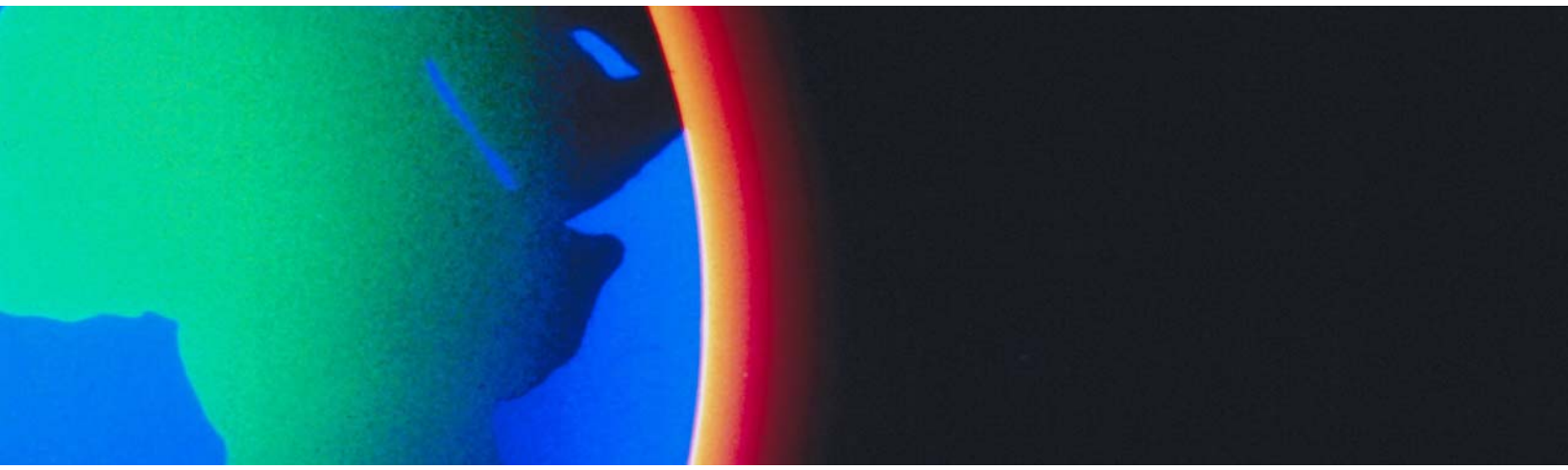
Impacts of Climate Change



A System Vulnerability Approach to Consider the Potential Impacts to 2050 of a Mid-Upper Greenhouse Gas Emissions Scenario

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Executive Summary

Climate change poses unique challenges to U.S. national security and interests. Yet current approaches and methods for understanding climate change and its impacts fall short in their efforts to help us anticipate and prepare for these eventualities. This white paper is intended to help imagine potential impacts of climate change and to develop alternative analytic approaches for understanding climate change disruptions.

In this paper, we explore several of the possible impacts of continued, relatively unrestrained greenhouse gas (GHG) emissions over the next half-century. These impacts, although not always highly likely, are plausible. In particular, we focus on already stressed systems that are vulnerable to being driven over the edge or past a tipping point by either radical or gradual shifts in climate. By doing so, we offer an alternative, analytic approach—a "system vulnerability approach" —to understanding and anticipating climate change disruptions. We conclude by considering both the security implications of the climate impacts discussed in this paper, and the analytic opportunities provided by the systems vulnerabilities approach.

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"I'm a believer in nonlinear systems theory. I don't think that a lot of these things will manifest themselves in an incremental way. I would expect, instead, that we might see some pretty sharp system shocks.... I think that the kind of crisis we might see would be a result of systems that are kind of stressed to the max already, where policymakers are trying to keep ten balls in the air simultaneously and keep all the various constituencies satisfied as best they can. And then there's some exogenous shock on an already highly stressed system that produces a kind of overload situation. I've always thought that 'overload theories' or 'overload explanations' of social breakdown are probably the most persuasive. The best theories of revolution and civil instability generally stress that societies face crisis when they're hit by multiple shocks simultaneously or they're affected by multiple stresses simultaneously."

