nature, we base the effects of a MOC collapse

in scenario three on the results of that study. Arnell forced a global climate model (HadCM3) with greenhouse gas emission scenario SRES A2 and separately forced a shutdown of the MOC by imposing an artificial freshwater pulse in the North Atlantic.[149] Temperature change from the A2 scenario is similar to that of the A1B scenario until late in the 21st century. The impact of shutting down the MOC was compared to impacts of the A2 scenario without the freshwater pulse to shut down the MOC. It is important to understand that the MOC would not have shut down in the model if not for this artificially imposed freshwater pulse, an experimental manipulation applied solely to assess the potential impacts of an MOC collapse.

In general, MOC collapse resulted in cooler temperatures around the high North Atlantic, with the largest effect centered south of Greenland and decreasing with distance from this central area. Areas of northwestern Europe cooled by as much as 3°C, with broader areas of Europe and northeastern North America cooling by 1 to 2°C. Many other parts of the world warmed because of a redistribution of heat from changes in ocean currents. Precipitation changes were more widespread than cooling, with attendant changes in runoff, drought, and flooding. The largest decreases in precipitation occurred in North Africa, the Middle East, Central America, the Caribbean, and northeast South America, including Amazonia. Intermediate decreases in precipitation were more widespread, including central North America, southern Greenland, central and southern Europe, central and southeast South America, Central and South Asia, western and southern Africa, and Australia. The largest increase in precipitation was centered on the southwestern United States, providing a net reduction in the number of people in the country under water stress. Increased precipitation also occurred in the eastern United States, Canada, East Africa, and northern, eastern, and Southeast Asia.

Several of the world's major grain-exporting regions, particularly in North America and South Asia, were affected by increased drought as a result of reduced precipitation after MOC collapse. In Europe this trend would be exacerbated by lower temperatures and shorter growing seasons. Hence, global food markets would likely be affected by short supply and high prices. In Europe and northeastern North America, demand for heating fuel would increase due to colder winters. Although demand for cooling fuel would decrease in these regions, most other regions of the world would experience increased demand for cooling fuel. The cost of maintaining and adapting transportation infrastructure and demand for heating fuel would increase in northern Europe and northeastern North America, resulting in a southward shift of economic activity and population.

Another consequence of a complete MOC collapse is likely to be an increase in sea level in the North Atlantic region, in addition to global mean sea level rise.[151] Model results and expert opinion suggest that this effect could add up to 1 meter of sea level rise in the Atlantic north of 45°N,[152] bringing total sea level rise for this region to 3 meters in our *catastrophic* scenario three, with attendant coastal impacts (see section on abrupt sea level rise below).

In general, the effects of accelerated global warming without MOC collapse are larger than the effects of MOC collapse. Broadly, however, accelerated climate change is expected to intensify current precipitation patterns, offering some degree of predictability and maintaining current geographic patterns of large-scale food production. By reorganizing precipitation patterns, MOC collapse may threaten major crop regions with decreased precipitation, raising the possibility of major disruptions in global food supply. It also appears to amplify the decrease of precipitation in Central America and Amazonia, threatening tropical forests and their dependent species with extinction and adding additional carbon to the atmosphere

through large-scale deforestation, amplifying the global greenhouse warming trend. Although water stress increases in parts of Africa and Asia, increased precipitation in East Africa and East and Southeast Asia results in a net of one billion fewer people under water stress with MOC collapse, but adds to flood hazards in these regions.

Abrupt sea level rise. The IPCC projects sea level rise in the range of 0.18 to 0.59 meters by the end of the century. As discussed above, however, this projection excludes an estimate of accelerated ice loss from the Greenland and Antarctic Ice Sheets and therefore cannot be considered either a best estimate or an upper bound for future sea level rise.[154] Moreover, the IPCC projections depict a gradual change in sea level over the next century, whereas abrupt and intermittent rises may be more likely (see Box 1). In the climate impacts scenarios outlined here, we assume that sea level rises 0.23 meters (scenario one) or 0.52 meters (scenario two) relative to 1990 by 2040, or 2 meters (scenario three) relative to 1990 by 2100 (Table 2). As noted above, under scenario three additional sea level rise of up to 1 meter would occur in the northern North Atlantic as a consequence of Atlantic MOC collapse.[155] Sea level rise could occur in abrupt, unpredictable pulses, a factor that should be considered in risk assessments.

Although it is safe to assume that greater sea level rise leads to relatively more severe impacts, studies of potential sea level rise impacts have not been conducted for most parts of the globe, and those that have been typically examine only one aspect of sea level impacts, such as beach erosion or storm surge height.[156] Sea level rise varies regionally and future regional patterns are unpredictable at present.[157] Moreover, a lack of highly resolved global demographic data for coastal areas has hampered systematic assessment of coastal hazards.[158] In recent months improved population estimates indicate that about one-tenth of the world's population lives in coastal regions within 10 meters of sea level, and the global population continues to migrate coastward.[159] This estimate offers a general sense of how many people could be generally susceptible to sea level rise impacts, but cannot tell us how many people are likely to be directly impacted by sea level rise of the magnitude assumed in our scenarios (0.23 to 2.0 meters). In sum, it is currently extremely difficult to quantify future damage to humanity from sea level rise, although damage from a rise of 2 meters during the current century would clearly be catastrophic for many regions, including key areas within the United States.[160]

Sea level rise causes or contributes to several distinct types of impacts, including inundation, increased flooding from coastal storms, coastal erosion, saltwater intrusion into coastal water supplies, rising water tables, and coastal and upstream wetland loss with attendant impacts on fisheries and other ecosystem services.[161] Current distribution of natural and human coastal systems has been adapted to past extreme high tides and storm surges. Future sea level rise will inundate additional land not so adapted. Only the lowest lying, unprotected areas will be extremely vulnerable to inundation within the timeframe of our 30-year scenarios. There are dozens of coastal cities worldwide in both industrialized and developing nations that lie at least partly below 1 to 2 meters elevation, but most of them have flood protection. Hence, inundation from extreme high tides alone might not rise to crisis proportions for most of these cities within the coming century, although enhanced defenses will be required to avoid increasing damages.

Inundation is a serious issue, nonetheless, for unprotected low-lying areas, including coastal wetlands that serve as natural nurseries for important fisheries, and productive agricultural lands situated on river deltas, a particularly sensitive problem for coastal aquifers and Asian megadeltas.[162] Because of their inherently low elevations,

proximity to the open sea, and general lack of flood protection, coastal wetlands are probably the most vulnerable of all natural systems to inundation and are also of underappreciated importance to society.[163] For example, about 75 percent of the commercial fish catch and 90 percent of recreational fish catch in the United States depends on wetlands that serve as nurseries and feeding grounds for fish and shellfish. Habitat loss and modification are the dominant causes of the worldwide decline in ocean fish catch during the past two decades.[164] One meter of sea level rise could eliminate or damage half of coastal wetlands globally, with the most vulnerable wetlands located along the Mediterranean and Baltic coasts and the Atlantic coasts of Central and North America, including the Gulf of Mexico.[165] Chronic saltwater inundation is devastating to agricultural production, as well, and the situation is similar for coastal groundwater supplies, which cannot be controlled by levees or other surface-level devices.

In the long term, sea level rise may far exceed 2 meters, such that inundation eventually redraws coastlines altogether.[166] For the near term, however, more frequent and more severe flooding from coastal storms is likely to be the largest impact of sea level rise along low-lying coastlines.[167] Existing flood protection systems built to withstand extreme storm surges will be overcome much more frequently as local sea levels rise.[168] For example, levees around New Orleans were designed to withstand storm surges associated with category three hurricanes,[169] which historically attained heights of 2.8 to 3.7 meters. Such defenses would be reduced effectively to category two-level protection with 1 meter of sea level rise and category one-level protection with 2 meters of sea level rise. Because weaker storms occur more frequently than the most intense storms, sea level rise portends a nonlinear increase in flood risk for protected areas in the absence of defense enhancement.[170] As another example, current flood defenses in New York City were designed to protect against the 100-year flood; that is, the highest flood waters expected to occur in a 100-year period based on average past climate. However, 1 meter of sea level rise would lower the return interval of such a flood to as little as five years.[171] This estimate does not account for storm intensification, which would raise maximum storm surge and wave heights further, and is expected to occur because of global warming.[172] The most critical areas of low-lying coastlines are cities and farmed deltas. Dozens of the world's most populous and culturally and economically important cities (e.g., New York, Miami, London, Copenhagen, Dublin, Sydney, Auckland, Shanghai, Bangkok, Calcutta, Dhaka, Alexandria, Casablanca, Lagos, Dakar, Dar es Salaam) are susceptible to sea level rise, as are some of the most important agricultural sites, such as the Sacramento, Ganges, Mekong, Yangtze, and Nile deltas.

Conclusion

The three climate scenarios described in this chapter outline plausible impacts *projections* and should not be taken to be or cited as *predictions* of future conditions. With this in mind, climate scenario one posits an expected level of climate change, with an estimated average warming of 1.3°C and an attendant .23 meters of sea level rise by the year 2040. Climate scenario two projects an average global warming of 2.6°C and a sea level rise of .52 meters by the year 2040. Our catastrophic climate scenario three depicts a much more devastating future where average global warming reaches 5.6°C with sea levels swelling 2 meters over a 100 year time span. For the purpose of our scenario exercise, these three projections provide the basis for assessing likely national security impacts of various futures. In the following chapters, national security experts will envision the possible consequence of these climate scenarios.

LOCATION: Marsabit District, Kenya — A young Ariaal girl carries a container of water pulled from a well.

EXPECTED

CLIMATE CHANGE
OVER NEXT **30 YEARS**

AT A GLANCE:

Time Span: 30 Years

Warming: 1.3°C

Sea Level Rise: .23 meters

By John Podesta and Peter Ogden[173]

Scenario Overview: Expected Climate Change

The effects of climate change projected in this chapter are based on the A1B greenhouse gas emission scenario of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.[174] It is a scenario in which people and nations are threatened by massive food and water shortages, devastating natural disasters, and deadly disease outbreaks. It is also inevitable.

There is no foreseeable political or technological solution that will enable us to avert many of the climatic impacts projected here. The world will confront elements of this climate change scenario even if, for instance, the United States were to enter into an international carbon cap and trade system in the near future. The scientific community, meanwhile, remains far from a technological breakthrough that would lead to a decisive, near-term reduction in the concentration of carbon dioxide in the atmosphere.

This scenario also assumes that climate change does not trigger any significant positive feedback loops (e.g., the release of carbon dioxide and methane from thawing permafrost). Such feedback loops would multiply and magnify the impacts of climate change, creating an even more hostile environment than the one projected here.

It is not alarmist to say that this scenario may be the best we can hope for. It is certainly the least we ought to prepare for.

The geopolitical consequences of climate change that we will explore in this are as much determined by local political, social, and economic factors as by the magnitude of the climatic shift itself. As a rule, wealthier countries (and wealthier individuals) will be better able to adapt to the impacts of climate change, while the disadvantaged will suffer the most. For example, an increase in rainfall can be a blessing for a country that has the ability to capture, store, and distribute the additional water; however, it is a deadly source of soil erosion for a country that does not have adequate land management practices or infrastructure.[175]

Consequently, even though the IPCC projects that the temperature increases at higher latitudes will be approximately twice the global average, it will be the developing nations in the Earth's low latitudinal bands and sub-Saharan Africa that will be most adversely affected by climate change. In the developing world even a relatively small climatic shift can trigger or exacerbate food shortages, water scarcity, destructive weather events, the spread of disease, human migration, and natural resource competition. These crises are all the more dangerous because they are interwoven and self-perpetuating: water shortages can lead to food shortages, which can lead to conflict over remaining resources, which can drive human migration, which, in turn, can create new food shortages in new regions.

Once underway this chain reaction becomes increasingly difficult to stop, and therefore it is critical that policymakers do all they can to prevent that first climate change domino — whether it be food scarcity or the outbreak of disease — from toppling. In this scenario, we identify each of the most threatening first dominos, where they are situated, and their cascading geopolitical implications.

Regional Sensitivity to Climate Change

The United States, like most wealthy and technologically advanced countries, will not experience destabilizing levels of internal migration due to climate change, but it will be affected. According to the IPCC tropical cyclones will become increasingly intense in the coming decades, and this will force the resettlement of people from coastal areas in the United States. This can have significant economic and political consequences, as was the case with the evacuation and permanent relocation of many Gulf Coast residents in the wake of Hurricane Katrina.[176]

The United States will also experience border stress due to the severe effects of climate change in parts of Mexico and the Caribbean. Northern Mexico will be subject to severe water shortages, which will drive immigration into the United States in spite of the increasingly treacherous border terrain. Likewise, the damage caused by storms and rising sea levels in the coastal areas of the Caribbean islands — where 60 percent of the Caribbean population lives — will increase the flow of immigrants from the region and generate political tension.[177]

It is in the developing world, however, where the impact of climate-induced migration will be most pronounced. Migration will widen the wealth gap between and within many of these countries. It will deprive developing countries of sorely needed economic and intellectual capital as the business and educated elite who have the means to emigrate abroad do so in greater numbers than ever before.[178]

The three regions in which climate-induced migration will present the greatest geopolitical challenges are South Asia, Africa, and Europe.

South Asia

No region is more directly threatened by human migration than is South Asia. The IPCC warns that "coastal areas, especially heavily populated

mega-delta regions in South, East, and Southeast Asia, will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from the rivers."[179] Bangladesh, in particular, will be threatened by devastating floods and other damage from monsoons, melting glaciers, and tropical cyclones that originate in the Bay of Bengal, as well as water contamination and ecosystem destruction caused by rising sea levels.

The population of Bangladesh — which stands at 142 million today — is anticipated to increase by approximately 100 million people during the next few decades, even as the impact of climate change and other environmental factors will steadily render the low-lying regions of the country uninhabitable.[180] Many of the displaced will move inland, which will foment instability as the resettled population competes for already scarce resources with the established residents. Others will seek to migrate abroad, creating heightened political tension not only in South Asia, but in Europe and Southeast Asia as well.

India will struggle to cope with a surge of displaced people from Bangladesh, in addition to those who will arrive from the small islands in the Bay of Bengal that are being slowly swallowed by the rising sea. Approximately 4 million people inhabit these islands, and many of them will have to be accommodated on the mainland eventually.[181]

Bangladeshi migrants will generate political tension as they traverse the region's many contested borders and territories, such as those between India, Pakistan, and China. Already, the India-Bangladesh border is a site of significant political friction, as evidenced by the 2,100 mile, 2.5 meter high iron border fence that India is in the process of building.[182] Due to be completed in 2007, this fence is being constructed at a time when there are numerous signs of rising Islamic extremism in Bangladesh. In the wake of the United States' invasion of Afghanistan, for instance, hundreds of Taliban and jihadists found safe haven in Bangladesh.[183] The combination of deteriorating socioeconomic conditions, radical Islamic political groups, and dire environmental insecurity brought on by climate change could prove a volatile mix, one with severe regional and potentially global consequences.[184]

Unfortunately, climate change is making many of the development projects being financed by the international community in South Asia and elsewhere less effective just as it is making them more necessary. The World Bank estimates that 40 percent of all overseas development assistance and concessional finance is devoted to activities that will be affected by climate change, but few of the projects adequately account for the impact that climate change will have. As a result, dams are built on rivers that will dry up, and crops are planted in coastal areas that will be frequently flooded.[185]

In Nepal, for instance, climate change is contributing to a phenomenon known as "glacial lake outburst," in which violent flood waves — reaching as high as 15 meters — destroy downstream settlements, dams, bridges, and other infrastructure. Millions of dollars in recent investment have been lost because hydropower and infrastructure design in Nepal largely fails to take these lethal floods into account. Ultimately, this puts further stress on the already beleaguered country as it struggles to preserve a fragile peace and reintegrate tens of thousands of Maoist insurgents. Neighboring the entrenched conflict zone of Kashmir and the contested borders of China and India, Nepal's stability has regional ramifications. An eruption of severe social or political turmoil could ripple across all of South Asia.

Nigeria and East Africa

The impact of climate change-induced migration will be felt throughout Africa, but its effects on Nigeria and East Africa pose particularly acute geopolitical challenges. This migration will be

both internal and international. The first domestic wave will likely be from agricultural regions to urban centers where more social services are available, which will impose a heavy burden on central governments. Simultaneously, the risk of state failure will increase as these migration patterns challenge the capacity of central governments to control stretches of their territory and their borders.

Nigeria will suffer from climate-induced drought, desertification, and sea level rise. Already, approximately 1,350 square miles of Nigerian land turns to desert each year, forcing both farmers and herdsmen to abandon their homes.[186] Lagos, the capital, is one of the West African coastal megacities that the IPCC identifies as at risk from sea level rise by 2015.[187] This, coupled with high population growth (Nigeria is the most populous nation in Africa, and three-fourths of the population is under the age of 30), will force significant migration and contribute to political and economic turmoil. It will, for instance, exacerbate the existing internal conflict over oil production in the Niger Delta.[188] To date, the Movement for the Emancipation of the Niger Delta (MEND) has carried out a successful campaign of armed attacks, sabotage, and kidnappings that has forced a shutdown of 25 percent of the country's oil output.[189] Given that Nigeria is the world's eighth largest (and Africa's single largest) oil exporter, this instability is having an impact on the price of oil, and it will have global strategic implications in the coming decades.[190] In addition to the Niger Delta issue, Nigeria must also contend with a Biafran separatist movement in its southeast.

