CLIMATIC CATACLYSM

KURT M. CAMPBELL
EDITOR

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THE FOREIGN POLICY AND NATIONAL SECURITY IMPLICATIONS OF CLIMATE CHANGE

BROOKINGS INSTITUTION PRESS
Washington, D.C.

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THE BROOKINGS INSTITUTION
1775 Massachusetts Avenue, N.W., Washington, D.C. 20036
www.brookings.edu

Library of Congress Cataloging-in-Publication data

Climatic cataclysm : the foreign policy and national security implications of climate change / Kurt M. Campbell, editor.
p. cm.
Summary: "Presents three scenarios of what the future may hold: expected, severe, and catastrophic and analyzes the security implications of each. Considers what can be learned from early civilizations confronted with natural disaster and asks what the largest emitters of greenhouse gases can do to reduce and manage future risks"—Provided by publisher.
Includes bibliographical references and index.
ISBN 978-0-8157-1332-6 (cloth : alk. paper)
1. Climatic changes—Government policy. 2. Climatic changes—Forecasting. 3. Climatic changes—Social aspects. 4. International relations—Forecasting. 5. National security.
I. Campbell, Kurt M. II. Title.
QC981.8.C5C625 2008
363.738'74526—dc22 2008012194

9 8 7 6 5 4 3 2 1

The paper used in this publication meets minimum requirements of the American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials: ANSI Z39.48-1992.

Typeset in Minion

Composition by Circle Graphics
Columbia, Maryland

Printed by R. R. Donnelley
Harrisonburg, Virginia

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A Partnership Deal: Malevolent and Malignant Threats

R. James Woolsey

> [There is] 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, *Pearl Harbor: Warning and Decision* (1962)

> 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.
>
> —Senior British intelligence official, retiring in 1950 after forty-seven years of service, quoted in Amory Lovins and Hunter Lovins, *Brittle Power: Energy Strategy for National Security*

The first two scenarios in this exercise 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 2.6°C (4.7°F) and sea level rise of approximately half a meter (1.6 feet) in a thirty-year period. The third scenario discussed catastrophic change where aggregate global temperature increased by 5.6°C (10.1°F) by the end of the century, accompanied by a dramatic rise in global sea levels of 2 meters (6.6 feet) 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 SUVs 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 carbon dioxide (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 unique approach. This is because few human beings naturally think in terms of the possibility of the exponential changes. We humans generally have what the inventor and futurist Ray 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, but he returns weeks later to find it covered with lily pads and the fish dead.[1] The owner, because the human mind thinks linearly, forgot that lily pads reproduce exponentially. 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 discusses 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 Intergovernmental Panel on Climate Change (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 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."[2] 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 freshwater from melting Greenland glaciers would slow the North Atlantic meridional overturning circulation, 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 West Antarctic and the 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.[3] If the permafrost were to thaw, much of this carbon would quickly convert to methane gas. At about one million tons annually, the increase in atmospheric methane content is much smaller than the increase in CO_2 content, which weighs in at about 15 billion tons per year.[4] However, a ton of methane affects climate twenty-five times more powerfully than a ton of CO_2 over a 100-year time horizon.[5] As a result, it would take only 600 million tons of methane to equal the global warming effect of 15 billion tons of CO_2. If this seems like an implausibly large increase in methane emissions, consider that it equates to only one-half of one-tenth of 1 percent of the organic carbon currently preserved in the permafrost (not to mention much larger amounts of frozen methane stored in shallow marine sediments). Therefore, if the permafrost begins to thaw quickly due to the initial linear warming trend we are experiencing today, the climate impact of methane emissions could come to rival that of CO_2 in future decades. 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 under way.[6]

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 (9 to 10.8°F) or more,[7] to the approximate level of temperature increase posited for the third scenario in this study. 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 4 to 6 meters (about 13 to 20 feet) higher than it is today and global temperature was only about 1°C (1.8°F) higher.[8] Being warmer than Antarctica, Greenland probably provided the initial slug of meltwater to the ocean. However, much of the ice of western Antarctica rests on bedrock far below sea level, making it less stable as sea level rises.[9] When the ice sheet is lubricated by melting where it is grounded, it begins to float and can cause coastal ice shelves to shatter, increasing the rate of ice stream flow into the ocean (*ice stream* is a region of an ice sheet that moves significantly faster than the surrounding ice).[10] As a result of this action, the West Antarctic Ice Sheet contributed perhaps 2 meters (6 or 7 feet) of the additional sea level 125,000 years ago.