– Thomas Homer-Dixon, author of *The Upside of Down: Catastrophe, Creativity, and the Renewal of Civilization*, 13 October 2006

Introduction

Climate change is a real and growing problem for the United States and for the world. As urgency around the issue continues to grow, so too does the scientific consensus that changes to Earth's climate will enormously affect the planet's future and the futures of all who inhabit it. Anthropogenic climate change is now widely considered to have the potential not just to cause perturbations in the weather, but also to create major discontinuities in many complex natural and human systems, including ecosystems, economies, human settlements, and even political institutions.

Over the past two decades, and especially in the last few years, climate change has become one of the most heavily researched subjects in science.[1] Yet climate change impact studies remain at the low end of usefulness for policymakers and others; they are not predictive enough to be actionable because the exact nature of the events that will jar the planet in the near- and long-term future—the wheres, whens, and hows of climate change—remains both unknown and unknowable. This paper offers policymakers an alternative approach to thinking about climate change and its impacts. *Instead of starting with climate change and working out toward impacts, we focus on systems that are already generally vulnerable first, and then consider what the geophysics of climate change may do to them*. This approach has two benefits. First, it limits the number of logical steps necessary for thinking about the impacts of climate change, enabling more confident insights and conclusions. Second, it cuts across analytic stovepipes and gives regional specialists a framework for thinking about what climate change will mean for their particular areas, based on expertise they already have.

In its analysis of climate change impacts, this paper makes the assumption that the global political economy will continue to operate under more or less the same conditions as it does today—in other words, with a continued emphasis on expanding global GDP as the No. 1 economic priority, heavy reliance on fossil fuels, no radical redistribution of global wealth or power, and no major political breakthrough on how to curb global greenhouse gas (GHG) emissions. Although for the purposes of our research we have used the SRES A2 marker scenario by the Intergovernmental Panel on Climate Change (IPCC) as the reference scenario,[2] our conclusions will apply to most other mid- to high-emissions scenarios.[3]

The Scientific Consensus on the Impact of Mid-Upper GHG Emissions

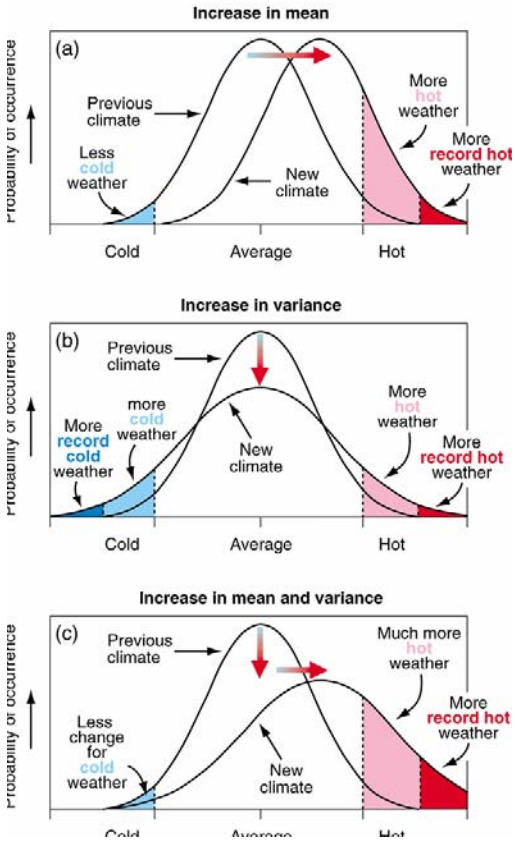
The scientific community now agrees on the expected overall geophysical effects of a "mid-upper" greenhouse gas (GHG) emissions scenario and on many of the first-order biophysical effects. In this paper, we work from the findings of the IPCC Working Group II's conclusions about the high-probability (67 to 95 percent likelihood) impacts of climate change: [4]