The threat of regional conflagration, however, is highest in East Africa because of the concentration of weak or failing states, the numerous unresolved political disputes, and the severe impacts of climate change. Climate change will likely create large fluctuations in the amount of rainfall in East Africa during the next 30 years—a 5 to 20 percent increase in rainfall during the winter months will cause flooding and soil erosion, while a 5 to10 percent decrease in the summer months will cause severe droughts.[191] This will jeopardize the livelihoods of millions of people and the economic

Figure 2: Key Migrant Routes from Africa to Europe

Source: BBC News. Available at http://news.bbc.co.uk/2/hi/europe/5313560.stm.

capacity of the region: agriculture constitutes some 40 percent of East Africa's GDP and 80 percent of the population earns a living from agriculture.[192]

In Darfur, for instance, water shortages have already led to the desertification of large tracts of farmland and grassland. The fierce competition that emerged between farmers and herdsmen over the remaining arable land combined with simmering ethnic and religious tensions to help ignite the first genocide of the 21st century.[193] This conflict has now spilled into Chad and the Central African Republic. Meanwhile, the entire Horn of Africa continues to be threatened by a failed Somalia and other weak states. Al Qaeda cells are active in the region, and there is a danger that this area could become a central breeding ground and safe haven for jihadists as climate change pushes more states toward the brink of collapse.

Europe

While most African and South Asian migration will be internal or regional, the expected decline in food production and fresh drinking water, combined with the increased conflict sparked by resource scarcity, will force more Africans and South Asians to migrate further abroad.[194] This will likely result in a surge in the number of Muslim immigrants to the European Union (EU), which could exacerbate existing tensions and increase the likelihood of radicalization among members of Europe's growing (and often poorly assimilated) Islamic communities.

Already, the majority of immigrants to most Western European countries are Muslim. Muslims constitute approximately 5 percent of the European population, with the largest communities located in France, the Netherlands, Germany, and Denmark.[195] Europe's Muslim population is expected to double by 2025, and it will be much larger if, as we expect, the effects of climate change spur additional migration from Africa and South Asia.[196]

The degree of instability this generates will depend on how successfully these immigrant populations are integrated into European society. This process has not always gone well (as exemplified in 2005 by the riots in the poor and predominantly immigrant suburbs of Paris), and the suspicion with which Europe's Muslim and immigrant communities are viewed by many would be greatly intensified by an attack from a "homegrown terrorist." Given that a nationalist, anti-immigrant backlash could result from even a small or unsuccessful attack, the risk that such a backlash will occur is high.

If the backlash is sufficiently severe, the EU's cohesion will be tested. At present, the ease with which people can move between EU countries makes it extremely difficult to track or regulate immigrants (both legal and illegal). In 2005, for instance, Spain granted amnesty to some 600,000 undocumented immigrants, and yet could provide few assurances that they would remain within Spain's borders.[197] The number of Africans who attempt to reach the Spanish Canary Islands—the southernmost European Union territory—has more than doubled since then. In 2006, at least 20,000 Africans attempted the perilous, often fatal, journey.[198]

Thus far, the EU has responded to this challenge with ad hoc measures, such as creating rapid reaction border guard teams.[199] While the influx of immigrants from Africa—Muslim and otherwise—will continue to be viewed by some as a potential catalyst for economic growth at a time when the EU has a very low fertility rate, the viability of the EU's loose border controls will be called into question, and the lack of a common immigration policy will invariably lead to internal political tension. If a common immigration policy is not implemented, there is the possibility that significant border restrictions will reemerge and, in so doing, slow the European Union's drive toward increased social, political, and economic integration.

Middle East and North Africa

Increasing water scarcity due to climate change will contribute to instability throughout the world. As we have discussed, in many parts of Africa, for instance, populations will migrate in search of new water supplies, moving within and across borders and creating the conditions for social or political upheaval along the way. This was the case in Darfur, and its effects were felt throughout the entire region.

But water scarcity also shapes the geopolitical order when states engage in direct competition with neighbors over shrinking water supplies. While this threat may evoke apocalyptic images of armies amassing in deserts to go to war over water, the likelihood of such open conflict in this 30 year scenario is low. There are a very limited number of situations in which it would make strategic sense for a country today to wage war in order to increase its water supply. Water does not have the economic value of a globally traded strategic commodity like oil, and to reap significant benefit from a military operation would require capturing an entire watershed, cutting supply to the population currently dependent upon it, and then protecting the watershed and infrastructure from sabotage.[200]

Thus, although we are not likely to see "water wars" per se, countries will more aggressively pursue the kinds of technological and political solutions that currently enable them to exist in regions that are stretched past their water limits.

This is likely to be the case in the Middle East, where water shortages will coincide with a population boom. The enormously intricate water politics of the region have been aptly described as a "hydropolitical security complex."[201] The Jordan River physically links the water interests of Syria, Lebanon, Jordan, Israel, and the Palestinian Authority; the Tigris and Euphrates Rivers physically link the interests of Syria, Turkey, Iran, and Iraq. This hydrological environment is further complicated by the fact that 75 percent of all the water in the Middle East is located in Iran, Iraq, Syria, and Turkey.[202] Such conditions would be cause for political tension even in a region without a troubled history.

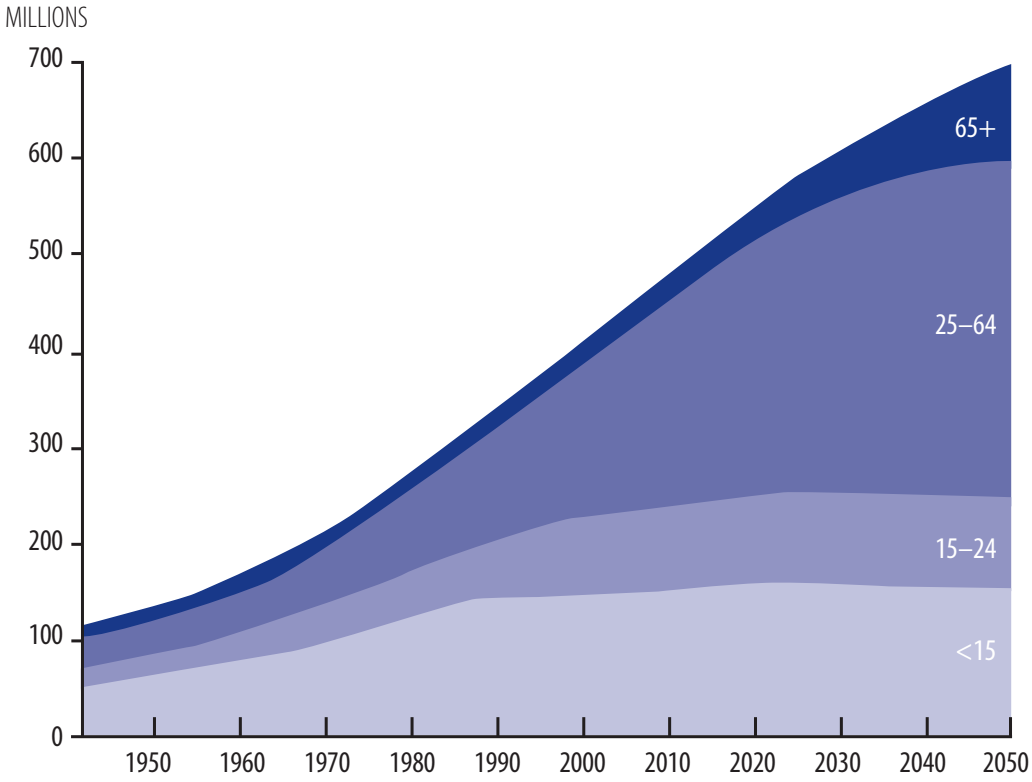
Turkey's regional position will likely be strengthened as a result of the water crisis. Situated at the headwaters of the Tigris and Euphrates Rivers, Turkey is the only country in the Middle East that does not depend on water supplies that originate outside of its borders. Though Turkey is by no means a water-rich country, climate change per se will not significantly threaten its water supply within the next three decades.

Israel, already extremely water poor, will only become more so. One thousand cubic meters of water per capita is considered the minimum amount of water necessary for an industrialized nation; by 2025, Israel will have fewer than 500 cubic meters of water per capita.[203] Over-pumping has also contributed to the gradual depletion and salinization of vital aquifers and rivers. Much of Israel's water, moreover, is located in politically fraught territory: one-third of it is in the Golan Heights and another third is in the mountain aquifer that underlies the West Bank.[204]

Israel will need to place additional importance on its relationship with Turkey, and a deeper alliance could be forged if a proposed water trading agreement—in which Turkey would ship water directly to Israel in tankers—is eventually completed.[205] This new source of supply would not offset the added pressures of climate change and population growth, but it would deepen their strategic ties and cushion any sudden, short-term supply disruptions or embargoes.[206]

Israel's relations with Syria will also be strained by its need for the water resources of the Golan Heights. Although there is a mutual recognition that any peaceful and sustainable resolution over

Figure 3: Population of Middle East and North Africa by Age Group, 1950–2050



Source: Ragui Assaad and Farzaneh Roudi-Fahimi, "Youth In the Middle East and North Africa," April 2007, *Population Reference Bureau,* http://www.prb.org/pdf07/YouthinMENA.pdf.

the Golan Heights will need to include a water sharing agreement, the issue of direct access to the Sea of Galilee will continue to complicate negotiations over the final demarcation of the border (as it did in 2000).

The region's water problems will be compound by its population growth (see Figure 3). According to current projections the Middle Eastern and North African population could double in the next 50 years.[207] In the Middle East, the fastest growing populations are in water-poor regions such as the Palestinian territories. In the West Bank, a lack of available freshwater has already contributed to food shortages and unemployment.

China's Climate Change Challenge

China's current pattern of energy production and consumption poses a tremendous long-term threat to the global environment. China is believed to have surpassed the United States as the world's largest national emitter of carbon dioxide (though, notably, it lags far behind on a per capita basis), while its energy demand is projected to grow at a rate several times that of the United States for decades to come.

China's steep carbon emissions trajectory is to a large extent the result of its reliance on coal. Currently, coal constitutes approximately two-thirds of China's primary energy consumption, and it will continue to be a major fuel source for

the foreseeable future because China has enormous coal reserves and coal is a far more cost-efficient energy source than imported natural gas at today's prices. China is now building traditional coal-fired power plants at a rate of almost one per week, each of which releases approximately 15,000 metric tons of CO_2 per day.[208]

Today, coal use accounts for more than 80 percent of China's carbon emissions, while automobile emissions only constitute approximately 6 percent.[209] However, cars and trucks will be an increasingly important factor in the future: the size of China's vehicle fleet is projected to grow from 37 million to as many as 370 million during the next 25 years.[210]

Unless its pattern of energy consumption is altered, China's carbon emissions will reinforce or accelerate several existing domestic environmental challenges—ranging from desertification to water shortages to the deterioration of air quality in urban areas—as well as become the primary driver of global climate change itself. China's future will be shaped by how its leadership reacts to intensifying domestic and international pressure to address these challenges.

China's first national report on climate change, released in late 2006, projected that national wheat, corn, and rice yields could decrease by as much as 37 percent in the next few decades.[211] Even a far smaller decrease, however, would require significant action by the central government.[212]

China, moreover, is severely affected by desertification, and the United Nations Framework Convention on Climate Change (UNFCCC) notes that desertification-prone countries are "particularly vulnerable to the adverse effects of climate change."[213] More than a quarter of China is already desert, and the Gobi is steadily expanding (it grew some 52,400 square kilometers between 1994 and 1999).[214] According to the United Nations Convention to Combat Desertification, this threatens the livelihoods of some 400 million people.[215]

Water shortages will also pose a major challenge to China. In 2004, the UN reported that most of China's major rivers had shrunk, and in December 2006 it found that the Yangtze River's water level dropped to an all time low because of climate change.[216] Northern China faces the greatest threat in this respect, as it will be subject to heat waves and droughts that will worsen existing water shortages. In addition, two-thirds of China's cities are currently experiencing water shortages, and their predicament will be exacerbated by the shifts in precipitation patterns and the increased water pollution.[217]

In spite of the colossal development projects that China has initiated in an attempt to mitigate growing environmental stress (e.g., the South-to-North Water Diversion project, which is anticipated to cost some $59 billion and take half of a century to complete), domestic social and political turmoil will increase. One source of unrest will be increased human migration within China due to environmental factors. Much of this migration will reinforce the current migratory trends from countryside to city, putting added pressure on already overpopulated and dangerously polluted urban centers.[218]

Regions of China that benefit from some additional rainfall will also need to cope with an influx of migrants from water scarce areas. In China's northwestern provinces, where rainfall may increase, the acceleration of the movement of Han Chinese into Muslim Uighur areas will aggravate tensions that have led to low-level conflict for many years. This conflict has intensified as China has begun to extract natural resources from these provinces and as larger numbers of Han Chinese have migrated there in search of employment. The

projected increase in Han migration to this area could provoke violent clashes and potentially lead to social turmoil.[219]

On the one hand, this may lead to internal political reform designed to address public concern. The central government may assume a much larger role in affairs and policies that to date have been left largely in the hands of regional or local officials.

However, it is also possible that the Chinese leadership will not make the necessary adjustments even as the effects of climate change and other environmental factors become increasingly severe. This could lead to larger protests and violent clashes with police, as well as more restrictions on the press and public use of the Internet. Relations with the West would rapidly deteriorate as a result.

A second factor that could shape China's future is not internal but external: namely, the growing pressure from the international community to curb carbon emissions and to enter into a global carbon reduction agreement. To date, China has resisted policies and treaties that restrict its carbon emissions, opting instead to set its own energy intensity targets. The current national goal is to reduce energy intensity by 20 percent by 2010, and to quadruple GDP while only doubling energy growth by 2020.[220] This target is considered extremely ambitious, and the added economic costs of constraining its carbon emissions would make it even more so.

Regardless, there will be escalating pressure on China to be a "responsible stakeholder" as its economic and political strength grow and as it surpasses the United States as the world's largest carbon emitter in the near future. Furthermore, mounting global awareness about the threats posed by climate change — and the harm it is inflicting on developing countries in which China is seeking to expand its political and economic influence — will make it difficult for China to remain outside of a U.S.-supported post-Kyoto regulatory framework on climate change without severely damaging its international standing.

Disease

Climate change will have a range of decisively negative effects on global health during the next three decades, particularly in the developing world. The manner in which countries respond — or fail to respond — to these health challenges will have a significant impact on the geopolitical landscape. The World Health Organization is nearing completion of a study projecting that the number of deaths linked to climate change will exceed 300,000 per year by 2030, and the total number of lost disease-adjusted life years (DALYS) — a measurement that accounts also for injury and premature death — will surge to more than 11 million. These numbers are all the more alarming because they only take into consideration a fraction of the impact that climate change will have on the spread of disease.[221]

Water-borne and vector-borne diseases (such as malaria and dengue fever) will be particularly prevalent in countries that experience significant additional rainfall due to climate change.[222] Shortages of food or fresh drinking water will also render human populations both more susceptible to illness and less capable of rapidly recovering. Moreover, the risk of a pandemic is heightened when deteriorating conditions prompt human migration.[223]

This increase in the incidence of disease will inevitably generate disputes between nations over the movement of people. Immigrants — or even simply visitors — from a country in which there has been a significant disease outbreak may not be welcomed and could be subject to quarantine. If the policies that underlie such practices are perceived as discriminatory or motivated by factors other than legitimate health concerns, it will severely damage political relations.

This outcome might be averted if countries establish in advance common immigration policies that are specifically designed to cope with international health crises. However, it is most likely that this kind of coordination will occur after the fact, as it did in Europe following several cholera pandemics in the mid-19th century.

In addition to the challenges posed by restrictions on the movement of people, restrictions on the movement of goods will be a source of economic and political turmoil. Pandemic-affected countries could lose significant revenue from a decline in exports due to limits or bans placed on products that originate or transit through them. The restrictions placed on India during a plague outbreak that lasted for seven weeks in 1994 cost it approximately $2 billion in trade revenue.[225] Countries that depend on tourism could be economically devastated by even relatively small outbreaks: the fear of Severe Acute Respiratory Syndrome (SARS) sharply curtailed international travel to Thailand in 2003, whereas the 2006 military coup had little impact on tourism.[226] And as with the controls placed on the movement of people across borders, restrictions on the movement of goods can be politicized in a way that generates significant international friction.

Even in the absence of trade restrictions, however, the economic burden that disease will place on developing countries will be severe. Added health care costs combined with a loss of worker productivity from worker absences will exact a large economic toll. In 2001, the U.S. General Accounting Office (now the U.S. Government Accountability Office) estimated that Africa's gross domestic product would be one-third higher if malaria had been eradicated in 1970.[227]

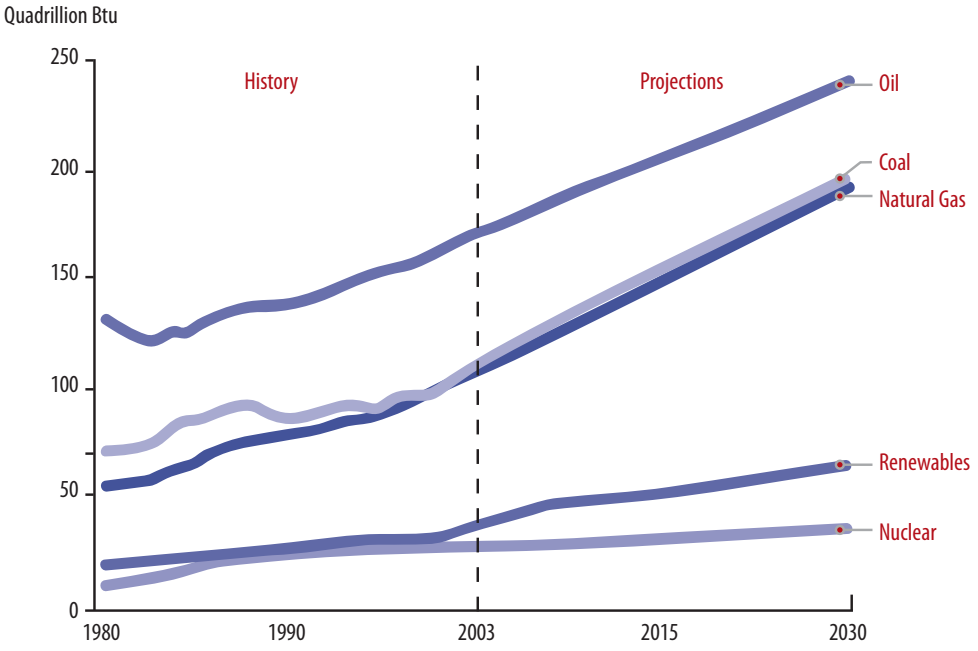
The outbreak of disease can also lead a government to adopt policies that may be seen as discriminatory or politically motivated by segments of its own population (e.g., treatment may be provided first, or exclusively, to a particular ethnic group, religious faction, or political party). This can provide anti-governmental groups with the opportunity to increase their popularity and legitimacy by providing those health services that the government does not.[228] When these groups are sponsored by foreign governments (e.g., Iran's support for Hezbollah in Lebanon) the line between medicine and foreign policy vanishes.