With just 1°C (1.8°F) of warming, therefore, we may be locked into about 4 to 6 meters (13 to 20 feet) of sea level rise.[11] James Hansen points out that

it is not irrational to worry about reaching this tipping point in this century. This study's catastrophic scenario assumes 5 to 6°C (9 to 10.8°F) of warming, which is significantly warmer than conditions 3 million years ago, before the ice ages. At that time, the Earth was 2 to 3°C (3.6 to 5.4°F) warmer and sea level was about 25 meters (82 feet) higher than today.[12] Although the time required for that much sea level rise to occur is probably more than 1,000 years, the third scenario, with 2 meters (6.6 feet) of sea level rise by the end of this century, appears quite plausible.[13]

Economic Development

Robert Zubrin, the author of *Energy Victory: Winning the War on Terror by Breaking Free of Oil,* who is something of a climate change skeptic, 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 twentieth century (about $5,000 in today's dollars).[14] In the twentieth century, world population quadrupled and world economic growth averaged 3.6 percent annually.[15] Even if we assume slower population growth, say a doubling of world population in the twenty-first 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 tenfold increase in CO_2 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 2,000 ppm"—and certain catastrophe.[16]

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 2008 and 2020. China alone represents a third of total growth.[17]

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.[18] For this reason,

James Hansen considers sea level rise as "*the* big global issue" that will transcend all others in the coming century.[19] 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 holds the potential for some 12 meters (40 feet) of sea level rise.[20] The melting of the East Antarctic shelf would add approximately 25 meters (80 feet); this would mark, in the Antarctic research scholar Peter Barrett's words, "the end of civilization as we know it."[21] 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

The catastrophic scenario outlined in chapter 6 listed among the regions in the developed world facing the likely prospect of inundation by the end of the century: 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 River 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 River Valley and the eastern and southern coasts of England.[22] Storm surges 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 (6.6 feet) 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, and so forth—the most affected countries, in addition to those just cited, would be Guyana, Surinam, and Mauritania. Substantial impacts would also occur in Gambia, Liberia, Senegal, Guinea, Thailand, Burma, Indonesia, Taiwan, Bangladesh, and Sri Lanka.

A 2-meter (6.6-foot) rise in sea levels—together with changed climate, agricultural disruptions and famines, the spread of disease, water scarcity, and severe storm damage—will not occur in a world that is otherwise sustainable and resilient. Many areas are already destabilized. In the Philippines, for example, sea level rise would add to a problem already created by excessive groundwater extraction, which is lowering the land annually by fractions of an inch in some spots to more than a tenth of a meter (3 or 4 inches) annually.[23] The Mississippi Delta has a similar problem with land subsidence. Some of the land south of New Orleans will likely lose about 1 meter (3 feet) of elevation by the end of this century as a result of subsidence.[24] Thus, about 6 feet (about 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 groundwater extraction. And the concentration of population in low-lying areas of course exacerbates the effect of these changes.

Meltwater 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 freshwater supply. As these glaciers shrink and produce less meltwater they will contribute 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 peak within mere decades.[25]

Potential National Security Consequences of Climate Change

In a world that sees a 2-meter (6.6-foot) 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 responded to natural disasters in the past, which John R. McNeill describes in chapter 2, could come together in one conflagration: rage at government's inability to deal with the abrupt and unpredictable crises; religious fervor and 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 freshwater.