Geophysical effect	Probability	Impacts likely to occur somewhere
Higher maximum temperatures, more hot days, and heat waves over nearly all land areas	Very likely (90-99%)	• Increased deaths and serious illness in older age groups and urban poor • Increased heat stress in livestock and wildlife • Increased risk of damage to a number of crops • Increased electric cooling demand and reduced energy supply reliability
Higher minimum temperatures, fewer cold days, frost days, and cold waves over nearly all land areas	Very likely (90-99%)	• Decreased cold-related human morbidity and mortality • Decreased risk of damage to a number of crops, and increased risk to others • Extended range and activity of some pest and disease vectors • Reduced heating energy demand
More intense precipitation events	Very likely (90-99%)	• Increased flood, landslide, avalanche, and mudslide damage • Increased soil erosion • Increased flood runoff • Increasing recharge of some floodplain aquifers
Increased summer drying over most mid-latitude continental interiors and associated risk of drought	Likely (67-90%)	• Decreased crop yields • Increased damage to building foundations caused by ground shrinkage • Decreased water resource quantity and quality • Increased risk of forest fire
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities	Likely (67-90%)	• Increased risks to human life and risk of infectious disease epidemics • Increased coastal erosion and damage to coastal buildings and infrastructure • Increased damage to coastal ecosystems such as coral reefs and mangrove swamps
Intensified droughts and floods associated with El Niño events	Likely (67-90%)	• Decreased agricultural and rangeland productivity in drought- and flood-prone regions • Decreased hydropower potential in drought-prone regions
Increased Asian monsoon variability	Likely (67-90%)	• Increase in flood and drought magnitude and damages in temperate and tropical Asia

It should be emphasized that these are only the effects about which there is broad scientific consensus, and *it is therefore not an exhaustive list of the impacts that are likely to take place.* For example, scientists are unsure about whether increased atmospheric GHGs will increase the intensity of mid-latitude storms. If this turns out to be the case, there will be increased risks to human life and health, increased property and infrastructure losses, and increased damage to coastal ecosystems in these latitudes.

Climate as a Dynamic, Chaotic System

It is important for those interested in the human significance of climate change to consider the fallacy of averages. While the SRES A2 scenario suggests that the average temperature of Earth will warm by between 0.7 and 2.0° Celsius (with an average of about 1.3° Celsius) by 2050, this warming will not occur as a smoothly rising average but rather will be punctuated by a series of extremes and excursions.



Schematic showing the effect on temperatures when (a) the mean temperature increases, (b) the variance increases, and (c) when both increase. (Source: http://www.grida.no/climate/ipcc_tar/wg1/088.htm)

Scientists largely agree on how some of this variance will play out; higher latitudes, for example, are likely to experience more extreme change than the tropics. Likewise, there will also be an increase in the variability of weather patterns globally—more frequent and more intense rainfall events, more intense heat waves, and prolonged droughts. The exact geographies of extreme events are difficult to forecast, but their occurrence *somewhere* is close to certain.[5]

It is also important to underscore that within a smoothly rising, long-term, global average, there are very likely to be unpredictable, nonlinear excursions from the global mean. Here, the science is less certain, but reasonable guesses can be made.[6] Viewed locally, the effects of climate change are likely to be either far greater or far less than whatever is expressed as the "average." Some places are very likely to experience great divergences from the global average: a series of summer snow storms in Stockholm, for example, or a host of hurricanes hitting Rio, or an endless drought in Delhi. But even if we assume a smoothly rising long-term average, the global climate as a whole may be subject to excursions from the gradually rising mean. In other words, the actual global average, while steadily rising over the long term, may be subject to medium-term (that is, geologically short but for humans rather long) excursions from the mean. These excursions may take the form of rapid aggregate rises (for example, global average temperature jumping 1° Celsius in five years) or perhaps medium-term flattening or even drops in average temperature.[7] The combination of greater standard deviations in weather (about which climate scientists are quite sure) and the likelihood of excursions from the overall mean (about which scientists are less sure) suggests a future of chaotic fluctuations.

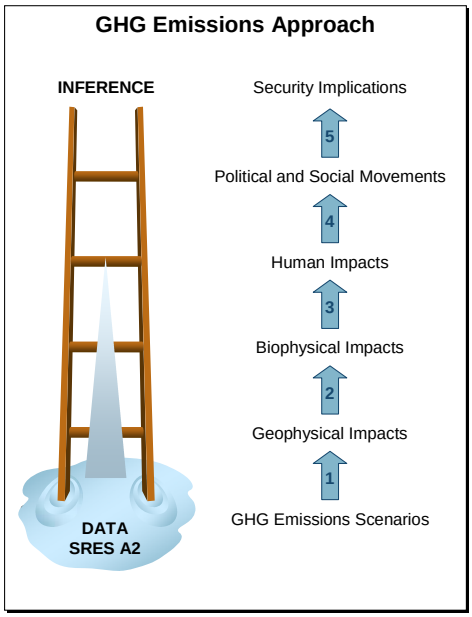
Finally, the high likelihood of extreme events and nonlinear excursions in global climate intersects with the question of threshold effects. As extreme events—perhaps compounded by medium-term excursions—take place, the chance that any given event will exceed the built-in resiliency of a natural or human system rises dramatically. And when such a threshold is passed, the amount of damage also rises steeply. As Eugene Linden observes:

> When pushed past a certain threshold, the damage of natural events increases exponentially. If natural buffers have been eliminated, that threshold is lower. The difference between a Red River crest of 49 feet (as was predicted for Grand Forks, North Dakota, during the 1997 flood) and 54 feet is 10 percent, but the economic damage resulting from a 54-foot crest might be more than 100 times greater because the flood would breach containing barriers built under the assumption that the river could never reach that level. This was a reasonable assumption, because the river had never before crested that high—the peak volume of the 1997 flood at Grand Forks was 27 times average flow and more than 50 percent higher than the "100-year" flood of 1979. Thus, efforts to contain natural events such as floods, combined with our conversion of natural buffers, has the triple effect of diminishing nature's capacity to modulate floods, increasing river levels, and dramatically increasing potential damage.[8]

In other words, the steady escalation of climate pressure will stretch the resiliency of natural and human systems, making individual regions and their systems increasingly vulnerable to increasingly frequent "outlier" weather events. In short, climate change pushes systems everywhere toward their tipping point.

Standard Approaches Using GHG Emissions

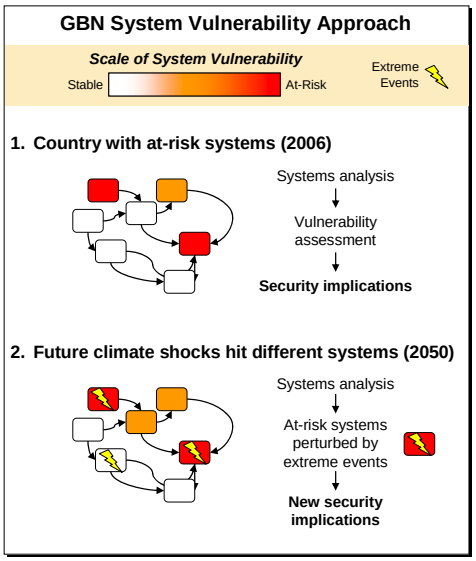
Traditional climate change assessments focus first and foremost on the likely "first-order" geophysical effects that increased GHGs will have on climate. From there, they consider (with somewhat less certainty) what second-order effects these climate changes will have on biophysical systems. The next step is to guess (with even less certainty) how these effects will in turn create third-order effects—changes in patterns for vector-borne disease, famines, increased heat deaths, environmental refugees, and so on—that greatly impact humans. Finally (and with very little certainty whatsoever), there may be speculation about how political or social systems might react to these third-order effects—by which time we're talking about *fourth-order effects*. Climate scientists (who, like all scientists, like to stay close to the facts) are often reluctant to make meaningful claims that rest on such an extended ladder of inference. The ironic result is that climate scientists, despite being collectively deeply worried about the impact of climate change, have often been hesitant to make strong claims about how climate change will affect human beings.



System Vulnerability Approach

To avoid this analytic trap, this paper inverts this traditional framework. Rather than begin with the climate, we instead look at human and natural systems that are *already* in a state of dynamic tension, or that can reasonably be expected to be entering a phase of dynamic instability. We then

suggest how climate change, while of uncertain specific effects, is likely to apply additional stress to these already-perturbed systems. In other words, *we start by looking at the objects of change themselves*, determining those that are in such a state of flux that the "certain uncertainty" of climate change may have a radically destabilizing, albeit specifically unknowable, effects on them. While we cannot know which exact systems will experience radical disruption as a result of climate change, we can predict with a high degree of confidence that at least *some* of the systems in some places will experience very serious perturbations in the next half century as a result of climate change.