In these economic and social circumstances a country's political direction can change rapidly. For instance, the inability or perceived unwillingness of political leaders to stop the spread of disease or to provide adequate care for the afflicted will undermine support for the government.[229] In countries with functioning democracies, this could lead to the election of new leaders with political agendas radically different from their predecessors. It could also breed greater support for populist candidates whose politics resonate in a society that believes that its economic and social hardships are due to neglect or mismanagement by the government. In countries with weak or non-democratic political foundations, there is a heightened risk that this will lead to civil war or a toppling of the government altogether.

Given the country's geopolitical significance, it is worth noting that Venezuela could be hit hard by a climate-induced increase in disease. In addition to experiencing the increased rainfall that will create favorable conditions for many waterborne and vector-borne diseases, people living along Venezuela's coast—which will be subject to more frequent storms and flooding due to climate change—are at heightened risk.[230]

There is also a small chance that the balance of power between neighboring states could suddenly and decisively shift if one country's military or political elites were seriously affected by a disease while the other country's were not.[231] The high HIV infection rate in several African militaries

Figure 4: World Marketed Energy Consumption by Region, 1980–2030



Source: International Energy Outlook 2006

provides a recent example of how a disease can come to have a disproportionate impact on a sector of the population that is critical to a country's national security.[232]

Regardless of the scenario, however, developing countries will look to the United States and the developed world for help in responding to these health crises. The gap between the world's "haves" and "have nots" will be made increasingly apparent, and the resentment that this will engender toward wealthy countries will only be assuaged if significant resources are devoted to combating disease outbreaks and to caring for the afflicted in the developing world.

Impact of Climate Change on Fuel Types

In its 2006 International Energy Outlook, the U.S. Energy Information Administration (EIA) forecasts increased global demand for every major fuel type through 2030, though the rate of growth varies significantly among them.

This EIA projection provides a useful policy-neutral reference case for analyzing the pressures that climate change will exert on patterns of energy production and consumption. There will be significant foreign policy and national security consequences for energy exporting and importing countries alike, including a strengthened geopolitical hand for natural gas exporting countries and, potentially, biofuel exporting countries as well; a weakened hand, both strategically and economically, for importers of all fuel types, who will find themselves increasingly vulnerable to supply disruption; growing nuclear safety and proliferation threats; and a steady increase in the economic and environmental cost of delaying the implementation of global carbon reduction policies.

Oil

Climate change will exert upward pressure on oil prices by causing supply disruptions and contributing to instability in some oil producing regions.

The increase in temperature brought about by climate change will not result in a large enough reduction in the use of home heating oil—which constitutes a small percentage of global demand—to offset these effects.[233]

In this scenario the increased frequency of major storms will lead to more damage to off-shore rigs and coastal refineries, while oil tanker shipments will be delayed by weather events. Oil exporting countries will benefit economically from the risk premium that climate change adds to the price of each barrel of oil.

Political instability in oil exporting countries will be exacerbated by climate change as well, leading to reduced output due to everything from acts of sabotage to lack of international investment. For instance, although the United States is currently projected to import between 25 and 40 percent of its oil from Africa by 2015, the adverse political and environmental conditions brought about by climate change may prevent Nigeria and the continent's nine other oil exporting countries from expanding their existing oil production levels to meet this demand.[234]

Oil-importing developing countries, meanwhile, will be disproportionately affected by increases in the cost of oil because their economies have high energy intensities and fuel switching is difficult. The International Energy Agency estimates that oil-importing and debt-burdened countries in sub-Saharan Africa will lose more than 3 percent of their GDP with each $10 increase in the price of oil.[235]

In spite of rising oil prices and an expanding biofuels market, oil will remain a key strategic commodity for the United States and the U.S. Navy will continue to protect global sea lanes in order to ensure the safe movement of oil shipments around the world. But as China develops its own blue water navy in the next few decades it too will become involved in securing global sea lanes, in particular the routes linking Northeast and Southeast Asia.[236] As a result, the U.S. and Chinese navies will need to find ways of coordinating their movements if they are to avoid miscommunication or accidental interference that could cause severe political tension.[237]

U.S.-Sino relations could also be strained if China continues to supplement its international energy deals with state-to-state arrangements that include significant non-market elements (e.g., building airports, offering credit, tying foreign assistance to energy investment). To date the list of countries with which it has made such arrangements includes Angola, Sudan, Iran, Algeria, and Saudi Arabia.

A second growing concern for the United States is China's practice of investing in countries where sanctions and other factors limit or preclude the major Western international energy companies from operating. Although China's motivation may be driven as much by economic as political factors—it is easier, after all, to compete in markets where there is less competition—such investment in sanctioned countries like Sudan and Iran runs counter to the strategic interests of the United States. As China's demand for imported oil increases in the coming years, so will these investments.

Natural Gas

The upward pressure that climate change exerts on the price of oil is likely to help drive demand for natural gas. Moreover, because natural gas is a less carbon-intensive energy source than coal or oil, it will become an increasingly attractive fuel choice (particularly for electricity generation) if stringent national or global carbon emission regulations are adopted.

One likely development will be an increase in the size and scope of the liquefied natural gas (LNG) market. The United States' overseas LNG imports

are poised to overtake imports from Canada as its primary source of natural gas within the next few years; Europe, China, and India have all been working to increase LNG imports as well.[238]

Although the development of a global LNG market will temper the strategic leverage of major natural gas exporters by providing some added security against targeted embargoes or price manipulation, the geopolitical power of countries that are rich in natural gas will nevertheless grow significantly by mid-century. This will create new security risks and new choke points around the world. Countries in Central Asia and the Caucasus will become more strategically important because they can offer energy supplies and routing alternatives to the Middle East and Russia.

It is Russia, however, that stands to benefit the most from the growing strategic significance of natural gas, as well as from the environmental impacts of climate change in general. Russia holds by far the world's largest proven natural gas reserves (almost twice those of Iran, the country with the second largest proven reserves) and currently supplies Europe with two-thirds of its imported natural gas.[239] A warmer climate will help to reduce domestic demand for energy: the IPCC anticipates that "in the United Kingdom and Russia a 2°C warming by 2050 will decrease space heating needs in the winter, thus decreasing fossil fuel demand by 5–10 percent and electricity demand by 1–3 percent."[240] In the longer term, increased temperatures could also open up ice-locked northern shipping routes for the export of LNG and oil throughout the year.

During the past few years, Russia has proven willing to use its energy assets for political leverage. In January 2006, for instance, Russia dramatically increased the price of natural gas in the run up to the Ukrainian parliamentary elections. Ukraine refused to pay the new rates, which led to a supply reduction that left it—as well as several EU countries that are supplied through pipelines that run through Ukraine's territory—short of natural gas in the middle of winter. As global demand for oil and natural gas grows Russia's energy assets are likely to become an increasingly potent—and frequently employed—political tool.

This tension will be exacerbated (and become a more direct challenge to the national security of the United States) if NATO expands to include Ukraine, Georgia, or other countries that are embroiled in ongoing energy conflicts with Russia. Senator Richard Lugar (R-Ind.), who as chairman of the Senate Foreign Relation Committee did much to draw attention to global energy security threats, has argued that the deliberate cutoff of energy supplies to a NATO country should trigger a compulsory Article 5 collective response by its members.[241] According to this interpretation, Russia's natural gas supply cutoff to Ukraine would have required U.S. action because Italy and other NATO allies were affected.

Another area of concern for the United States and its allies will be Russia's relationship with China. As Russia becomes an important supplier of energy to East Asia, the strategic interests of China and Russia may become more closely aligned, particularly with regard to Central Asia. Their joint leadership in the Shanghai Cooperation Organization (SCO), a regional group that includes Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, could enable them to exert significant influence over this critical region's energy supplies and pipelines as well as its overall political and strategic relationship with the West. At their July 2005 summit, for instance, SCO members issued a declaration calling for the closure of U.S. military bases in the region, and before the end of the month the United States had been formally evicted from its base in Uzbekistan.[242]

There also remains a possibility that a natural gas cartel will develop out of the Gas Exporting Countries Forum, in which Russia plays a role analogous to that played by Saudi Arabia within OPEC. At present, natural gas is primarily distributed through pipelines that involve long-term, regional contracts, and natural gas pricing is closely linked to oil prices. However, the International Energy Agency projects an expansion of global LNG capacity from 246 billion cubic meters per year in 2005 to 476 billion cubic meters by 2010. Simultaneously, a larger spot market for LNG will emerge, and this will make pricing more susceptible to manipulation by a cartel of natural gas suppliers. As the global natural gas giant, Russia stands to gain the most from this development.

Coal

For the first time in 16 years of forecasting worldwide energy use, the 2006 International Energy Outlook projects that the rate of growth in coal consumption will exceed that of natural gas.[243] Although there is only one-tenth of a percent difference between their projected rates, this signals an alarming trend given the enormous environmental threat posed by carbon emissions from coal-fired power plants. In the absence of international carbon emission restraints, climate change will likely reinforce this trend by increasing the price of natural gas and oil relative to coal.

Given coal's low cost as a fuel source for electricity generation and its wide distribution among developed and developing nations, it is inconceivable that it can or will be largely replaced in the next 30 years.[244] Rather, the question is whether coal will continue to be a driver of climate change or if the development and implementation of clean coal and, in particular, carbon dioxide capture and storage (CCS) technology can make it a viable fuel source in a carbon-constrained economy. A 2007 MIT study, "The Future of Coal," found that, in spite of the lead times involved, CCS technology can in fact be deployed on a wide enough scale to reduce significantly the carbon emissions from coal-fired power plants by 2050, though only if a global carbon emissions restriction or tax is in place and near-term government investment in R&D is increased.[245]

Nuclear Power

The EIA projects a slight decline in the installed nuclear capacity of OECD countries by 2030, but rapid growth in the nuclear sectors of non-OECD countries such as China.[246] Two of the factors that drive the use of nuclear power are high fossil fuel prices and energy insecurity. As we have seen, climate change will contribute to both.

There is a risk of proliferation associated with this fast expansion of nuclear power. The development of nuclear power capabilities and the associated facilities for the manufacturing and production of nuclear fuels could bring many more countries to the brink of nuclear weapon status. There is also a smaller risk that commercial fuel cycle technology will be transferred to a country that is interested in developing a clandestine nuclear weapons program (as has occurred in Iran).

Approximately a dozen countries in the Middle East and North Africa have recently sought the International Atomic Energy Agency's assistance in developing nuclear energy programs.[247] Political insecurity coupled with the increased availability of nuclear fuel cycle technology may lead these countries over time to pursue nuclear weapons programs as well.

There is also a risk that a Sunni Arab country will receive assistance from scientists or government officials from Pakistan, the only Sunni state that already possesses nuclear weapons. In addition, non-nuclear Bangladesh could be tempted to pursue such a program if climate change destabilizes the region and its relations with its nuclear neighbor, India, deteriorate further.

Furthermore, rapid nuclear expansion heightens the risk of a nuclear accident. In addition to the local health and environmental consequences, a large-scale accident anywhere in the world could provoke a global backlash against nuclear power. This would increase the economic burden of limiting carbon emissions by forcing countries to switch to more expensive alternatives and could cause countries to reconsider any carbon reduction policies in place.

If global carbon reduction policies are adopted in this timeframe, nuclear energy will become more cost-competitive with fossil fuels. This could provide added political justification for countries to develop domestic commercial nuclear power programs that might lead to weapons programs or rekindle interest in weapons programs that had been abandoned. Despite these risks, however, nuclear power will continue to play an integral role in the energy strategies of many countries that are seeking to reduce their carbon emissions, making it all the more imperative that the international community redouble its nonproliferation efforts.

Biofuels

Biomass fuels have the potential to emerge as a competitor to oil, particularly in the transportation sector. This is most likely to occur if a global carbon reduction policy is adopted that creates a strong market incentive for investments in both R&D and infrastructure for such fuels. The United States and Brazil currently account for more than 70 percent of global ethanol production, but other countries in Latin America and elsewhere could be poised to participate in an expanded international biofuels market.[248] This would help to offset some of the geostrategic importance of oil suppliers.[249] China could be a significant biomass fuel consumer, as it would rather import this fuel than sacrifice food crops for energy crops, particularly if its food security is threatened by climate change. Japan already imports ethanol from Brazil.

The biofuels market will need to be managed effectively in order for it to grow to scale and avoid replicating some of the flaws that plague the fossil fuel market. This requires developing and implementing policies that minimize the total "fields to wheels" carbon emissions from biofuels (which includes emissions from any fossil fuel used to raise energy crops, refine these crops into fuel, and distribute the fuel to consumers).[250] It is also important to consider non-environmental externalities, such as the impact that replacing food crops with energy crops could have on food prices around the world. Although to date productivity gains have enabled U.S. farmers to raise sufficient quantities of crops to meet demand for both food and fuel, policymakers will need to monitor this issue closely as demand increases in the coming decades.

Conclusion

The effects of climate change we describe in this scenario are not alarmist; rather, they are to a large degree inescapable. The scientific evidence is clear that we will see effects at least as dramatic as those we outline here. What is not inevitable, however, is how human society responds to global warming and its attendant resource scarcity, extreme weather, and rise of disease. Indeed, many of the conflicts and challenges we describe are tightly interwoven with underlying social, political, and economic factors that exist independently of climate change. It is critical that governments, particularly in the wealthier nations that have the requisite tools and resources, begin to plan on an urgent basis for how to prevent, mitigate, and manage the consequences of climate change. Delaying this planning process risks touching off a chain reaction of crisis that will be nearly impossible to stop once it is firmly underway.

LOCATION: A Chinese river—A local fisherman plies his boat through a fish kill.

SEVERE

CLIMATE CHANGE
OVER NEXT **30 YEARS**

AT A GLANC E:

Time Span: 30 Years

Warming: 2.6°C

Sea Level Rise: .52 meters

By Leon Fuerth[251]

Scenario Overview: Severe Climate Change[252]

The projection of severe climate change employed in this chapter is based on IPCC findings,[253] with an adjustment to account for possible "tipping point" events such as the abrupt release of massive quantities of methane from melting tundra or of carbon dioxide as the sea warms up. Under these conditions, adverse trends could accelerate abruptly, as follows:

- Over the next 30 years, average global surface temperature rises unexpectedly to 2.6°C above 1990 levels, with larger warming over land and at high latitudes. Dynamical changes in polar ice sheets accelerate rapidly, resulting in 52 centimeters of sea level rise. Based on these observations and improved understanding of ice sheet dynamics, climate scientists by this time express high confidence that the Greenland and West Antarctic Ice Sheets have been destabilized and that 4 to 6 meters of sea level rise are now inevitable over the next few centuries, bringing intense international focus to this problem.

- Water availability decreases strongly in the most affected regions at lower latitudes (dry tropics and subtropics), affecting 1 to 2 billion people worldwide. The North Atlantic overturning circulation slows significantly, with consequences for marine ecosystem productivity and fisheries.

- Crop yields decline significantly in the fertile river deltas because of sea level rise and damage from increased storm surges. Agriculture becomes essentially nonviable in the dry subtropics, where irrigation becomes exceptionally difficult because of dwindling water supplies, and soil salinization is exacerbated by more rapid evaporation of water from irrigated fields. Arid regions in the low latitudes have spread significantly by desertification, taking previously marginally productive crop lands out of production.

- Global fisheries are affected by widespread coral bleaching, ocean acidification, substantial loss of coastal nursery wetlands, and warming and drying of tributaries that serve as breeding grounds for anadromous fish.
- The Arctic Ocean is now navigable for much of the year because of decreased Arctic sea ice and the Arctic marine ecosystem is dramatically altered. Developing nations at lower latitudes are impacted most severely because of climate sensitivity and high vulnerability. Industrialized nations to the north experience net harm from warming and must expend greater proportions of GDP adapting to climate change at home.

This projection serves as the basis for a scenario depicting the possible societal consequences of severe climate change over the course of thirty years. These consequences are not to be taken as predictions: they represent a selected construct of the future, intended to encourage reflection about the consequences of continued inaction.

The Role of Complexity

Climate change is a manifestation of phenomena that are complex in the technical sense of that word. Complex phenomena are nonlinear and unstable. "Nonlinear" means that incremental change in the level of inputs to a system can result in major, and even discontinuous changes in the system's output. "Unstable" means that it is not possible to create a single, normative model for the system's behavior: instead, modeling must assume the possibility of surprise. It is readily seen that even incremental levels of climate change will have political consequences, but a less obvious, and major, premise of this chapter is that *nonlinear climate change will produce nonlinear political events.*

If the environment deteriorates beyond some critical point, natural systems that are adapted to it will break down. This applies also to social organization. Beyond a certain level climate change becomes a profound challenge to the foundations of the global industrial civilization that is the mark of our species.