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 portion 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, extrapolating from current demographic trends, we estimate that there will be fewer than 100 million Russians by 2050, nearly a third of whom will be Muslims. 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 appropria-

tions of north Central Asia, and Siberia may be more agriculturally productive after a 5 to 6°C (9 to 10.8°F) 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 highly destructive 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 that have announced nuclear programs "for electricity generation." The United States borrows more than 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, according to Lawrence Wright in *The Looming Tower: Al-Qaeda and the Road to 9/11,* covers "90 percent of the expenses of the entire faith, overriding other traditions of Islam."[26] Wahhabi teachings are murderous with respect to Shi'ite Muslims, Jews, homosexuals, and apostates; are hideously repressive of women; 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 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. In 2002 the National Research Council published its report on the use of science and technology to combat terrorism. It stated: "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."[27]

As of 2008 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 substations 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 an electromagnetic pulse (EMP). In 1962 both Soviet and American atmospheric nuclear tests revealed 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 1,610 kilometers (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 (25 and 250 miles) 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.[28]

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 a seventy-two hours' supply.[29] Food available in supermarkets generally supplies about one to three days of requirements for customers, and regional food warehouses usually stock enough for a multicounty area to last about one month.[30]

Toward a Partnership to Deal with Both Malignant and Malevolent Threats

These malignant and malevolent risks seem to stem from very different causes—and different kinds of people, with different backgrounds, tend to look at them separately. This cultural separation—analogous in some ways to C. P. Snow's famous description some decades ago of the intellectual world's division into the two cultures of literature and science—hinders cooperative action. For the issues at hand, let's call this a division between the tree-hugger culture, focused on carbon, and the hawk culture, focused on terrorism.

Both the malignant and malevolent problems described here are extraordinarily grave, and much too urgent to await a lengthy debate between the two cultures about how intensely we should believe that each risk will become manifest. This is especially true because, as suggested below, the steps needed to contend successfully against both types of problems appear to have a great deal in common, at least in the important field of energy.

A hawk who is steeped in the history of the Muslim Brotherhood but has no time for the history of glaciers need not be required to pledge his belief that climate change will hit a certain degree by a certain date. Scientific theories, Karl Popper taught us, must always be held tentatively; they are productive precisely to the degree that they offer an invitation to be *dis*proved. Even as society used Newton's theories for centuries, the path of human progress was to give others a chance to create theories that would replace his. Eventually Einstein's did.

Nevertheless, we should argue to our hawk that as a matter of judgment, not certainty, there is sufficient evidence of developing climate change that he or she should take the issue seriously. Further, if we consider together plausible climatic tipping points and the increased emissions from world economic development, there is a risk that such change could become cataclysmic. Thus, the only responsible course of action is to begin now to deal with the problem as sensibly and affordably as we can.

We should say something similar to a tree hugger who is quite attentive to possible change in the North Atlantic meridional overturning circulation but who believes that to deal with terrorism now and for the foreseeable future we need only enforce the criminal law—and that a rogue state or terrorist EMP attack on the United States must be someone's idea of a film plot for the PG-13 market. The tree hugger's blind spot is precisely where the hawk's eyes are trained, and vice versa. But our tree hugger needs to remember that fanatic enemies with access to destructive technology have already wreaked mass death on modern societies. The tree hugger needs to keep an open mind, remember the Nazis, and recognize that evil exists, and happens.

As a thought experiment we might try inviting a tree hugger, someone strongly committed to reducing the risk of climate change, to address a major malignant issue by producing a short list of policies that could soon lead to substantial reductions of emissions. We will ask the tree hugger to focus on the ways in which we generate electricity, fuel transportation, power industry, and operate buildings, leaving such topics as preventing

deforestation and promoting proper agricultural practices until later. We want him to focus on energy because we are going to submit his list to someone else for comment—a hawk who is heavily focused on energy security—to see if there is anything on which they can agree.