What follows, then, are examples of the kinds of systems that are already in flux, under pressure, or in a state of nonlinear disruption; this list is non-exhaustive, and a similar mode of analysis can be applied to many other systems. We begin by explaining the current dynamic challenges facing each system, and then suggest ways in which climate change might further unsettle it, yielding nonlinear surprises.

It is worth noting here that many of these vulnerable systems are interconnected in complex and profound ways. As the global macrosystem becomes increasingly complex and interconnected, it also becomes more vulnerable to cascading failures. A single stressed system, when confronted by the acute impact of climate change, may generate results even more surprising or extreme than what we depict here. We will return to this point in the conclusion to the paper.

Vulnerable Systems

Ecosystems

Imagine If…

Increasing temperatures and rainfall result in the reemergence of malaria in the southern U.S. Local environmentalists mount a massive PR campaign to prevent the spraying of pesticides such as DDT, leaving the government with the serious dilemma of how to stop the disease from spreading.

Currently, many ecosystems worldwide are under intense pressure. Much of this pressure is the result of human encroachment via urbanization, the harvesting of natural resources, or clearing for farmland. Where changes to the natural environment are gradual, ecosystems often can migrate or restabilize. But rapid change is very difficult for ecosystems to deal with; for those that are already highly distressed, an additional shock can result in ecosystem implosion.[9] Collapsing ecosystems not only bring great hardship on people who depend on the products of these ecosystems for their livelihood, but also are ripe grounds for invasive species and the release of new pests. The World Health Organization has identified 30 new diseases in the past 20 years, nearly all arising from distressed ecosystems.[10]

Climate change exacerbates the problem of stressed ecosystems. In the past, as climate changed, ecosystems could shift to new zones. But with human settlements and infrastructure blocking migration paths, already-stressed ecosystems will be largely unable to shift location.[11] As Stephen Carpenter, past president of the Ecological Society of America, explains, "There is a common pattern we're seeing in ecosystems around the world: gradual changes in vulnerability accumulate and eventually you get a shock to the system, a flood or a drought, and boom, you're over into another regime. It becomes a self-sustaining collapse."[12] Sixty percent of the world's ecosystems are degraded to the point that people can no longer rely on the benefits they provide; some of the most severely stressed include the Aral Sea basin in Central Asia, the North Sea, the Arctic, the Great Lakes region in Africa, and the Amazon basin. Even a relatively short-term excursion from the normal climate could tip any of these systems into full-scale collapse. While ecosystems have always been dynamic and changing (and subject to collapse), the scientific ability to track such collapses, and the media visibility of such collapses, is far greater than it has ever been. How the global public will react to such collapses is largely unknown.

Water Availability

Imagine If…

A Chinese industrial complex dumps toxic sludge into the Brahmaputra River, irreversibly contaminating downstream polluted water in the Lower Ganges, increasing disease among the downstream Indian and Bangladeshi populations, and sparking a regional conflict over available water.

Water is indispensable to human survival and to most forms of economic production. Today, with more than 500 million people living in semi-arid areas and more than 200 million people in arid areas, access to water and water allocation is a key source of tension.[13] Lack of access to clean water is a huge problem in most cities (and many rural areas) in the Global South. In places experiencing rapid

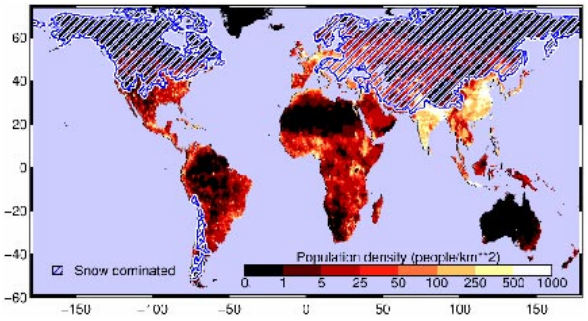


Image courtesy of Scripps Oceanographic Institute: http://scrippsnews.ucsd.edu/article_detail.cfm?article_num=703

population growth, such as South Asia and Central Africa, there are likely to be rapid increases in water withdrawals, causing a similarly rapid increase in untreated return flows to the freshwater systems, which will endanger public health and aquatic ecosystems. Agricultural intensification may also lead to the contamination of surface and groundwater.