Regional Sensitivity to Severe Climate Change

According to the IPCC findings the poorest nations will suffer first and also most deeply from climate change. Despite this, my analysis of the international consequences of climate change begins with the wealthiest and strongest societies since it is their responses that will make the difference between relative order and freefall.

United States

Even at lesser degrees of climate change we should expect more severe weather along our coasts, with increasingly violent storms coming in from the sea at much higher rates of incidence. Very early on in this process important social readjustments will occur—if only because of measures that the insurance and mortgage industries will take in their own defense. This is already visible along the Gulf Coast in Hurricane Katrina's aftermath.

Even at linear rates of sea level rise, such as those forecast at the lower range of the scenario, exponentially greater numbers of people would be affected. One storm model concludes that what is now a 100-year flooding event in New York City will be a 4-year event with an additional meter of sea level.[254] Early on, there will be talk of massive engineering efforts to protect major economic centers along the coasts, including oil and gas production in the Gulf. In our scenario, however, estimates of conditions abruptly become worse as science adjusts for new theory and new data. Given this deteriorating prospect for the future, the idea of resisting nature by brute engineering will give way to strategic withdrawal, combined with a rear guard action to protect the most valuable of our assets. Optimists might hope for a gradual relocation of investment and settlement from increasingly vulnerable coastal areas. After a certain point, however, sudden depopulation may occur.

Severe climate change will attack the West Coast's economic foundations because of drastic, permanent water shortage—resulting not only from reduced annual rainfall, but also from the disappearance of mountain snow, whose spring melt-off is vital to the entire region's hydrology. The water requirements of the great West Coast cities are already in conflict with the region's requirements for agriculture. In the more destructive ranges of the severe scenario, it would no longer be possible to bridge this conflict through political compromise or adroit water management. Political tensions would be severe. Moreover, the damage to American agriculture will not be limited to California. There will be intensified dependence on irrigated farming in the Midwest, and this will result in the accelerated depletion of the Ogallala aquifer, upon which the entire region's agrarian economies depend.[255]

The United States' federal system may also experience stress. As noted above, one possible consequence of severe climate change will be greatly increased frequency of region-wide disasters as the result of an increasing number of especially violent storms. At some level, even a well-prepared Federal Emergency Management Agency (FEMA) system might be overwhelmed. As the cumulative magnitude of such damage increases, the federal government would likely leave state governments to shoulder more and more of the burden. The effect would be to strain the ligaments that hold the federal system together.

State governments are already pulling away from federal leadership on the environment. California is the leading example but others are coming along, mainly in the form of regional groupings.[256] The federal government is already fiscally compromised by defense costs in competition with escalating costs for maintaining the social contract. The additional costs entailed by climate change will make these problems unmanageable without drastic tradeoffs. At some point the government's ability to plan and act proactively will break down because the scale of events begins to overwhelm policies before they can generate appreciable results.

Western Hemisphere

Accumulated stresses owing to severe climate change may cause systemic economic and political collapse in Central and Latin America. The collapse of river systems in the western United States, for example, will also have a devastating effect on northern Mexico.[257] In Mexico, climate change likely means mass migration from central lowlands to higher ground. Immigration from Guatemala and Honduras into southern Mexico (whether for employment in Mexico, or passage to the United States) is already a major issue for the Mexican government, and will intensify dramatically. The pass-through consequence for the United States is that border problems will expand beyond the possibility of control, except by drastic methods and perhaps not even then. Efforts to choke off illegal immigration will have increasingly divisive repercussions on the domestic social and political structure of the United States.

Severe climate change will likely be the deathblow for democratic government throughout Latin America, as impoverishment spirals downward. In these circumstances we should expect that populist, Chavez-like governments will proliferate. Some regions will fall entirely and overtly under the control of drug cartels. Some governments will exist only nominally, and large regions will be essentially lawless, much as has been the case in Colombia. The United States will lack adequate means for responding effectively, and will likely fall back on a combination of policies that add up to quarantine.

Tensions will increase between the United States and Canada, including clashes over fishing rights on both coasts. Two-thirds of Canadians rely on the Great Lakes (a relatively small watershed). Water levels are projected to decline by up to one

foot in this century, attributable to increased evaporation, coupled with population growth. If the United States decides to divert water from the Great Lakes to compensate for the effects of climate change, the makings are in place for a fundamental clash of interests with Canada. There will also be an entirely new set of problems relating to navigation and resource rights, as the result of the opening of a northwest passage. It cannot be excluded that Canada's tensions with the United States will play into domestic issues affecting the stability of Canada itself: most notably, the western provinces' new role as oil exporter.

The cumulative effect of all these and related factors will be to render the United States profoundly isolated in the Western Hemisphere: blamed as a prime mover of global disaster; hated for measures it takes in self-protection.

Europe/Eurasia

The prospect of a new ice age in Europe caused by the Gulf Stream's collapse is *not* an element of the severe climate scenario that serves as the basis for this chapter. But there is enough bad news for Europe in the scenario as it stands. Severe climate change will threaten every major port city in Europe (the UK included). This will translate into huge economic costs at the national level, and prompt demands for EU intervention that are likely to exceed both its economic *and* its political resources. The Netherlands will be a particularly wrenching problem: a society at the core of European culture, which physically exists by restraining the sea, will be threatened by inundation. How will Europe share the costs of redesigning an entire nation?

Environmental pressures will accentuate the migration of peoples to levels that effectively change the ethnic signatures of major states and regions. In Europe the influx of illegal immigrants from Northern Africa and other parts of the continent will accelerate and become impossible to stop, except by means approximating blockade. There will be political tipping points marked by the collapse of liberal concepts of openness, in the face of public demands for action to stem the tide. As the pressure increases, efforts to integrate Muslim communities into the European mainstream will collapse and extreme division will become the norm.

The beginnings of these trends are present now. But severe climate change will cause them to become far worse. One of the casualties of this process may be any prospect for the cultural, much less the political integration of Turkey into the EU. Even if Turkey were to be admitted, the increasing reaction of Europeans against Islam may alienate the Turkish people, thereby destroying the hoped-for role of Turkey as a bulwark against radical Islam. At severe levels of climate change, civil disorder may lead to the suspension of normal legal procedures and rights. The precedents for dealing with large, unwanted minorities have already been set in Eurasia under fascism and communism. Under conditions marked by high levels of civil confusion and fear, political leaders and movements will emerge who might not resist these solutions.

In parts of the Russian Federation the Slavic population will continue receding while immigration from Asia intensifies. At some point these tensions may accumulate to the point where Moscow and Beijing collide over matters each believes to be vital to its own political stability and to the survival of its regime. Growing Asian settlement in portions of the Russian Federation will also result in increased friction, specifically with Russia's rapidly growing Islamic population.

The Russian core of the Federation will certainly not respond to these developments by shifting to liberal democracy. On the contrary, the anti-democratic legacy of the Putin period will be reinforced. Russia will return to its roots — to a

czarist-like system in all but name, with the wealth of the country divided among a new "boyar" class as payment for loyalty. This regime will anchor itself ideologically in Russian nationalism, and economically on the basis of a dominant energy position, which it will exploit aggressively. These trends are established already. Severe climate change will intensify them under Putin's successors.

Rising sea levels and accentuated storm systems will threaten China's industrialized coastal regions. Chinese economic growth will suffer as a result of the accelerated loss of land fertility due to salinization of river deltas, compounding shortages of arable land lost to urbanization. Decreased rainfall will accelerate China's already critical shortage of water, not only for drinking but also for industrial purposes. This will also cancel out the promised effects of massive hydro-engineering projects such as the Three Gorges Dam.

There will be significant environmental pressures arguing for an inland shift of economic activity. China might be better able than other societies to accomplish this kind of transition, but the western reaches of China are water and resource poor. China will also find itself in direct confrontation with Japan and even the United States over access to fish, at a time when all major fisheries will likely have crashed as the result of today's unsustainable fishing practices, combined with the ongoing, worldwide decimation of wetlands.

All this can place tremendous additional pressure on the national concept and on the Chinese political system. That system is already under stress; witness tens of thousands of clashes each year between the populace and local authorities. Political reform and liberalization of government control may be the necessary response to this kind of discontent, but severe climate change is much more likely to push China's central government, as well as the provincial governments, in the opposite direction.

Indian Subcontinent

On the Indian subcontinent the impact of global warming will be very destabilizing. As glaciers melt the regions bounding the Indus and Ganges Rivers will experience severe flooding. Once the ice-packs are gone the floods will be replaced by profound and protracted drought. The inland backflow of salt water, caused by higher sea levels, will contaminate low-lying, fertile delta regions. Bangladesh, already famously vulnerable to storm surges, will become more so as sea levels rise.

Given the subcontinent's size and the variety of its regions, it is not possible to confidently interpolate from the IPCC's very broad findings down to the specifics needed for detailed political and security analysis. It is reasonable to say, however, that new and intense environmental pressures will be bad for the internal stability of each country on the subcontinent, and bad for their relations with each other. At severe levels of climate change, the survival of Indian democracy will be at risk.

The Indus River system is the largest contiguous irrigation system on Earth with a total area of 20 million hectares and an annual irrigation capacity of more than 12 million hectares. The headwater of the basin is in India; thus India is the most powerful player.[258] Currently, Pakistan, Bangladesh, and Nepal are engaged in water disputes with India. The Indus Water Treaty of 1960 settled some overarching issues, but frequent disagreements persist. (Pakistan now considers India in breach of the treaty for having caused "man-made river obstructions.")[259] Climate change will exacerbate these tensions. Because of India's clear upper hand, Pakistan may resort to desperate measures in seeking water security.

North Africa and the Middle East

The northern tier of African countries will face collapse as water problems become unmanageable, particularly in combination with continued population growth. Morocco may be destabilized as a

result of drought-induced failure of that country's hydroelectric power system and its irrigation-based agriculture. Those countries that can afford it may follow Libya's lead and attempt to tap major aquifers in a zero-sum struggle for survival. Muammar al-Qaddafi's $20 billion mass-irrigation project would drain much of Great Nubian Sandstone Aquifer (nearly the size of Germany) in 50 years. Newly oil-rich Sudan is seeking to irrigate some of the Sahel; Ethiopia has claimed that any Sudanese effort to divert water from the Nile would provoke military response. Egypt will clash with Sudan and/or Ethiopia over any effort by either to manipulate the flow of waters tributary to the Nile.

Efforts to design a solution to the Israeli-Palestinian struggle will be abandoned for the indefinite future because of a collective conclusion that the problem of sharing water supplies must be regarded as permanently intractable. War between Israel and Jordan over access to water is conceivable. Moreover, Iraq, Syria, and Turkey are likely to be enmeshed in an escalating struggle over the latter's command of waters feeding the Tigris/Euphrates systems. In the Gulf countries there will be a rapid expansion of nuclear power for desalinization. This will, in turn, become a contributing factor in the regional proliferation of nuclear weapons as insurance against predation.

Rising sea levels will cause extensive damage to delta regions (normally among the most fertile and heavily settled) as sea water presses further upstream. This is already a problem in the Nile Delta, where the accelerated loss of fertile land will compound the impact of Egypt's oncoming demographic "youth bulge."

Sub-Sahara and the Horn of Africa

In sub-Saharan Africa, hundreds of millions of already vulnerable persons will be exposed to intensified threat of death by disease, malnutrition, and strife. Natural causes such as long-term drought will play a major role, but political factors will either make these disasters much worse, or even precipitate them as the result of a mix of mismanagement and miscalculated policy. Such was the case in Ethiopia during the rule of Col. Mengistu Haile Mariam. The ongoing genocide in Darfur may have begun as a consequence of water scarcity, as noted elsewhere in this report.

Under conditions of severe global climate change environmental factors will push already failed states deeper into the abyss, while driving other states toward the brink. The stronger regional states, such as South Africa, will be affected not only by internal social and economic stress related to changing climatic patterns, but also by southward flows of refugees hoping for rescue and safety.

Contemporary Africa aspires to be a unified system but falls far short. Severe climate change would, in a grim way, provide for the first time the missing element of connectivity. From one end of the African continent to the other, severe climate change will become the common denominator of turbulence and destruction.

Systemic Events

As noted above, this chapter's analytic premise is that massive nonlinear events in the global environment will give rise to massive nonlinear societal events. The specific profile of these events will vary, but very high intensity will be the norm.

- We could see class warfare as the wealthiest members of every society pull away from the rest of the population, undermining the morale and viability of democratic governance, worldwide.
- It is possible that global fish stocks will crash. Signs are that this process is already well established and accelerating. Aquaculture will expand dramatically to mitigate fish protein shortages, but the destruction of natural marine food chains will have an incalculable impact on the viability of the oceans themselves.

- Climate change may have serious impacts on disease vectors. Under conditions of extreme climate change the risk of pandemic explosions of disease increase.

- As drinkable water becomes scarcer it will become an increasingly commercialized resource. Governments, lacking the necessary resources, will privatize supply. Experience with privatized water supply in poor societies suggests the likelihood of violent protest and political upheaval.

- Human fertility may collapse in economically advanced regions, as the consequence of increasingly difficult living conditions and of general loss of hope for the longer term.

- Globalization may end and rapid economic decline may begin, owing to the collapse of financial and production systems that depend on integrated worldwide systems.

- Corporations may become increasingly powerful relative to governments as the rich look to private services. This may engender a new form of globalization in which transnational business becomes more powerful than states.

- Alliance systems and multilateral institutions may collapse — among them the UN, as the Security Council fractures beyond compromise or repair.

Moral Consequences

Massive social upheaval will be accompanied by intense religious and ideological turmoil, as people search for relief and hope. For this purpose, it is fair to consider that certain kinds of political doctrine may be thought of as religious. Fascism and communism certainly filled that role for true believers during the 20th century. Among traditional religious beliefs, the "losers" are likely to be those faiths that have formed the closest associations with the secular world and with scientific rationalism. Among political systems, authoritarian ideologies would certainly be the "winners." One way or the other, severe climate change will weaken the capacity of liberal democratic systems to maintain public confidence.

This intensified search for spiritual meaning will be all the more poignant under conditions of severe climate change. Governments with resources will be forced to engage in long, nightmarish episodes of triage: deciding what and who can be salvaged from engulfment by a disordered environment. The choices will need to be made primarily among the poorest, not just abroad but at home. We have already previewed the images, in the course of the organizational and spiritual unraveling that was Hurricane Katrina. At progressively more extreme levels, the decisions will be increasingly harsh: morally agonizing to those who must make and execute them — but in the end, morally deadening. For comparison one might look to estimates of the effects of a new global pandemic carried by avian flu.

Die-off

War and disease can be the means to achieve a grim kind of environmentally sustainable relationship between humankind and nature. Hundreds of millions of people already survive on a hand-to-mouth basis, living essentially on the leavings and limited charity of those who are better off. As climate change deepens, even the "donor" portion of society will feel the effects, and those below will be much worse off than before.

Severe climate change will put additional stress on all systems of social support. Already tenuous health care systems may collapse. Vulnerability to new forms of disease will increase. In some regions the process may resemble the abrupt die-offs that are thought to have occurred on a smaller scale among ancient peoples. Instead of focusing on ways to save modern civilization, social efforts may increasingly focus on sheer survival. Preemptive desertion of urban civilization will

occur. Attention to the long-term requirements of society will attrite, in view of a public conviction that nothing can be done to alter the downward course of events.

Survival and Reconstruction

The consequences of even relatively low-end global climate change include the loosening and disruption of societal networks. At higher ranges of the spectrum, chaos awaits. The question is whether a threat of this magnitude will dishearten humankind, or cause it to rally in a tremendous, generational struggle for survival and reconstruction.

If that rally does not occur relatively early on, then chances increase that the world will be committed irrevocably to severe and permanent global climate change at profoundly disruptive levels. An effective response to the challenge of global warming cannot be spread out across the next century, but rather must be set in place in the next decade, in order to have any chance to meaningfully alter the slope of the curves one sees in the IPCC report. We are already in the midst of choosing among alternative futures. The onset of these choices is rapid, and the consequences are likely to be irreversible. Moreover, the upper end of the "severe, 30-year scenario" can just as well be a prelude to even worse circumstances, if the political will to deal with global warming collapses early on under the weight of universal pessimism.

In order to emerge from a period of severe climate change as a civilization with hopes for a better future and with prospects for further human development, the very model of what constitutes happiness must change. Globalization will have to be redirected. It cannot continue forever in its present form, based on an insatiable consumption of resources. The combined demands of China and India alone cannot be satisfied in a world already heavily burdened by the consumption patterns of the United States, Europe, and Japan.

Levels of demand will have to be brought into line with the availability of resources. This can occur either as the result of the collapse of the present system, or by its purposeful reconfiguration. The promise that it is possible to achieve high levels of consumption for all people everywhere would be unable to be fulfilled. The ideal of international development would be seen to have failed, with profound political consequences. Neither China nor India can voluntarily accept that their hopes for full-fledged consumer societies cannot be realized.

Conclusion

As discussed above, the reduction of humankind's burden on the environment can occur as the result of deteriorating physical conditions and attendant pandemics. It can also occur as the result of war and its aftermath. Under the circumstances described above, it is clear that even nuclear war cannot be excluded as a political consequence of global warming. Moreover, so-called "limited nuclear war" in any part of the world can escalate to a full-scale nuclear exchange among the big nuclear powers. Even if one assumes that there will be very large reductions of nuclear weapons in the inventories of the United States and the Russian Federation, it should be kept in mind that the weapons on board a *single* submarine armed with ballistic missiles are fully capable of destroying a nation of continental size.

The alternative to reducing populations by decimation is to reduce them by demographic management. Every nation has a demographic curve, showing the rate at which the size and composition of its population will change over time, given certain assumptions. Today, advanced states use macroeconomic techniques to manage their economies: tomorrow, such states may be looking for macro-techniques to manage reproductive choice against basic targets. This is a radical departure, given the way people everywhere feel about

reproductive freedom. But if the alternative is truly ruinous, what is presently unthinkable may wind up on the table. China will be an early bellwether.