For our tree hugger we decide to summon the shade of John Muir, the father of our national parks system and the first president of the Sierra Club, and for our hawk, the shade of George S. Patton, commander of the Third Army in World War II. They eye each other warily, but agree to undertake our project.

After sitting and pondering thoughtfully for a time under some redwoods, Muir submits a list of nine proposals for Patton's consideration:

1. Begin with improving the energy efficiency of buildings.
Muir notes that Wal-Mart 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. And Muir has seen a recent McKinsey & Company report that says 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 QBTUs (quadrillion British thermal units) by 2020, 20 to 24 percent of end-use demand. The vast majority of this, 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.[31] Muir knows that the Rocky Mountain Institute's thorough work shows even more opportunity for energy savings from reduced energy use in buildings.[32]

"I'm completely with you on this one," says Patton. "Less need for energy, less need to add generating capacity and transmission lines to the grid. Every day, the grid reminds me more and more of the Maginot Line, just sitting there vulnerable to being taken out by creative tactics—the less we need it the better. And I like the fact that this efficiency stuff makes money for the folks who implement it rather than costing something."

2. Radically increase the use of combined heat and power (CHP).
His second item, Muir says, could be implemented relatively quickly and would let us get dual use from energy instead of wasting a lot of the heat our industry produces by just venting it into the atmosphere. About a third of Denmark's electricity, for example, comes from CHP. Only about 8 percent of

U.S. electricity comes from CHP, but the problem—like building efficiency—is not that we don't have the technology. Rather, Muir says, our commitment to wasting heat is determined by culture and regulations. Much of the reason CHP struggles in the United States is because of the opposition of state public utility commissions (PUCs). Certain steps are needed to ensure safety, Muir concedes, but the Danes have figured this out and completely changed their system in just twenty years. To do what they've done we just need to change most states' PUC policies. CHP generally has the effect of generating electricity and heat closer to where they are used, in relatively small facilities, Muir notes.

"Go, Danes!" says Patton. "You know, John," he continues, "I admit I was pretty skeptical when I agreed to do this with you, but I've gotta admit I'm learning some things and I like this one, too. Just using energy we're already producing—makes all the sense in the world. And it looks like each of these two ideas of yours reduces the need for new centralized power generation plants as well as new long-distance transmission lines. Relying on smaller, more distributed, production should improve resilience against terrorist attack. Keep 'em coming."

3. Create strong long-term incentives for small-scale (single-building-based) distributed generation of electricity and heating and cooling.

Forty out of fifty states, Muir says, now have "net metering" laws that in principle make it possible for those who have generating capacity—say roof-top 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 sharply, says Muir. As thin-film and nano-solar technologies come on the market at costs substantially below those of today's silicon cells, and as 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 lower wind speeds than the large wind turbines, are beginning to come into 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 is showing promise for heating and cooling of 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, Muir notes: a coal-fired power plant will not fit on a roof.

"John," says Patton, "anyone who has ever been in combat knows that you need flexibility and initiative at the small-unit level because the unexpected always happens, and if your small units are good you can adapt faster. I've always said, "Small had damned well better be beautiful." You have to be able to put maximum reliance on your platoon leaders and sergeants—that's how I was able to relieve Bastogne so fast. You're making me see that the same logic applies to having an energy system that's resilient against terrorist and EMP attack. Damn, are you sure you don't have a military background?"

4. Follow California's lead and decouple sales from earnings for electric utilities to encourage conservation and grid modernization.

This is a big one, says Muir. California, he notes, initiated this simple step some twenty years ago; there, and (very recently) in several other states, utilities' earnings are based on their investment, not their sales of electricity. But in the other forty-plus states, utilities must sell more electricity in order to earn more for their shareholders. It doesn't matter if it's used wastefully—the incentive systems established by forty-some PUCs don't deter waste. In California and the other few states, though, if a utility invests in making the grid "smarter," say, to help consumers conserve electricity, it earns more for its shareholders. The effect of decoupling sales from earnings is dramatic: over the last twenty years, electricity use per capita in California has stayed flat, while that of the rest of the country has increased 60 percent. Major double-digit improvements in energy efficiency are possible if the other approximately forty PUCs would just admit that what a few states have done is problem-solving and that their own current policies are problem-creating.

"Sounds great," says Patton. "I know California screwed up on the Enron thing a while back—hell, everybody screws up sometimes—even I did once. But the Californians sure have this decoupling right. Say, who writes those other forty PUCs' fitness reports? Why don't their superior officers just relieve them of command and put somebody in charge who's willing to learn from what the California folks have done?"

5. Give steady and long-term encouragement to the deployment of renewable electricity generation for the grid from wind, solar, hydro, and geothermal.

Muir tells Patton that many incentives such as tax credits for such deployment have been periodically interrupted, delaying, for example, production of wind turbines and slowing the introduction of these technologies.

"Well," says Patton, "if we have to add to the grid I suppose these are okay. The grid will be around for a long time, so we have to improve its resilience by stockpiling transformers and defending better against cyber attacks in any case. But even if we improve its defenses and make it cleaner, increasing our reliance on a Maginot Line is not my favorite way to go. I liked your efficiency and CHP and rooftop ideas better, but I guess I can go along with these—I like the fact that at least some of them probably won't be too large and can be distributed to some extent. Also, power plants using sun, wind, hydro and geothermal aren't vulnerable to terrorist interruption of their fuel supplies."

6. Vigorously develop carbon capture and storage (CCS) for coal-fired power plants.
Muir points out that this may well rely on the already-developed technology of integrated gasification combined cycle (IGCC) plants, which facilitates CO_2 capture. The hard part is sequestering the CO_2 permanently where it will not leak into the atmosphere. The CO_2 gas may be pumped into existing oil and gas wells to enhance recovery from them. Pumping it into saltwater aquifers deep beneath the earth also shows promise for long-term sequestration.

Again, Patton is only lukewarm. "Adding to the grid just gives the terrorists eyeing our transformers and the crazy guys with EMP attack plans a bigger target," he says. "But if we can't get all the power we need by implementing your ideas about reducing demand and increasing distributed generation, then I'm okay with this CCS stuff, but reluctantly."

7. Provide tax incentives for the purchase of plug-in hybrid gasoline-electric vehicles (PHEVs). Now for transportation, Muir says. GM has announced the production of the Chevrolet Volt plug-in hybrid (PHEV) in 2010 (they call it an "electric vehicle with range extension"); Toyota's Prius was designed originally with an all-electric mode for driving, so it is well on the way to being a plug-in once a battery more capable than that in the current Prius is supplied. Other manufacturers are gearing up to produce plug-ins as well. There are dozens of hybrid vehicles, principally Priuses, that their owners have converted into PHEVs using currently available batteries. A PHEV that is plugged into a standard 120-volt socket in a garage overnight can be driven 32 to 65 kilometers (20 to 40 miles) the next day on this charge. Once it reaches the end of the electricity supplied in its overnight charge it becomes an ordinary hybrid, using both gasoline and electricity until it can be charged again. These

vehicles seem to be getting over 160 kpg (100 mpg) once their initial all-electric driving is factored in. (Muir suggests to Patton he take a look at the websites pluginamerica.com and calcars.org.

The average U.S. light vehicle is driven just over thirty miles a day, Muir adds. It is clear that, in addition to providing consumers the ability to drive for some tens of miles a day on inexpensive off-peak overnight electricity at a fraction of the cost of driving on gasoline, moving from a standard internal-combustion-engine vehicle to a PHEV reduces greenhouse gas emissions substantially. A recent Pacific Northwest National Laboratory study has estimated that if 73 percent of the current U.S. fleet of light-duty vehicles were converted to PHEVs that were able to drive just over thirty miles all-electrically and were charged during off-peak hours, no new power plants would be needed. Moreover this would displace 6.5 million barrels of oil equivalent per day, or approximately 52 percent of the nation's oil imports. The average reduction nationally of greenhouse gases would be in the range of 27 percent per car, more in states using little coal to produce electricity, around zero in heavy coal-using states.[33] And over time cleaning up the grid also cleans up PHEV emissions: as electricity production is modified—say, via renewables or coal with carbon capture and sequestration—CO_2 emissions are further reduced.