Climate change represents a permanent shift in the relationship of humankind to nature. Since we already have attained the power to alter natural cycles we are now accountable for regulating our impact upon them. To fulfill this stewardship responsibly we must improve the capacity of governance to deal with all kinds of complex phenomena: through earlier recognition and response to important challenges; deeper awareness of interactions across substantive and bureaucratic boundaries; and the ability to organize and execute policy for operation over extended periods of time. Finding and applying the necessary political and governmental innovations is daunting, but it is a task within our capabilities, as has been repeatedly demonstrated in the course of our history.

LOCATION: U.S.-Mexico Border — A man peers around a section of border fence.

CATASTROPHIC

CLIMATE CHANGE
OVER NEXT **100 YEARS**

AT A GLANCE:

Time Span: 100 Years

Warming: 5.6°C

Sea Level Rise: 2.0 meters

By R. James Woolsey [260]

Scenario Overview: Catastrophic Climate Change

Earlier chapters have dealt generally with climate change, the role of greenhouse gas emissions therein, and the regional consequences of smaller but substantial changes—up to a temperature rise of 1.3 to 2.6°C and sea level rise of approximately half a meter in a 30-year period. This chapter will not repeat those assessments. The agreed assumptions for this chapter's discussion of catastrophic change are that aggregate global temperature increases by 5.6°C by the end of the century, accompanied by a dramatic rise in global sea levels—2 meters in the same time period.

We might call climate change a "malignant," as distinct from a "malevolent," problem—a problem of the sort Einstein once characterized as sophisticated (raffiniert) but, being derived from nature, not driven by an evil-intentioned (boshaft) adversary. Sophisticated malignant problems can still be awesomely challenging. For example, because complex systems can magnify even minor disturbances in unpredictable ways—the so-called butterfly effect—a tree branch touching some power lines in Ohio during a storm can produce a grid collapse. In 2003 such a tree-branch-power-line connection deprived the northeastern United States and eastern Canada of electricity for some days. Similarly, our purchases today of gas-guzzling SUV's can contribute to sinking portions of Bangladesh and Florida beneath the waves some decades hence.

With respect to climate change three factors should lead a prudent individual to consider such catastrophic change plausible: first, the possibility that some positive feedback loops could radically accelerate climate change well beyond what the climate models currently predict; second, the prospect of accelerated emissions of CO_2 in the near future due to substantial economic and population growth, particularly in developing countries such as China; and third, the interactive effects between these two phenomena and our increasingly integrated and

fragile just-in-time — but certainly not just-in-case — globalized economy.

Exponential Change and Scenario Planning

The possibility of catastrophic exponential change necessitates a different approach to constructing a scenario. This is because few human beings naturally think in terms of the possibility of the exponential changes.

We humans generally have what Kurzweil calls an "intuitive linear" view of phenomena rather than a "historical exponential" view. In *The Singularity Is Near*, he uses the example of a property owner with a pond who frequently cleans out small numbers of lily pads. Then, with the pads covering only 1 percent of the pond, the owner goes away, returning weeks later to find it covered with lily pads and the fish dead.[262] The owner forgot that lily pads reproduce exponentially despite the fact that the human mind tends to think linearly. When change is exponential we often have great difficulty comprehending it, whether it is manifested in lily pad growth or climatological tipping points.

A related difficulty is that the adaptability of human society itself is difficult to predict in the presence of great and continuing catastrophe. The conflicts over land, migrating populations, or resources described elsewhere in this study might well be overshadowed in such a case by broader societal collapse.

Massively Destructive Terrorism

Another growing threat also holds out the possibility of massive damage and loss of life in this century: religiously-rooted terrorism. The scope of death and destruction sought by the perpetrators of this sort of terrorism is also something most people find difficult to envision. This chapter later addresses terrorism (a "malevolent" rather than a "malignant" problem such as climate change) because of a somewhat surprising confluence: the aspects of our energy systems that help create the risk of climate change also create vulnerabilities that terrorists bent on massive destruction are likely to target. We need to be alert to the possibility that although our current circumstances are doubly dangerous, this confluence could give us an opportunity to design a set of changes in our energy systems that will help us deal with both problems.

Positive Feedback Loops and Tipping Points

The climate models agreed upon by the IPCC deal with some, but by no means all, of the warming effects of emissions that can occur as a result of positive feedback loops. This is because climatologists, as scientists, are given to producing testable

"…a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered looks strange; what looks strange is therefore improbable; what seems improbable need not be considered seriously."

—Thomas C. Schelling, Foreword to Roberta Wohlstetter, Pearl Harbor: Warning and Decision (1962)

hypotheses and there are often not enough data to satisfy that requirement for a number of the feedback loop issues. But a number of climatologists have nevertheless assessed the data and offered judgments about the importance of possible feedback effects, even in this century. NASA's James Hansen puts it succinctly: "I'm a modeler, too, but I rate data higher than models."[263]

Positive feedback loops can relatively quickly accelerate climate change to the tipping point at which it becomes impossible to reverse destructive trends, even with future reductions of greenhouse gas emissions from human activities. Several such positive feedback loops are conceivable in this century, such as the risk that fresh water from melting Greenland glaciers would slow the meridional overturning circulation in the Atlantic, changing ocean currents and attenuating the Gulf Stream's ability to warm Europe.

Polar Regions

Tipping points at which there might be irreversible thawing of Arctic permafrost or the melting and breakup of the Western Antarctic and Greenland Ice Sheets have such stunning implications they deserve particular attention.

Somewhere around a million square miles of northern tundra are underlain by frozen permafrost containing about 950 billion tons of carbon — more than currently resides in the atmosphere.[264] If the permafrost were to thaw, much of this carbon would quickly convert to methane. Current methane emissions are probably still below 50 million tons annually, but over 100 years a ton of methane affects climate 23 times more powerfully than a ton of CO_2, so this current emission rate is the warming equivalent of about 1 billion tons of carbon dioxide. Today carbon dioxide emissions from fossil fuels are about 30 billion tons per year, or just over 4.5 tons per person on average. If the permafrost thaws enough due to the initial linear warming trend we are experiencing today, significantly more methane will be added to the atmosphere, possibly increasing its impact to rival that of CO_2. Consequent accelerated warming and faster thaw leading to more methane emissions could produce a tipping point beyond which humans no longer control the addition of excess greenhouse gases to the atmosphere, and no options remain under our control for cooling the climate. We don't know the exact point at which this vicious circle would begin, but there are some indications that a substantial permafrost thaw is already underway.[265] Because of methane's potency its release could provide a substantial short-term kick to climate change. Such release over a few decades could raise worldwide temperatures by 5 to 6°C or more,[266] to the approximate level of temperature increase posited for this scenario.

Another potential feedback loop lurks in the prospect of melting — and sliding — ice sheets in Greenland and West Antarctica. Around 125,000 years ago, at the warmest point between the last two ice ages, global sea level was four to six meters higher than it is today and global temperature was only about 1°C higher.[267] Being warmer than Antarctica, Greenland probably provided the initial slug of melt water to the ocean. However, much of the ice on West Antarctica rests on bedrock far below sea level,[268] making it less stable as sea level rises. When the ice sheet is lubricated by melting where it is grounded, it begins to float and can cause coastal ice shelves to shatter and increase the rate of ice stream flow into the ocean.[269] As a result, the West Antarctic Ice Sheet contributed perhaps 2 meters of the additional sea level 125,000 years ago. With just one more degree of warming, therefore, we may be locked into four to six meters of sea level rise.[270] James Hansen points out that it is not irrational to worry about reaching this tipping point in this century. Our catastrophic scenario includes 5 to 6°C of warming, which is similar to 3 million years ago, before the ice ages. Sea level then was about 25 meters higher than today.[271] Although

the time required for that much sea level rise to occur remains in question, our scenario with 2 meters of sea level rise by the end of this century appears quite plausible.[272]

Economic Development

Robert Zubrin suggests a simple thought experiment to illustrate the power of economic growth to affect climate change—a process that could create a climatic tipping point sooner rather than later. The world today has achieved an average GDP per capita comparable to U.S. GDP per capita at the beginning of the 20th century (about $5,000 in today's dollars).[273] In the 20th century, world population quadrupled and world economic growth averaged 3.6 percent annually.[274] Even if we assume slower population growth, say a doubling of world population in the 21st century, and also a lower growth rate of 2.4 percent—the latter producing a fivefold increase in GDP per capita—unless fuel use per unit of GDP changes substantially, we would see a 10-fold increase in carbon dioxide emissions by century's end. This prospect leads even a climate change skeptic such as Zubrin to imagine an extraordinary scenario in which presumably all known and some unknown feedback loops become activated and thus it "only tak[es] a few decades to reach Eocene carbon dioxide atmospheric concentrations of 2000 ppm"[275] and certain catastrophe.

To take only one example of the impact of vigorous economic development on CO_2 emissions, China is building approximately one large coal-fired power plant per week for the foreseeable future. Rapidly growing developing countries are expected to account for an overwhelming 85 percent of energy demand growth between today and 2020. China alone represents a third of total growth.[276]

Sea Level Rise and Challenges to Existing Infrastructure

The 2007 IPCC Working Group I Contribution to the Fourth Assessment Report points out that the prospect of climate change and sea level rise coming to a tipping point is particularly troubling because once such a point has been passed, sea level rise will probably continue for centuries.

For this reason, James Hansen considers sea level rise as "*the* big global issue" that will transcend all others in the coming century.[277] Even if the East Antarctic Ice Sheet is not destabilized, the steady melting of the Greenland Ice Sheet together with the perhaps sudden melting of the West Antarctic Ice Sheet hold the prospect for some 12 meters of sea level rise.[278] The melting of the East Antarctic shelf would add approximately 25 meters, marking in Antarctic research scholar Peter Barrett's words "the end of civilization as we know it."[279] Even without a melting of the East Antarctic shelf, civilization would be experiencing an inexorable encroachment of seawater over decades and centuries.

Moreover, humanity would have to face the coastal inundation and related destruction while dealing with substantial disruption of agriculture and food supplies, and resulting economic deprivation, due to changing availability of water—some places more arid, some wetter—and a much smaller percentage of available water would be fresh.

Coastal Regions

In this scenario, among the regions in the developed world facing the likely prospect of inundation by the end of the century would be: major portions of cities and wide regions of the U.S. coast from South Texas to West Florida and from East Florida to New York; extensive areas bordering the Chesapeake Bay and most of South Florida and eastern North Carolina; the lower Hudson Valley; huge shares of the coasts of San Francisco Bay; much of Sydney and all of Darwin, Australia; a large share of Japanese ports; Venice and a major share of coastal Tuscany; the majority of the Netherlands; much of Dublin; a major share of Copenhagen; and the Thames and the eastern

and southern coasts of England.[280] Storm surge would affect people much farther inland and on more elevated coastlines.

Even without considering storm surge, sea level rise in the range of 2 meters in this century could have a potentially catastrophic effect on a number of developing countries. According to a February 2007 World Bank Policy Research Working Paper, these include particularly Egypt, Vietnam, and the Bahamas and a number of other island nations. It could also have "very large" effects on a number of other states, including China and India. Considering all factors—land area, urban area, population, etc.—the most affected countries, in addition to the above, would be Guyana, Surinam, and Mauritania. Substantial impacts would also occur in Gambia, Liberia, Senegal, Guinea, Thailand, Burma, Indonesia, Taiwan, Bangladesh, and Sri Lanka.

The above rise in sea levels—together with changed climate, agricultural disruptions and famines, spread of disease, water scarcity, and severe storm damage—will not occur in a world that is otherwise sustainable and resilient. In the Philippines, for example, sea level rise would add to a problem already created by excessive ground water extraction, which is lowering the land from between several centimeters to more than a tenth of a meter annually.[281] The Mississippi Delta has a similar problem. Some of the land south of New Orleans will likely lose about 1 meter of elevation by the end of this century as a result of subsidence.[282] Thus 2 meters of sea level rise by the end of the century may well be additive to the substantial lowering of land levels in some areas by such extraction. And the concentration of population in low-lying areas of course exacerbates the effect of these changes.

Melt water runoff from mountain glaciers also supplies agricultural and drinking water as well as electricity from hydropower. More than 100 million people in South America and 1 billion to 2 billion in Asia rely on glacial runoff for all or part of their fresh water supply. As these glaciers shrink they will add substantially to the need to emigrate in search of water and arable land. The relevant glaciers are retreating rapidly and some are already virtually gone. This problem is likely to come to peak within mere decades.[283]

Potential National Security Consequences of Climate Change

In a world that sees 2 meter sea level rise, with continued flooding ahead, it will take extraordinary effort for the United States, or indeed any country, to look beyond its own salvation. All of the ways in which human beings have dealt with natural disasters in the past, which J.R. McNeill describes earlier in this study, could come together in one conflagration: rage at government's inability to deal with the abrupt and unpredictable crises; religious fervor, perhaps even a dramatic rise in millennial end-of-days cults; hostility and violence toward migrants and minority groups, at a time of demographic change and increased global migration; and intra- and interstate conflict over resources, particularly food and fresh water.

Altruism and generosity would likely be blunted. In a world with millions of people migrating out of coastal areas and ports across the globe, it will be extremely difficult, perhaps impossible, for the United States to replicate the kind of professional and generous assistance provided to Indonesia following the 2004 tsunami. Even overseas deployments in response to clear military needs may prove very difficult. Nuclear-powered aircraft carriers and submarines might be able to deploy, but aviation fuel or fuel for destroyers and other non-nuclear ships could be unobtainable.

Overseas air bases would doubtless be tangled in climatic chaos, and aircraft fuel availability overseas highly uncertain. Further, the Navy is likely to be principally involved in finding ways to base,

operate, overhaul, and construct ships, as many ports and harbors south of New York on the East Coast and overseas disappear or become usable only with massive expenditures for protection from the rise in sea levels. Civilians will likely flee coastal regions around the world, including in the United States. The U.S. military's worldwide reach could be reduced substantially by logistics and the demand of missions near our shores.

Population Changes and Migrations

If Americans have difficulty reaching a reasonable compromise on immigration legislation today, consider what such a debate would be like if we were struggling to resettle millions of our own citizens — driven by high water from the Gulf of Mexico, South Florida, and much of the East Coast reaching nearly to New England — even as we witnessed the northward migration of large populations from Latin America and the Caribbean. Such migration will likely be one of the Western Hemisphere's early social consequences of climate change and sea level rise of these orders of magnitude. Issues deriving from inundation of a large amount of our own territory, together with migration toward our borders by millions of our hungry and thirsty southern neighbors, are likely to dominate U.S. security and humanitarian concerns. Globally as well, populations will migrate from increasingly hot and dry climates to more temperate ones.

On the other hand, based on current demographic trends, there will be fewer than 100 million Russians by 2050, nearly a third of whom will be Muslim. Even a Europe made colder by the degrading of the Gulf Stream may experience substantially increased levels of immigration from south of the Mediterranean, both from sub-Saharan Africa and from the Arab world. Many of Europe's Muslim minorities, including Russia's, are not well-assimilated today, and the stress of major climate change and sea level rise may well foster social disruption and radicalization. Russia and Europe may be destabilized, shifting the global balance of power.

Northern Eurasian stability could also be substantially affected by China's need to resettle many tens, even hundreds, of millions from its flooding southern coasts. China has never recognized many of the Czarist appropriations of Chinese territory, and Siberia may be more agriculturally productive after a 5 to 6°C rise in temperatures, adding another attractive feature to a region rich in oil, gas, and minerals. A small Russian population might have substantial difficulty preventing China from asserting control over much of Siberia and the Russian Far East. The probability of conflict between two destabilized nuclear powers would seem high.

Energy Infrastructure

Interactions between climate change and the existing infrastructure could create major failures in the systems that support modern civilization. All other systems — from operating telecommunications to distributing food, pumping water, and more — depend on energy. Yet energy systems themselves are vulnerable. Hydroelectric electricity generation may be substantially affected by reduced glacial runoff or by upstream nations diverting rivers in some parts of the world. Nuclear power plant cooling may be limited by reduced water availability. Increased numbers and intensity of storms could interfere with long-distance electricity transmission, already heavily stressed in the United States and elsewhere.

Sea level rise and chaotic weather patterns may interfere with oil production in a number of locations, particularly from sea-based platforms and in parts of the Middle East, and with the operation of large oil tankers. Many U.S. oil refineries are in the Gulf Coast region and thus more vulnerable to disruption by storms than if they were located

elsewhere. Hurricane Katrina came very close to shutting down the Colonial Pipeline, the major link from the Gulf Coast to the eastern seaboard.

In short, the pressures on U.S. society and the world would be significant, and the international community's ability to relieve those pressures seriously compromised. The abrupt, unpredictable, and relentless nature of the challenges will likely produce a pervasive sense of hopelessness.

A Malevolent Threat: Mass Terrorism

Our society, our way of life, and our liberty face serious current challenges beyond the infrastructure fragility exacerbated by climate change. The most salient is attack by terrorist groups or an enemy state, or a combination thereof, aimed at massive damage and massive casualties. These are not unintentional "malignant" results of our habitual behavior but are rather "malevolent" and planned carefully by those who want to do far more than many terrorist groups in the past: namely, to destroy our entire civilization and way of life.

Oil presents a panoply of opportunities for and encouragement of mass terrorism. Our transportation is fueled over 96 percent by petroleum products. Consequently oil has a transportation monopoly in much the same way that, until around the end of the nineteenth century, salt had a monopoly on the preservation of meat. Oil's monopoly creates a litany of vulnerabilities for our society.