Finally, PHEVs can replace certain "ancillary services" that cost about $12 billion annually, such as fossil fuel purchases to stabilize and regulate the grid's operations and "spinning" reserves to deal with power outages. Keeping just a small number of PHEVs plugged into the grid after they are charged creates vehicle-to-grid (V2G) connections that replace fuel-consuming functions.[34] This can mean a lot less use of fossil fuel and also substantial payments back to plug-in hybrid owners. One Federal Energy Regulatory Commission member even calls plug-ins "cash-back hybrids." Grid modernization can help implement such major innovations.

"John, now you're talking again," says Patton. "Electricity (and plug-ins) can do to oil what electricity (and refrigeration) did to salt around the time I was born—destroy the damned stuff as a strategic commodity. Salt used to be a really big deal because it was the only way to preserve meat. People even fought wars over it. But now nobody gives a damn what country has salt mines. Since around the time I commanded the Third Army, maybe before, the number one strategic commodity has been oil. It sure was in the war. If old Tooey Spaatz, God bless him, hadn't persuaded FDR to let him hit Ploesti and Leuna and take out the Germans' fuel, they would have had enough for the Panzers to get to Antwerp and the Battle of the Bulge could have gone the other way."

Patton shakes his head sadly. "You know, John, there are some jaspers at the Council on Foreign something-or-other in New York who say we're doing a 'disservice to the nation' by trying to get the country away from oil dependence. Do they think it's a 'service' to make it easier for some other country to have the leverage over us that we had over the Germans in the war? Those guys would probably also tell drunkards to make sure they have a glass or two of red wine every day for their health—not crazy in the abstract, but sure as hell not the message a guy in his cups needs to hear. But you're telling those council guys to get with the program and help get us off oil fast—John, you're my man."

8. Mandate a rapid transition to flexible fuel vehicles (FFVs).
Muir says this is simple, and would mean that both U.S.-produced vehicles and imports could use at least gasoline, ethanol (particularly cellulosic), butanol, and methanol in any mixture. This would create a market for renewable fuels by removing a needless barrier, Muir points out. He adds that using such fuels can substantially reduce greenhouse gas emissions, especially when the feedstocks are biomass and waste. The cost is modest—around $100 per vehicle or less. Between 2002 and 2005, Brazil moved from 5 percent to 75 percent of their new vehicles' being FFVs. Incentives such as tax credits should be provided promptly to encourage pumps for these fuels to be installed at stations.

"Hey, John," Patton booms. "I'm fine with markets and cap-and-trade and all that, but sometimes ya gotta just tell people to, damn it, *do* it. I got no problem with mandates—hell, if you gotta move fast and it's important, I absolutely *love* 'em. We did it for cars with seat belts and air bags because people's lives were at stake. Well, they're at stake because of oil dependence too. Getting away from that dependence is a matter of national security. Somebody just needs to show as much gumption as the Brazilians and issue a damned *order* about obvious stuff like this."

9. Provide incentives for the production of renewable fuels and specialty chemicals from cellulosic biomass; give special attention to the desirability of using waste products as a feedstock, particularly where methane is thereby reduced.
Muir points out that we should be moving away from hydrocarbons and toward carbohydrates generally as feedstocks for liquid fuels, electricity generation, and chemical production. But he is especially worried about a number of wastes producing methane if left in their natural state because of the latter's potency as a greenhouse gas—more than twenty times that of CO_2.

"Fine with me, John," says Patton. "Let's clean stuff up while we get off oil—a threefer: helps thwart the terrorists, reduces that carbon you're so worried about, and things smell better. I'm gonna start calling you 'God's janitor.' Basically you're nine for nine. Pretty interesting—we keep getting to the same place as long as we don't have to agree with one another's reasons for going there. Who'da thought it?"