Since around two-thirds of the world's proven reserves of conventionally produced oil are in the Persian Gulf region, together with much of oil's international infrastructure, the world's supplies are vulnerable to terrorist attacks such as two already attempted by al Qaeda in Saudi Arabia and emphasized in al Qaeda's doctrine. Some oil states' governments (Iran) are quite hostile today; others (Saudi Arabia) could become so with a change of ruler. A nuclear arms race appears to be beginning between Iran and six Sunni states which have announced nuclear programs "for electricity generation." The United States borrows approximately a billion dollars a day at today's prices to import oil, substantially weakening the dollar. The Wahhabi sect of Saudi Arabia profits massively from oil income and covers, according to Lawrence Wright in *The Looming Tower*, "90 percent of the expenses of the entire faith, overriding other traditions of Islam."[284] Wahhabi teachings are murderous with respect to Shia, Jews, homosexuals, and apostates, and are mirrored by the views of al Qaeda and similar groups except with respect to their allegiance to the Saudi state. And finally, as Bernard Lewis puts it: "there should be no taxation without representation but it should also be noted that there is no representation without taxation." Extremely wealthy oil-exporting states are thus

> *"Year after year the worriers and fretters would come to me with awful predictions of the outbreak of war. I denied it each time. I was only wrong twice."*[261]
>
> —Senior British intelligence official, retiring in 1950 after 47 years of service

often dictatorships and autocratic kingdoms without institutions that check and balance the ruler.

The other major energy sector of our economy, electricity generation and distribution, is also highly vulnerable to attack by terrorists and rogue states.

Over five years ago the National Research Council published its report on the use of science and technology to combat terrorism. It stated that:

> The most insidious and economically harmful attack would be one that exploits the vulnerabilities of an integrated electric power grid. 'A chain is only as strong as its weakest link' applies here. Simultaneous attacks on a few critical components of the grid could result in a widespread and extended blackout. Conceivably, they could also cause the grid to collapse, with cascading failures in equipment far from the attacks, leading to an even larger long-term blackout.[285]

Five years later very little has been done to implement the Council's seventeen detailed recommendations to deal with this, particularly with regard to improving the security of, or even stockpiling spares for, the large transformers at grid sub-stations or effectively protecting the grid's Supervisory Control and Data Acquisition (SCADA) control systems from destructive hacking.

Additionally, the electricity grid has a major vulnerability to electro-magnetic pulse.

In 1962 both Soviet and American atmospheric nuclear tests detected a troubling phenomenon: three types of electromagnetic pulses generated at high altitude by nuclear detonations could seriously damage or destroy electronic and electrical systems at as much as 1,000 miles from the blast. The 2004 Report of the U.S. Electromagnetic Pulse Commission pointed out that the detonation of a single nuclear warhead between 40 and 400 kilometers above the Earth could cause "unprecedented cascading failures of our major infrastructures," primarily "through our electric power infrastructure" crippling "telecommunications…the financial system…means of getting food, water, and medical care to the citizenry… trade…and production of goods and services." The Commission noted that states such as North Korea and Iran, possibly working through terrorist groups, might not be deterred from attack (say using a relatively small ship carrying a simple SCUD missile) in the same way as were our adversaries in the Cold War.[286]

The Commission concluded that detonation of a single nuclear warhead at these altitudes could "encompass and degrade at least 70 percent of the Nation's electrical service, all in one instant." It also notes that, as a result of fire safety and environmental concerns, locally stored fuel for emergency power supplies such as diesel for generators is often limited to about 72 hours' supply.[287] Food available in supermarkets generally supplies about one to three days of requirements for customers and regional food warehouses usually stock enough for a multi-county area to last about one month.[288]

Toward a Partnership to Deal With Both Malignant and Malevolent Threats

The malignant and malevolent threats set out above each have strong advocates for their importance. If we use the shorthand of characterizing those who are heavily focused on malignant threats, especially climate change, as "tree huggers" and those who are heavily concentrated on malevolent ones, especially mass terrorism, as "hawks" we often find them talking past one another, trying to convince others that their problem is far and away the more serious.

But what if tree huggers and hawks took a break from their insistent and vigorous disagreements about whose threat was more important and concentrated instead on what to do about energy, according to each of their lights. They might find some interesting common possibilities.

Energy Efficiency

Recent studies by both the Rocky Mountain Institute and McKinsey & Company stress the extreme importance in the campaign to reduce CO_2 emissions of reducing energy use (especially electricity) in buildings. The McKinsey report finds that merely by using existing technologies (where there is an internal rate of return of 10 percent or more), we can reduce world energy demand by 125 to 145 Quadrillion British thermal units (QBtu) by 2020, or 20 to 24 percent of end-use demand. The vast majority of this reduction, the report says, would be in buildings of all sorts, including industrial facilities, and would contribute up to half the greenhouse gas emission abatement needed to cap the long-term concentration of greenhouse gases in the atmosphere at 450 to 550 ppm.[289] This is not just a theory: Wal-Mart, for example, is finding that with such simple steps as painting its store roofs white and adding skylights, the company is getting 20 percent improvement in energy efficiency today and expects 25 to 30 percent improvements by 2009. It should be stressed that these investments in efficiency produce economic returns, and they don't add cost over a ten-year period. The Rocky Mountain Institute characterizes the savings as "negawatts."

Regulatory reform can also help promote efficiency and conservation. California, for example, decoupled electric utility revenues from earnings some twenty years ago; there, and (very recently) in Idaho, utilities' earnings are based on their investment, including investment in energy efficiency, not on their sales of electricity. In part because of this step California's per capita use of electricity has been level for twenty years while the rest of the country's use has gone up 60 per cent. In the other 48 states, utilities must sell more electricity in order to earn more for their shareholders, deterring waste not at all.

Decreasing electricity demand in these ways is good for resilience, lessening the congestion on the grid and reducing the need for new generating capacity. Some of the savings could be used, for example, to protect and stockpile transformers and to protect control systems from cyber attack.

It's difficult to see any reason why both tree huggers and hawks would not support such steps: carbon emissions would be reduced, the grid would become more resilient, and money would be made or redirected from production of electricity to conservation rather than spent.

Distributed Generation of Electricity

Heat that is produced by industrial processes and generally wasted can be used to generate electricity at many sites, and for local heating and air conditioning. Twenty years ago Denmark decided to go this route and now half of that country's electricity is produced by such combined heat and power (CHP, or co-generation). But only about eight percent of U.S. electricity comes from CHP. Like improving building efficiency, the problem is not that we don't have the technology. Our practice of wasting heat instead of using it to produce electricity is determined by culture and regulations. If we will learn from Denmark we can accomplish two things: relatively quickly we could begin to get dual use from the heat that industry generates instead of just venting it into the atmosphere, and we could make substantial progress toward decentralizing electricity production, reducing the need for new power plants and transmission lines. This would make "islanding" easier, or enabling parts of the grid to be locally self-sufficient if need be and thus reducing the likelihood that terrorists could take out large sections, much less all of it.

We can also create strong, long-term incentives for small-scale electricity generation and heating/cooling. Forty out of fifty states now have "net metering" laws that in principle make it possible for those who have generating capacity — say

rooftop solar photovoltaic systems—to sell some home-generated electric power back to the grid. But in practical terms, state laws and regulations leave a lot to be desired in making this work.

The cost of home-generated power is about to decline substantially as thin-film and nano-solar begin to come into the market at costs significantly below today's silicon cells. The National Renewable Energy Laboratory (NREL), working with the Defense Advanced Research Projects Agency (DARPA) and several corporations, has recently announced the successful testing of thin-film solar with stunning (over 40 per cent) efficiencies. As such solar collectors are integrated into building materials such as shingles, these technologies can begin to have a substantial effect on the need for central power generation. Small-scale wind turbines, operating at much lower wind speeds than the large turbines, and hence far more widely deployable, are beginning to enter the single-building market as well. Distributed solar and wind technologies complement one another since generally the sun shines at a different time of day than the wind blows, and increased use of both can be facilitated by storing electricity in improving batteries. Shallow (heat pump) geothermal can work effectively in many areas to heat and cool individual buildings; together with distributed solar and wind it may be able to satisfy a very substantial share of individual building energy needs. Distributed generation will be renewable and hence not carbon-emitting: a coal-fired power plant will not fit on a roof. And the power losses (often well above 50 percent) inherent in central station power-plant electricity generation and transmission are avoided by distributed generation.

Finally, the highly decentralized nature of small-scale distributed generation is a significant plus for security against a range of attacks, from small explosive attacks on transformers to electromagnetic pulse detonations. It would be relatively easy to harden new components for individual building electrical systems against EMP compared with hardening the entire grid—a transmission line that runs only from your roof to your house's electrical sockets is a comparatively simple system to protect.

Transforming Transportation

If we can shift the focus of transportation reform from single (expensive) solutions such as hydrogen fuel cells to a portfolio approach we can make important progress quickly in moving away from oil dependence. Our objective should be to destroy not oil, but oil's dominance of transportation the way electricity and refrigeration a century ago destroyed salt's dominance of meat preservation.

One major part of the portfolio would be to provide incentives for as rapid as possible a transition to plug-in hybrid-electric vehicles (PHEVs) that are also flexible fuel vehicles (FFVs). The average U.S. light vehicle is driven around 30 miles daily. In addition to providing consumers the ability to drive for some tens of miles a day on inexpensive off-peak overnight electricity—at a fifth to a tenth of the cost of driving on gasoline—moving from a gasoline-fueled vehicle to a PHEV reduces greenhouse gas emissions substantially. In states without coal-fired generation (such as on the West Coast), the greenhouse gas reduction has been estimated at over 80 percent, although the reduction is less than that (30 percent or so) in parts of the grid that use an average share (51 percent) of coal, and small to negligible in states that have almost entirely coal-fired grids. Still, as the CO_2 emissions of electricity production are reduced over the years, cleaning up the grid also cleans up PHEV emissions. And by keeping PHEVs plugged into the grid after they are charged they may be used, as the grid is modernized, in Vehicle-to-Grid (V2G) connections to substitute for around $12 billion annually in fossil fuel costs for "ancillary services," such as stabilizing and regulating the grid's operations and providing "spinning" reserves to deal with power outages.[290]

With a flexible fuel capability, when PHEVs have used up their overnight charge and operate as regular hybrids using some liquid fuel the market will sort out which fuels produced from biomass or waste — ethanol, butanol, biodiesel, renewable diesel, etc. — are the most efficient in terms of cost and reduced carbon. A 50 mpg hybrid that is given a more capable battery, turning it into a PHEV will, for average daily driving, be getting over 100 miles per gallon of gasoline; if its liquid fuel is, say, 85 percent ethanol, its gasoline mileage goes up to around 500 mpg of gasoline. Both tree huggers and hawks should be pleased.

Agreements and Disagreements between Tree Huggers and Hawks

Insofar as new or replacement central power plants are needed after the above-described steps toward energy efficiency and distributed generation, the national decisions about what sort of plants to build will be driven by the relative weight given to carbon reduction on the one hand and cost on the other. Hawks would probably be more focused on improving grid security than on the type of fuel used for central plants. Some types of generation at central power plants may score well in both cost and carbon reduction (e.g., large wind turbines) and some will do well in one category but not the other (coal plants without carbon capture and sequestration). From a tree hugger's point of view although some methods of reducing carbon may be expensive, such as proving and implementing the sequestration portion of CCS, or providing publicly-funded insurance for nuclear power plants, any method is likely to be preferable to adding carbon to the atmosphere.

There is only one rather definite tree hugger-hawk disagreement, and that is over coal-to-liquid (CTL) transportation fuels. Tree huggers would resolutely oppose their production because of the resulting extent of carbon release; hawks might be tempted to support them because coal is domestically available and such fuels could help destroy oil's monopoly of transportation. In time, progress toward the electrification of transportation (via PHEVs) and toward lower-cost biomass and waste feedstocks for renewable liquid fuels may make this one dispute obsolete.

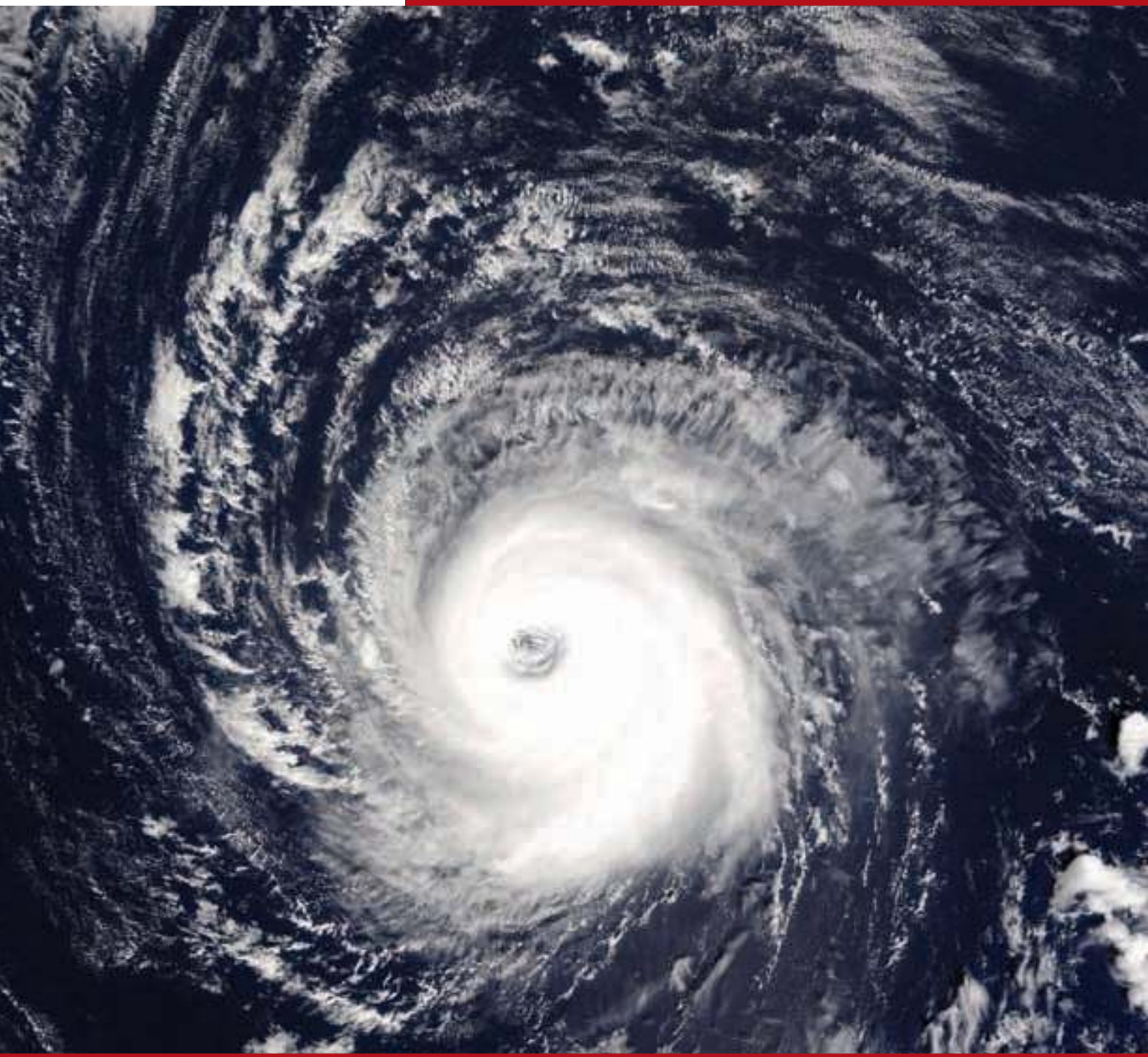
Conclusion: Getting Down to Work

The 9/11 terrorist attacks marked the end of the reasonably sunny post-Cold War world assumed by most Americans. Although there were warning signs that major terrorist networks of global reach were going to be a driving threat in the 21st century, few correctly interpreted the signals. Now this threat is concrete and real, and many, perhaps most, Americans (at least in their more reflective moments) understand that we will be in an extremely difficult, long-term struggle against terrorist groups seeking to cause massive damage — indeed to end our way of life — for decades.

Warning signs of the need to deal with the very different kind of threat posed by climate change are now also troubling, and more Americans are beginning to grasp them. But as with the case of pre-9/11 assessments about mass-damage terrorism, it comes down to a matter of judgment. The difference is that if we wait for absolute certainty of the threat — for a climatological 9/11 — we may then be past a tipping point from which there is no recovery.

While we continue our debates and disagreements, wouldn't it be wise to take steps — particularly when many of them are financially attractive — that reduce *both* the risk of mass terrorism *and* the chance of catastrophic climate change? Are we incapable of agreeing to work together even when we are lucky enough to find that different groups of us with different concerns have different reasons to take the same sensible steps?

The survival of our way of life may depend upon whether in our divided society we can, from one another, take yes for an answer.



LOCATION: The Atlantic Ocean — An aerial view of Hurricane Kate.

THE RACE TO REPLACE KYOTO BY 2012

By Julianne Smith, Alexander T. J. Lennon, and Derek Mix

In the global approach to climate change, 2007 has been a landmark year. It began in January with President Bush's State of the Union address, for the first time acknowledging "the serious challenge of global climate change," and will conclude in December in Bali, Indonesia, where global negotiators will seek to finalize an agenda for a framework to replace the Kyoto Accord, due to expire in 2012. While this is the ambitious officially declared agenda, Yvo de Boer, the executive secretary of the UN Framework on Global Climate Change (UNFGCC), revealingly stated in an October 2007 interview that "I think the challenge in the next two years will be to design a climate policy that is good for the United Sates, good for China, and good for the EU."[291]

According to the World Resource Institute's Climate Analysis Indicator Tool (CAIT)[292] these three global powerhouses alone are responsible for roughly half of global greenhouse gas emissions (GHG), emitting 20.4, 14.1, and 14.7 percent of global GHG emissions, respectively, in the most recent year for which all GHG emissions figures are available (2000). No other country is responsible for more than 5.7 percent. If these three players can agree, then the core of a global framework exists. The question is: can they? This chapter examines the ways in which Europe, the United States, and China see the challenge of global climate change.