"But there are three things you didn't mention," he adds: "Nuclear power, hydrogen, and coal-to-liquid transportation fuels. I've seen a lot of guys lobbying lately on all three of those—must be some money behind 'em. What do you think?"

Patton and Muir talk for a while and agree that nuclear power plants may be an acceptable last resort if we have to add generating capacity in the United States. Muir winces at the prospect, but in spite of the waste storage problem he's always been worried about, he's come reluctantly to support nuclear in some cases because of nuclear plants' lack of carbon emissions. Patton has a nagging problem with terrorist threats to power plants, but agrees that it would be very hard to cause a core meltdown. The two agree we should definitely oppose spreading nuclear energy around the world to new countries, since with today's treaties and inspections it's impossible in practical terms to stop countries from using their nuclear "electricity" programs as a way to get into the nuclear weapons business.

The hydrogen discussion just takes a few seconds. Both see some uses for hydrogen, but when they start talking about driving the "hydrogen highway" in family cars with hydrogen fuel cells and hydrogen storage and pumps at neighborhood filling stations, they shake their heads, amazed at the cost—especially, they chuckle, since the only infrastructure fueling cost you need for plug-in hybrids is an extension cord for each car-driving household.

Coal-to-liquids (CTL) is their only area of disagreement. Muir hates the carbon it would produce; Patton likes the way it undermines oil. As they finish their discussion, Patton puts a hand on Muir's shoulder and says, "John, tell you what I'll do. Even though CTL plants would use American coal, which I like, some plants might need a big infrastructure that could be vulnerable to terrorists, which I don't like. I'm happy with your transportation ideas because they move us toward small local plants and distributed production of fuel, whether electricity or liquid—nicely resilient. How about this: unless they figure out how to sequester enough of the carbon from CTL to satisfy you, I won't drop this option but I'll move it down to the bottom of my list—but in exchange I'd like a little help from you on

another matter: I think the Army needs at least two to three more armored divisions. What do you say?"

"George," laughs Muir, "You're a piece of work. I might be able to talk myself into rolling over for one or two of those things, but, if I do, for each one I support I'm going to need your backing for at least one new national park."

"John," says Patton, "I like your style. Say, can you hunt in those places?"

"George," gasps Muir, "you are absolutely imposs—"

Patton grins. "Just pullin' your chain."

As they stroll off together into the evening haze, Patton's ghost begins slightly to resemble Humphrey Bogart, and Muir's, Claude Raines. Patton grins and says, "Y'know, Johnny, this could be the start of a beautiful friendship."

Notes

Epigraphs: Roberta Wohlstetter, *Pearl Harbor: Warning and Decision* (Stanford University Press, 1962); Amory Lovins and Hunter Lovins, *Brittle Power: Energy Strategy for National Security* (Andover, Mass.: Brick House, 1982).

1. Ray Kurzweil, *The Singularity Is Near* (New York: Viking, 2005), p. 8.

2. Fred Pearce, *With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change* (Boston: Beacon Press, 2007): 58.

3. S. A. Zimov, E. A. G. Schuur, and F. S. Chapin III, "Permafrost and the Global Carbon Budget," *Science* 312 (2006): 1612–13.

4. L. Denman, G. Brasseur, A. Chidthaisong, and others, "Couplings between Changes in the Climate System and Biogeochemistry," in *Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* edited by Susan Solomon and others (Cambridge University Press, 2007).

5. P. Forster, V. Ramaswamy, P. Artaxo, and others, "Changes in Atmospheric Constituents and in Radiative Forcing," in *Climate Change 2007: The Physical Science Basis.*

6. Pearce, *With Speed and Violence,* pp. 77–85.

7. Ibid., p. 85 (citing L. Smith).

8. J. T. Overpeck and others, "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise," *Science* 311 (2006): 1747–50.

9. Joseph Romm, *Hell and High Water: Global Warming: The Solution and the Politics—and What We Should Do* (New York: HarperCollins, 2007), p. 86.