Europe's Leadership

The new Energy Policy for Europe (EPE) presented by the European Commission in January 2007 and approved by the spring 2007 European Council makes it clear that addressing climate change is a top EU priority. The EPE commits the EU to independently reducing its greenhouse gas emissions by 20 percent by 2020 (compared to 1990), with a pledge for 30 percent reduction should other developed countries follow suit.[293] The action plan for the EPE calls for the EU, already the global pacesetter in renewable energy (with, for example, nearly two-thirds of the world's wind energy

market), to triple its use of renewable energy sources by 2020 to provide for 20 percent of overall consumption. The plan additionally sets out, albeit in general terms, new regulatory measures to improve energy efficiency. This includes leveraging the internal European energy market while pointing out the importance of the use and development of energy-saving and low-carbon technologies.[294]

Although the European continent deserves kudos for its ability to match its rhetoric on climate change to tangible action, there are differences within Europe on how countries have chosen to address the challenge. The size and composition of national industrial and transportation sectors, for example, make for differences in greenhouse gas emission levels in the type and level of adjustments a national economy can tolerate in the name of protecting the environment. Similarly, individual countries have their own unique mixture of energy dependencies, both in terms of their core sources and from where they come. Thus, although an EU-wide consensus on the issue of climate change and the need to address it does indeed exist, there are also 27 underlying national perspectives—not to mention those of non-EU members such as Norway on the importance of and best solution to the problem.

Germany is an important leader of the European charge on climate change policy and shoulders a substantial part of the burden. As Europe's largest economy, Germany's planned 21 percent reduction of carbon dioxide emissions by 2012 under Kyoto accounts for nearly three-quarters of the overall 8 percent EU reduction. With the ambitious commitments of the EPE, Europe is faced with the challenge of achieving a further 12 percent reduction between 2012 and 2020, and with its weighted portion factored in, Germany is looking at a total 40 percent reduction in CO2 generation over a 15-year period.

Achieving such an ambitious goal requires a holistic approach, linking a gradual overhaul of the way German industry operates and a society-wide commitment to changes in everyday lifestyle, including a strong emphasis on energy efficiency from the industrial level all the way down to household electrical appliances and possibly such controversial measures as a blanket 130 kilometer-per-hour speed limit on the autobahn.[295] Supplementing its own national vision, Germany has put considerable effort into garnering more international support for climate change initiatives at a regional and global level; Chancellor Angela Merkel opted to push climate change and environmental issues as a key part of the agenda during Germany's 2007 presidencies of both the EU and the Group of Eight (G8).

Under Prime Minister Tony Blair the United Kingdom set about achieving its Kyoto commitment of a 12.5 percent emissions reduction by raising emissions standards for automakers, introducing a graduated auto tax based on fuel efficiency, and aiming to increase national use of biofuels. In March 2007 Blair also set a long-term national goal of a 60 percent CO_2 emissions reduction by 2050, which will be implemented through a series of five-year "carbon budgets."[296] Although it is debatable whether the UK is currently on pace to meet the target for 2050, it is on track to fulfill its Kyoto commitment. Yet the tactics of British climate change policy do split along party lines. The Labour Party stance emphasizes the importance of international agreements and the role of positive incentives to change behavior, such as lower taxes for environmentally friendly vehicles and buildings. The Conservatives, however, advocate managing the issue through higher national taxation on emissions-causing behavior, such as emissions taxes on airline passengers and airplane fuel.

In general, the French government and public are in line with the European consensus regarding the importance of countering climate change.

Initially, though, France did oppose the EPE because its nuclear power, which provides for more than three-fourths of France's power needs, was excluded from national calculations of emissions responsibility. Once the EU agreed to take the French nuclear sector fully into account as a low carbon energy source, France threw its complete political backing behind the EPE. Today, France can boast that its emissions have actually slightly decreased even though the French assignment under Kyoto was simply to maintain emissions at 1990 levels. France is expected to play an even larger role in Europe's climate policy with the arrival of French President Nicolas Sarkozy, who has already made a number of pledges to strengthen his country's commitment to combating global warming. In his acceptance speech, Sarkozy also urged the United States to show more leadership on tackling global warming.

Despite Europe's laudable focus on climate change at the regional and national levels, fruitful action has not always followed the rhetoric. Countries such as the United Kingdom, France, and Sweden are on track to meet or even exceed their Kyoto targets for CO_2 emissions reduction, but others such as Spain, Portugal, and Ireland are badly off pace.[297] Although the EU Emissions Trading Scheme (ETS) carries real symbolic importance, the first phase (2005 to 2007) has witnessed a number of serious shortcomings, and the EU will need to vigorously apply its lessons to the second phase from 2008 to 2012, including setting stricter emissions limits and auctioning off rather than handing out credits.[298]

Beyond emissions trading, intra-European east-west tensions flared during the European Council negotiations of the EPE. The economies of the new member states of central and eastern Europe are generally far more dependent on coal, gas, and CO_2-generating manufacturing than their western counterparts. Poland, for example, derives 90 percent of its energy from coal. These countries also have a much lower portion of renewable sources in their energy mix. Estonia's renewables account for 1 percent of energy sources, whereas Austria's account for 60 percent. These facts led the Czech Republic, Hungary, and Poland to oppose the EPE. They felt that the potential economic burdens of emission reduction would be too great and the difficulty of meeting the renewable energy targets too extreme. In the resulting compromise the implementation of the EPE will mean more permissive emissions targets for the new members, and possibly west-to-east subsidies of technology and energy supply.[299]

The desirability and acceptability of nuclear power as a carbon-free energy source is another persistent topic of passionate debate in Europe. This issue has led to the creation of unlikely coalitions of interest, with pro-nuclear energy countries such as the Czech Republic, Finland, France, and Slovakia on one side and countries with broadly anti-nuclear publics, such as Austria, Denmark, and Ireland, on the other. Despite its appeal, some countries have already taken dramatic steps to reduce their reliance on nuclear energy. In a decision made under the Red-Green government of Chancellor Gerhard Schroeder, Germany plans to do away with its nuclear plants, which currently provide one-third of the country's power, by 2020.

Finally, business leaders have predictably expressed concern that the EPE will hurt competitiveness and that it is unclear how the targets can be met. In January 2007, the heads of BMW, DaimlerChrysler, and Volkswagen sent a joint letter to the European Commission complaining that the EPE would unduly burden and harm the German auto industry. Although German carmakers have introduced some new technologies that reduce auto emissions and are gradually introducing hybrid vehicles, manufacturers often argue that significantly lower emissions limits simply cannot be met by most of the car models currently made by companies such as Audi, BMW, Mercedes, and Porsche.

Changing U.S. Views

The global perception of the United States vis-à-vis climate change is that of a laggard. Given its size and large contribution to global emissions, many countries around the world believe the United States could and should be doing more to combat climate change. Data from the Pew 2007 Global Attitudes project show that in 34 of the 37 countries surveyed, the United States is named by a majority or a clear plurality as the country that is "hurting the world's environment the most."[300] Although the U.S. government has been dragging its feet on addressing climate change there have been some shifts in U.S. policy in recent months. Scientific evidence, support from businesses and industry, the promotion of climate-friendly policies as an element of faith, state and local initiatives, and the Democratic majority in Congress are enabling progress on this contentious issue.

First, the science has become both stronger and more visible. The Third Assessment Report of the IPCC, published in 2001, provided the media, policymakers, the general public, and academics with much stronger evidence of a warming Earth (even though parts of the report were strongly contested). It also highlighted the role of greenhouse gas emissions. Perhaps most striking was the observable evidence, often through satellite imaging, that the report provided on the impacts of warming on the biosphere and on human societies. The Fourth Assessment in 2007 had an even greater impact, confirming with near certainty that carbon dioxide and other greenhouse gases from human activity are the main cause of global warming. Various extreme climate incidents—ranging from the European heat wave of 2003 to destructive storms such as Hurricane Katrina in 2005 to severe droughts and dwindling water resources in eastern Australia—have also provided skeptics in the United States and elsewhere with troubling firsthand accounts of the impact of warming on their societies.

Second, increasing numbers of business leaders have gradually come to consider action on global warming as imperative for the sake of energy security, economic growth, trade, and U.S. global leadership. Industry has also discovered that "going green"—however vaguely defined—has considerable appeal among the public. Furthermore, businesses now see economic opportunities in new "green" technologies. Therefore, as the science of climate change advanced and grew in scope in the 1990s and both the indirect and direct benefits of becoming environmentally friendly became more apparent, corporations began pulling out of the Global Climate Coalition, reducing the threat of the business veto on U.S. government action.

Third, many evangelical Christian groups have come to view combating climate change to be an obligation of faith. At first these groups promoted individual responsibility to conserve. But some prominent church leaders have recently taken their cause to Washington, urging the federal government to take a more aggressive stance in addressing the problem. In early 2006, for example, a coalition of evangelical leaders issued "An Evangelical Call to Action," asking Congress and the Bush administration to restrict carbon-dioxide emissions.[301] That call triggered some fierce debates inside the evangelical community. But the increased attention on this issue among both evangelicals and a wide array of other religious groups, including Roman Catholics and Jews, has heightened awareness among the general public and caught the ears of Republican leaders in Congress and the administration.

Fourth, absent federal-level participation in Kyoto, the United States has witnessed a number of innovative approaches at the local and state levels. The best-known model is California, which has established a state Climate Action Team to devise greenhouse gas emission reduction strategies based on both technology and regulation. Numerous businesses in California including DuPont and

IBM have voluntarily agreed to state emission reduction targets. The state's motor vehicle plan aims to reduce car emissions, the greatest source of greenhouse gas emissions, by 30 percent by 2016. If the entire United States reduced its per capita emissions to California's level, U.S. pollution would be significantly lower than that called for by Kyoto.[302] California is not the only state in the union showing muscle on this issue. Twelve other states have adopted caps on auto emissions and 435 U.S. mayors, Republicans and Democrats alike, have signed the U.S. Mayors Climate Protection Agreement, committing their cities to meeting the Kyoto emissions targets.[303]

Finally, the Democratic takeover of Congress in 2006 has also advanced climate change debates in Washington. According to a recent Zogby International post-election survey, half of Americans who voted in the 2006 midterm elections said concern about global warming made a difference in their vote.[304] A handful of global warming skeptics lost influential posts in that political transition, including the chairman of the Environment and Public Works Committee in the Senate, Senator James Inhofe (R-Okla.), who has called global warming "the greatest hoax ever perpetrated on the American people."[305] He was replaced as committee chair by Senator Barbara Boxer (D-Calif.), an outspoken critic of the administration, particularly on climate issues. To date, however, concrete progress in Congress on climate change has been slow. Mandates for more energy efficiency in federal buildings and a $2 million program to better measure greenhouse gas emissions have been approved, but major climate legislation has yet to surface. Democrats blame the White House and continuing opposition from industry, but claim that they will push for a major bill in late 2007 to reduce emissions.

China's Awakening

While the United States has been viewed as a laggard, China has been portrayed as distracted or even avoiding the problem. Obsessed with economic development, and unwilling to assume responsibility for what is viewed as an issue created by over a century of developed world industrialization, Beijing has been perceived as a country that will not be bothered with climate change negotiations, at least until the developed world reaches their own serious agreements. Yet just as U.S. views have been changing, so have China's of the climate change challenge and what to do about it. In June of this year, for example, China released its first National Climate Change Program. As a developing country with over three times as many people as Europe and four times as many as the United States, China views at least the metrics of climate change differently. But as Beijing has begun to see climate change itself as a potential drain on the Chinese economy and a source of popular instability, China's perceptions have evolved on the risks involved and what to do about it.

While China's greenhouse gas emissions have dramatically risen with its astounding economic growth since 1979, Beijing takes issue with three ways in which emissions are typically measured. First, rather than annual current emissions or projections that dominate most discussions, Beijing cites cumulative historical emissions to assess who is responsible for the problem. According to the World Resource Institute's CAIT, the United States and EU emitted over 55 percent of carbon dioxide from 1850 to 2003, while China was responsible for less than 8 percent. Second, China cites its low per capita GHG emissions, which ranked 100th in the world in 2000 according to the CAIT. Finally, Beijing also focuses on efficiency or energy intensity, the ratio of energy consumption to GDP, and consequently to emissions intensity, or the ratio of carbon dioxide equivalent emissions to GDP. From 1980 to 2000 China's energy consumption doubled

but its economy quadrupled, improving its energy intensity dramatically.[306] Collectively, these standards mean that according to Beijing, as Chinese Foreign Ministry spokeswoman Jiang Yu said, "The key issue of the current international negotiations on climate change is that developed countries must continue to take the lead in cutting emission of greenhouse gases."[307]

China's top priority, quite simply, remains economic growth, with officials citing it as a "right" for developing countries. At the September 24, 2007 UN High-Level Event on Climate Change Foreign Minister Yang Jiechi framed his remarks by opening "climate change is an important development issue."[308] Last year, Chinese State Councilor Hua Jianmin also at least sought to deflect international pressure, making the converse argument that "economic development is not only a prerequisite for the subsistence and progress of human beings, but also a material foundation for the protection and improvement of the global environment."[309] Recently, however, China has begun to see the consequences of environmental damage generally and climate change specifically such as drought, crop shortages, and typhoons as threats to economic growth. A February 2007 Lehman Brothers report cited estimates by Chinese researchers that environmental pollution in 2004 cost the Chinese economy 3.1 percent of GDP.[310] At the end of 2006, the Chinese Ministry of Science and Technology claimed specifically that "global climate change has an impact on the nation's ability to develop further."[311]

Chinese concerns about the environment transcend the economy to social stability itself, a terrifying prospect for the Chinese leadership. Thousands of Chinese have demonstrated across the country in riots such as the 2005 incidents in Huaxi village and in Xinchang that John Podesta and Peter Ogden previously discussed in this study. While these clashes were both narrowly over factory pollution, they raise the prospect that the Chinese people are willing to speak and act out over access to clean water. Chinese officials are aware of the threat warming presents. Earlier this year the deputy director of China's office of Global Environmental Affairs in the Ministry of Science and Technology, Lu Xuedu, pointed out that river levels will decline while droughts and floods increase because of climate change, specifically warning that demand would outstrip the supply of water in western China by up to 20 billion cubic meters from 2010 to 2030. Qin Dahe, an expert at the Chinese Academy of Sciences, also recently raised the concern that glaciers on the Qinghai-Tibet plateau could shrink to 100,000 square kilometers by 2030 (from 500,000 in 1995), reducing the melting water that feeds many major rivers in Asia and jeopardizing the water supply for up to a billion people.[312] *Financial Times* columnist Gideon Rachman put it best: "The government in Beijing faces a dilemma. Terrified of social unrest, it is reluctant to do anything that might slow economic growth — such as stopping the building of coal-fired power stations. Yet water shortages are already causing social unrest in the countryside and the water table is falling fast in Beijing."[313] Clearly what China is willing to do to mitigate or adapt to climate change will be shaped by economic pressures but its views are changing because climate change is now viewed as an economic problem and a threat to political stability.

To combat climate change, China's National Development and Reform Commission released its National Climate Change Program in June 2007, on the eve of the G8 summit. The 60-page document outlines China's guidelines, basic principles, specific objectives, and policies to mitigate and adapt to the threat. The programs mentioned are mostly an amalgamation of policies implemented throughout the economy, particularly in the energy sector, that have the effect of reducing GHG emissions, even if they have been instituted for other reasons. For example, the plan claims

credit for its one-child policy reducing the number of Chinese people able to increase carbon emissions. China's focus remains on improving energy efficiency, increasing the use of renewable energy, and reviving the gains it had made in energy intensity through 2002. Beijing has set ambitious targets, such as reducing emissions by 20 percent by 2010, but it faces a severe challenge in getting provincial and local officials to enforce these measures. To date, there has been a genuine lack of incentives and penalties to cut emissions and adopt environment-friendly technologies from Beijing to provincial leaders and businesses. Beijing may, however, begin to evaluate local leaders on energy efficiency improvements,[314] and even consider how to use non-governmental environmental groups to serve as watchdogs on provincial and local leaders without threatening political stability.

Internationally, China will continue to feel the pressure to deal with the effects of climate change, as it did when it was unable to significantly respond to regional calls for help after the Indian Ocean tsunami, and to be a "responsible stakeholder" in global negotiations to construct a post-Kyoto framework. China's international position is embodied in a July 2005 six-country initiative among Australia, China, India, Japan, South Korea, and the United States called the Asia-Pacific Partnership for Clean Development and Climate, or the AP6 for short. The AP6 encourages new technologies to address climate change while promoting "sustainable economic growth and poverty reduction." Although the countries are criticized for not putting money toward the agreement its principle is still clear: don't regulate current businesses, but create new businesses through incentives to develop and transfer cleaner, more efficient technology.

In China's eyes, the transfer of such technology is a critical component of any post-Kyoto framework. In a global opinion poll on views of global warming, China's population was among the most concerned with 83 percent responding global climate change should be addressed, split between 42 percent believing that global warming is a "serious and pressing problem" and that immediate action should be taken, and 41 percent responding it "should be addressed, but it's effects will be gradual, so we can deal with the problem gradually by taking steps that are low in cost." When asked about the scenario if developed countries provide aid, 79 percent would agree to reduce emissions.[315]

Conclusion

Any viable solution to the challenge of climate change rests on the ability of the international community—particularly Europe, the United States, and China—to engage each other to combine their strengths, experiences, and perspectives into a post-Kyoto framework. The year 2007 marks the beginning of that engagement. The global negotiations can be envisioned as a standing line of dominoes, each either pressuring or hiding behind the other. At the front of the line stands Europe, leaning on the United States, which to date has resisted approaches such as mandatory caps. Behind the United States stands China. Realistically, with U.S. presidential elections to be held in November 2008, negotiators can make progress at the working level but political leaders will be anxiously waiting what happens next. If a new U.S. administration takes a different stance toward, for example, some form of carbon cap-and-trade system, and the proverbial U.S. domino falls, it will lean on China and pressure will pass to Beijing. Behind China stand other developing countries such as India and Brazil, as well as the countries of the Middle East, and other developed countries such as Russia, Japan, and Canada, all of whom are undergoing their own national evaluations but will be influenced by the global line of dominoes.

One of the unique ways that the global climate debate has been changing is that a wider array of expert communities is being integrated into the

debate. To date, a handful of studies, including this one, have worked to bridge the gap between the national security and climate communities so that global warming receives the due attention it warrants. Climate change will have major ramifications for migration, force posturing, failed states, and federal resourcing. The sooner national governments recognize climate change as the national security issue that it is, the faster it will receive the intellectual, financial, and diplomatic resources it merits.

LOCATION: Mid-western U.S. — Wind turbines producing renewable energy.

SUMMARY AND IMPLICATIONS OF GLOBAL CLIMATE CHANGE

By Kurt M. Campbell and Richard Weitz

This study was the product of a year of collaboration and discussion among a new community of scientists, climate experts, and foreign policy and national security practitioners. As our work came to a close, Al Gore and the IPCC were awarded the 2007 Nobel Peace Prize for efforts to raise public understanding of climate change and its daunting implications. Nothing could better underscore that the time is right: there is an urgent need to understand the nature of the climate change challenge and, more to the point, there is an urgent need for Americans of all walks to come together to take action.

This diverse group undertook a scenario exercise in hopes of reaching a better understanding of the consequences the world could realistically face from climate change, across the range of plausible effects. Our intention was to influence the public debate about climate policy. We came away with considerable clarity in our own minds: the United States can expect that climate change will exacerbate already existing north-south tensions, dramatically increase global migration both inside and between nations (including into the United States), spur more serious public health problems, heighten interstate tension and possibly conflict over resources, challenge the institutions of global governance, cause potentially destabilizing domestic political and social repercussions, and stir unpredictable shifts in the global balance of power, particularly where China is concerned. The state of humanity could be altered in ways that create strong moral dilemmas for those charged with wielding national power, and also in ways that may either erode or enhance America's place in the world.

Taken together or even one at a time, some of these challenges have the potential to overwhelm national governments and international institutions. It is difficult to anticipate how that will ultimately unfold, but the prospects for destabilizing global effects are clearly on the horizon. The

Table 3

SUMMARY OF KEY ENVIRONMENTAL AND NATIONAL SECURITY IMPLICATIONS OF THREE CLIMATE SCENARIOS

	SCENARIO 1 Expected Climate Change	SCENARIO 2 Severe Climate Change	SCENARIO 3 Catastrophic Climate Change
Summary of climate change assumptions	• Average 1.3°C warming • .23 meters of sea level rise • Approximately 30 year time frame	• Average 2.6°C warming • .52 meters of sea level rise • Approximately 30 year time frame	• Average 5.6°C warming • 2.0 meters of sea level rise • Approximately 100 year time frame
Key selected environmental stresses based on scenario assumptions	• Water scarcity affects up to 1.7 billion people • Changed distribution of some infectious disease vectors & allergenic pollen species • Up to 3 million additional people at risk of flooding • Up to 30 million more people at risk of hunger due to crop failure	• Water scarcity affects up to 2 billion people • Increased burden from malnutrition, diarrheal, cardio-respiratory & infectious diseases • Up to 15 million additional people at risk of flooding • Changes in marine and ecosystems due to weakening of the meridional overturning circulation	• Water scarcity affects 3.2 billion people • Increased morbidity & mortality from heat waves, floods, & droughts • Approximately 30 percent loss of coastal wetlands • Up to 120 million more people at risk of hunger due to crop failure • Possible collapse of the meridional overturning circulation
Key selected national security implications based on scenario assumptions	• Conflict over resources due to and driving human migration • Immigrants—or even simply visitors—from a country in which there has been a significant disease outbreak may not be welcomed and could be subject to quarantine & lead to loss of national income from restricted tourism • Dissatisfaction with state governments could radicalize internal politics and create new safe havens in weak and failing states • A strengthened geopolitical hand for natural gas exporting countries and, potentially, biofuel exporting countries; a weakened hand, both strategically and economically, for importers of all fuel types • Social services will become increased burden on central government where available • The regional positions of Turkey and others will likely be strengthened as a result of the water crisis	• Wealthiest members of society pull away from the rest of the population, undermining morale and viability of democratic governance • Global fish stocks may crash, enmeshing some nations in a struggle over dwindling supplies • Governments, lacking necessary resources, may privatize water supply; past experience with this in poor societies suggests likelihood of violent protest and political upheaval • Globalization may end and rapid economic decline may begin, owing to the collapse of financial and production systems that depend on integrated worldwide systems • Corporations may become increasingly powerful relative to governments as the rich look to private services, engendering a new form of globalization in which transnational business becomes more powerful than states • Alliance systems and multilateral institutions may collapse—among them, the UN, as the Security Council fractures beyond compromise or repair	• Migration toward U.S. borders by millions of hungry and thirsty southern neighbors is likely to dominate U.S. security and humanitarian concerns • A shrinking Russian population might have substantial difficulty preventing China from asserting control over much of Siberia and the Russian Far East; the probability of conflict between two destabilized nuclear powers would seem high • Rage at government's inability to deal with the abrupt and unpredictable crises • Religious fervor, perhaps even a dramatic rise in millennial end-of-days cults • Hostility and violence toward migrants and minority groups • Altruism and generosity would likely be blunted • U.S. military's worldwide reach could be reduced substantially by logistics and the demand of missions near our shores • Electricity generation and distribution highly vulnerable to attack by terrorists and rogue states

overwhelming message is that early steps to limit or mitigate climate change are essential because longer-term efforts to adapt or anticipate may not be possible.

As Table 3 summarizes and this report makes clear, climate change has the potential to be one of the greatest national security challenges that this or any other generation of policymakers is likely to confront.

Although our charge was to offer projections based on scientific modeling, rather than predictions, the *expected* climate change scenario in this report is appropriately considered "expected," and can be taken as a minimum basis for planning. As Podesta and Ogden write in Chapter III, the environmental effects in this scenario are "the least we ought to prepare for." National security implications include: heightened internal and cross-border tensions caused by large-scale migrations; conflict sparked by resource scarcity, particularly in the weak and failing states of Africa; increased disease proliferation, which will have economic consequences; and some geopolitical reordering as nations adjust to shifts in resources and prevalence of disease. Oil and natural gas exporters might gain an upper hand, while energy importers will suffer geopolitically. All these things could cause the internal politics of nations to radicalize or destabilize. Across the board, the ways in which societies react to climate change will refract through underlying social, political, and economic factors.

In the case of *severe* climate change, projected massive nonlinear events in the global environment give rise to massive nonlinear societal events. In this scenario, nations around the world will be overwhelmed by the scale of change and pernicious challenges, such as pandemic disease and water and food shortages. The internal cohesion of nations will be under great stress, including in the United States, due to a dramatic rise in migration, changes in agricultural patterns and water availability, and wealthier members of society pulling away from the rest of the population. Protests, civil unrest, and violent upheaval of governments are possible. The flooding of coastal communities around the world, especially in the Netherlands, the United States, South Asia, and China, has the potential to challenge regional and even national identities. Armed conflict between nations over resources and even territory, such as the Nile and its tributaries, is likely, and nuclear war is possible. Globalization could halt and alliances collapse.

The *catastrophic* scenario finds strong and surprising intersections between the two great security threats of the day—global climate change and international terrorism waged by Islamist extremists. The catastrophic scenario means the destruction of hope itself, as human society struggles to adapt. Both migration and religious fervor are likely to spike. The scenario notes that understanding the threat in light of the other great threat of our age, terrorism, can be illuminating. Although distinct in nature, both threats are linked to energy use in the industrialized world, and, indeed, the solutions to both depend on transforming the world's energy economy—America's energy economy in particular. Indeed, aviation fuel and non-nuclear fuel for destroyers could become unobtainable just as logistical issues and the demand for military use are strained.

These scenarios aim not to speculate centuries into the future, as some scientific models do, but to consider plausible developments using a reasonable timeframe for making acquisition decisions or judgments about larger geopolitical trends. In national security planning, it generally can take about 30 years to design a weapons system and bring it to the battlefield, so it is important to anticipate future threat environments and to begin preparations now. The same is true of climate change.

Implications

Although the scenarios are certainly interesting in and of themselves, the point of such an exercise is to draw observations and lessons that can help guide decision making in the present tense. In that sense, there are 10 highly consequential implications of climate change that can be drawn from this report:

1. **Soft Power and North-South Tensions will Increase.** Problems of equity arise in the entire climate debate. Developing countries will generally suffer most from adverse impacts of global climate change due to their limited response capacities. Their ability to triumph through several of such events simultaneously or in succession is less likely yet. In contrast, wealthier countries (and their most wealthy citizens) appear better positioned to cope with at least early consequences of modest climate change. To add to this tension, the wealthiest nations became so in no small part by burning the very fossil fuels responsible for increasing the concentration of atmospheric greenhouse gasses. A failure of the developed nations to assist developing countries to manage the climate change challenge will almost certainly cause a further spike in north-south tensions.

2. **Migration and Immigration will Rise, Producing a Strong Backlash.** A profound increase in the movement of people will cause greater tensions and perhaps violent conflicts between and within countries over uncontrolled immigration issues. Such massive migrations within a relatively short time are likely to be deeply problematic for the "host" countries for these climate refugees. In the Western Hemisphere, Americans may find themselves struggling to resettle tens of millions of their own citizens, driven by high water from the Gulf of Mexico, South Florida, and much of the East Coast reaching nearly to New England. Under severe scenarios, climate-induced migration could transform the ethnic character of major countries and world regions, especially the European Union. An influx of Muslims into Europe, for example, could lead to new tensions over foreign policy priorities (e.g., toward Muslim countries or Islamist terrorism). Historical reactions to natural disasters, such as public rage at government's inability to deal with the abrupt and unpredictable crises, increased religious fervor, and hostility and violence toward migrants and minority groups, could dramatically worsen perennial tensions about immigration.

3. **Public Health Problems will Grow.** Climate change will also have profoundly negative consequences for global health, especially in poorer regions of the world. Not only will some areas become more hospitable for vector-borne diseases, but any climate-induced shortages in local food and water supplies will also increase the population's susceptibility to illness. The resulting increase in deadly or debilitating diseases could worsen poor economic conditions in the affected regions by limiting tourism, decreasing worker productivity, and requiring governments to spend more on public health rather than other priorities.

4. **Resource Conflicts and Vulnerabilities will Intensify.** Over the next three decades, climate change-exacerbated water scarcity could well contribute to instability in many regions of the world—a dire problem in itself that may also be a detriment to agriculture and basic subsistence. Tensions could increase within and between states that experience shrinking water supplies; countries with an abundant water supply could seek to exploit it for diplomatic advantage. Climate change could also affect the international politics of energy production and consumption. Oil and natural gas exporting countries, especially Russia, could gain geopolitical footing relative to fuel-importing

countries, such as those in Europe. Any oil or gas importing nation with high energy intensity could suffer disproportionately due to the difficulty of switching to alternative fuel supplies. As is aptly underscored in scenario three, energy infrastructure could also become more vulnerable, both in the United States and globally. Hydroelectric power generation may be substantially affected by reduced glacial runoff or by upstream nations diverting rivers in some parts of the world. Nuclear power plant cooling may be limited by reduced water availability. Increased numbers and intensity of storms could interfere with long-distance electricity transmission, already heavily stressed in the United States and elsewhere. In a future world where climate change leads also to an increased likelihood of state failure, addressing vulnerable energy infrastructure addresses two problems: heightened risks of resource-related terrorism and the need to find alternative energy sources that mitigate further climate change impacts.

5. **Nuclear Activity will Increase, with Attendant Risks.** Climate change may well mean a global renaissance in nuclear energy—driven partly by the expectation that its increased production and consumption will reduce the use of carbon-emitting fossil fuels—which could worsen problems of nuclear safety and proliferation. According to current plans, many developing countries will begin operating their own commercial nuclear reactors during their next few decades. This would increase the total number of nuclear reactors around the world, including those under the control of nations that may lack the experience to safely conduct these operations. The threat of global climate change also provides governments interested in acquiring nuclear weapons yet another justification to pursue nuclear-related research and nuclear technologies. For example, the oil-rich countries of the Middle East are among the largest emitters of greenhouse gases per capita; these nations could reasonably claim a need for nuclear power to help desalinate water or cut greenhouse gas emissions.

6. **Challenges to Global Governance will Multiply.** Severe or sudden climate change presents a profound challenge to existing social and political organizations in countries rich and poor. International cooperation might increase as people rally to save human civilization, or individuals and groups might become preoccupied with promoting their own survival. Under enormous stress brought on by climate change, the United Nations and other existing international institutions will have great difficulty managing the full range of adverse consequences. The implications of new international alignments driven by environmental factors are uncertain, but the complex and inherently divisive nature of climate change is likely to impede collective responses.

7. **Domestic Political Repercussions and State Failure will Occur.** Climate change could have deep implications for the effectiveness and viability of existing governments. Political authorities unable to manage climate-induced challenges might well lose necessary public support. National leaders professing authoritarian ideologies could become more attractive if liberal democratic systems fail to marshal sufficient political will to manage the climate challenge. In some instances people might resort to violent means—especially when opportunities to change leaders through elections are circumscribed—to remove existing governments. In a few places people might turn to non-state actors, including religious movements or terrorist groups for comfort or to effect more dramatic change. Moreover, under conditions of severe global climate change, environmental factors may push already failed states deeper into the abyss of ungovernability, while driving other states toward the brink.

8. **The Balance of Power will Shift in Unpredictable Ways.** Climate change has the potential to affect world politics, given that problems ensuing from climate change likely will affect states very differently and some countries will respond more effectively than others. Certain nations could require increased public health assistance in the face of urgent domestic needs, some could experience limits on their exports of people and goods because of unanticipated changes in the global trading regime due to climate-related effects. Others could become more vulnerable to foreign predation if a stronger neighbor suddenly desired their land or resources. Over the long term, the very divergent regional effects of climate change could affect the evolving global distribution of power with unpredictable consequences for international security.

9. **China's Role will be Critical.** The economic and political decisions made by this generation of Chinese leaders will have a decisive effect on our global future. China is becoming the primary driver of global climate change, now emitting more carbon dioxide in aggregate (though not per capita) than any other nation.[316] A recent *New York Times* editorial denounced China and the United States for establishing an "alliance of denial" in which the two countries "are using each other's inaction as an excuse to do nothing."[317] Many members of the international community are calling on Beijing to adopt more rigorous policies to limit the growth of China's carbon emissions to reflect the country's status as an emerging global stakeholder sharing the burdens of world leadership. Some of these appeals have been less than effective as China's reasoning that the United States is not showing itself to be serious still holds. According to the World Bank, 16 of the world's 20 most polluted cities are in China—the air is so polluted that it causes 400,000 premature deaths every year.[318] As such, China's own population is emerging as an important voice inside the country arguing for more responsive environmental policies.

10. **The United States Must Come to Terms with Climate Change.** Americans are unlikely to escape the plausible adverse consequences of global climate change. If climate change results in a very substantial rise in sea levels, it could well lead to a massive depopulation of U.S. coastal regions, with widespread damage to New York, California, and other core industrial and agricultural regions of the United States. In the immediate aftermath of any natural disaster, whether caused by climate change or other factors, the international community will look to the United States, with its unique world role and response assets (including those in the U.S. military), to assume a leading role in organizing the relief operation. How or whether the United States is able to perform this role effectively will contribute considerably to the perceptions of Americans in many countries. The new politics of global climate change will not obviate the need for U.S. policymakers, like their colleagues elsewhere, to continue weighing trade-offs among competing objectives and values, and managing climate change may not always emerge as the most important consideration. There is no question that climate change will mean fundamental shifts in how Americans see themselves and their role in the world, based on the findings of the scenarios in this study. In all but the extreme scenario, in which most of the world is put in a fundamentally severe set of circumstances, the unique character of the American people, with the depths of optimism and penchant for practicality, will be a major asset.

Conclusion

In the course of writing this report we found inescapable, overriding conclusions. In the coming decade the United States faces an ominous set of challenges for this and the next generation of foreign policy and national security practitioners. These include reversing the decline in America's global standing, rebuilding the nation's armed forces, finding a responsible way out from Iraq while maintaining American influence in the wider region, persevering in Afghanistan, working toward greater energy security, re-conceptualizing the struggle against violent extremists, restoring public trust in all manner of government functions, preparing to cope with either naturally occurring or manmade pathogens, and quelling the fear that threatens to cripple our foreign policy—just to name a few.

Regrettably, to this already daunting list we absolutely must add dealing responsibly with global climate change. Our group found that, left unaddressed, climate change may come to represent as great or a greater foreign policy and national security challenge than any problem from this list. And, almost certainly, overarching global climate change will complicate many of these other issues.

While all those who collaborated in this study completed the process with a profound sense of urgency, we also collectively are encouraged that there is still time for the United States and the international community to plan an effective response to prevent, mitigate, and where possible adapt, to global climate change. We hope this study will help in that endeavor.

Indeed, the overall experience of these working groups helped underscore how much needs to be done on a sustained basis in this emerging field of exploration. This study hopefully will help illuminate how security concerns might manifest themselves in a future warming—and worrisome—world. Moving forward, the United States and other nations must chart a new path, for we already live in an age of consequences.

LOCATION: Bayou Savage, Louisiana — Severe drought and heat have caused the earth to crack.

ENDNOTES

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