10. Ibid., p. 86; Pearce, *With Speed and Violence,* p. 58.

11. Overpeck and others, "Paleoclimatic Evidence for Future Ice-Sheet Instability."

12. J. Hansen and others, "Climate Change and Trace Gases," *Philosophical Transactions of the Royal Society* 365 (2007): 1925–54, doi: 10.1098/tsta.2007.2052. (http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_2.pdf).

13. James Hansen, "Scientific Reticence and Sea Level Rise," *Environmental Research Letters* 2 (March 23, 2007) (http://arxiv.org/ftp/physics/papers/0703/0703220.pdf).

14. Robert Zubrin, *Energy Victory* (Amherst, N.Y.: Prometheus Books, 2007), p. 109, quoting Louis D. Johnston and Samuel H. Williamson, "The Annual Real and Nominal GDP for the United States, 1790–Present," *Economic History Services* (July 27, 2007); see also http://www.measuringworth.com/datasets/usgdp/result.php.

15. Zubrin, *Energy Victory,* p. 109.

16. Ibid., pp. 109–10.

17. McKinsey Global Institute, "Curbing Global Energy Demand Growth: The Energy Productivity Opportunity," report (New York: McKinsey & Company, May 2007), p. 11.

18. IPCC, "Summary for Policymakers," in *Climate Change 2007: The Physical Science Basis.*

19. Pearce, *With Speed and Violence,* p. 59.

20. Romm, *Hell and High Water,* p. 86.

21. Ibid., quoting Peter Barrett.

22. Jay Gulledge, of the Pew Center on Global Climate Change, generated maps showing inundation patterns in May 2007. See appendix B in chapter 3 of this volume, pp. 89–91.

23. Roger Pielke and others, "Climate Change 2007: Lifting the Taboo on Adaptation," *Nature* 445 (2007): 597–98, citing Kelvin S. Rodolfo and Fernando P. Siringan, "Global Sea-level Rise Is Recognised, but Flooding from Anthropogenic Land Subsidence Is Ignored around Northern Manila Bay, Philippines," *Disasters* 30 (2006): 118–39.

24. J. L. González and T. E. Törnqvist, "Coastal Louisiana in Crisis: Subsidence or Sea Level Rise?" *Eos: Transactions of the American Geophysical Union* 87, no. 45 (November 7, 2006): 493–508.

25. Raymond S. Bradley and others, "Climate Change: Threats to Water Supplies in the Tropical Andes," *Science* 312 (2006): 1755–56.

26. Lawrence Wright, *The Looming Tower: Al Qaeda and the Road to 9/11* (New York: Knopf, 2006), p. 49.

27. National Research Council, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* (Washington: National Academy of Sciences, 2002), p. 182.

28. John S. Foster Jr. and others, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack* (Washington: U.S. Electromagnetic Pulse Commission, 2004), pp. 1–2.

29. Ibid., pp. 17–18.

30. Ibid., pp. 40.

31. McKinsey Global Institute, "Curbing Global Energy Demand Growth," p. 12

32. The Rocky Mountain Institute (RMI) describes itself as "a nonprofit organization that fosters the efficient and restorative use of resources so that companies, governments and organizations are more efficient, make more money, and do less harm to the environment." For more information, see www.rmi.org.

33. Michael Kintner-Meyer and others, "Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional Power Grids," Part I, "Technical Analysis," report prepared by the Pacific Northwest National Laboratory for the U.S. Department of Energy, November 2007 (www.pnl.gov/energy/eed/etd/pdfs/phev_feasibility_analysis_combined.pdf).

34. Willett Kempton and Jasna Tomic, "Vehicle-to-Grid Power Fundamentals: Calculating Capacity and Net Revenue," *Journal of Power Sources* (2005)(www.sciencedirect.com).