Meanwhile, insufficient attention to water quality protection is leading to water scarcity.[14] In China, for example, failure to prevent contamination of the water supply through water treatment is enabling large-scale production and circulation of water that is unsuitable for human use. Yet the lack of clean water has a direct and massive impact on human health. As the Pacific Institute observes, "If no action is taken to address unmet basic human needs for water, as many as 135 million people will die from these diseases by 2020. Even if the explicit Millennium Goals announced by the United Nations in 2000 are achieved…between 34 million and 76 million people will perish from water-related diseases by 2020."[15]

At a local level, violent conflicts over water—particularly fight over the privatization of drinking water and access to water points—are already widespread. Virtually all of the world's major rivers run through multiple countries, yet there are few international structures, treaties, or institutions in place to efficiently and peacefully manage shared water resources.[16] Upstream countries could withhold or contaminate water, creating tensions with downstream neighbors. Conflict between countries that share a river basin could hinder sustainable development, thus indirectly driving poverty, migration, and social instability. Such tensions may also exacerbate non-water-related conflicts.[17]

As the World Water Council explains, climate change mainly increases "the frequency of events that have always been at the heart of the concerns of water managers."[18] As noted above, climate change will significantly change precipitation and evapotranspiration patterns. According to the IPCC, "By 2050, as much as 42 percent of the world's population may have to live in countries with insufficient freshwater stocks to meet the combined needs of agriculture, industry, and domestic use."[19] A warming climate means more water will fall in the form of rain rather than snow, meaning less snow accumulation in the winter and earlier snow-derived water runoff in the spring, challenging the capacities of existing water reservoirs in parts of the world reliant on snowmelt. (The Western U.S. and Central Asia are especially vulnerable to this effect.) Facing even more serious consequences by 2050 will be regions dependent on glacial melting for water: once the glaciers have melted, there will be no replacement. Glaciers in Peru have experienced a 25 percent reduction in the past three decades, with further shrinking anticipated. The biggest impacts from glacial melting, however, will be felt in Asia, where hundreds of millions of people rely on waters from vanishing glaciers on the Tibetan plateau.[20]

Climate change will also cause extreme rainfall events and droughts that will increase vector-borne diseases.[21] With rainfall and temperature more variable, agricultural productivity is likely to fall, perhaps dramatically, in much of Africa and South Asia. Finally, the direct security implications of climate-driven changes to water supplies include the possibility of "war waters" between Israel and its enemies, between China and India, between India and Bangladesh, between

Angola and Namibia, and between Egypt and Ethiopia.[22] Desertification, perhaps occurring rapidly during an extreme drying excursion, may cause as many as 30 million people to attempt to flee sub-Saharan Africa for Europe.[23]

Urban Forms

Alongside the global population explosion, the greatest demographic story of the past century has been the urbanization of the human population. In 1900, only one in 20 of the world's 1.6 billion people lived in cities; today, about half of the world's 6.6 billion people live in urban areas. As world population grows to between 9 billion and 10 billion (and possibly higher) by 2050, the vast majority of that growth will take place in the cities of the Global South.[24]

Imagine If…

An already overheated Sao Paolo is struck by a 10-day heat wave with temperatures soaring above 100 degrees. The demand for energy overwhelms the regional power grid, leaving millions sweltering in the dark. Industrial production essentially shuts down in Brazil, disrupting global supply chains.

Cities depend on vast flows of goods to sustain their populations: food, water, fuel, and construction materials must be constantly imported; sewage and other waste must be exported; and fresh air must circulate. Although cities in developed countries appear to have solved the most pressing health and economic problems associated with hyperdense human settlement, rapid growth in Global South countries has led to extreme shortages of basic social services, a glaring lack of infrastructure, and chronic air and water pollution. These problems will only worsen, as most of the oncoming growth will inevitably take place on less desirable, more at-risk land: hillsides, gullies, swamps, and so on. Because the urban poor live in appalling sanitary conditions, cities are ideal breeding grounds for vector-borne diseases. Not coincidentally, urban spaces have often been flashpoints for political discontent and uprisings. Without question, urban planning and control will be a critical skill for the U.S. government.

Climate change is likely to exacerbate all the nocuous aspects of urban life in the Global South. More frequent and severe heat waves will increase the risk of heat-related mortality in cities. Because of their energy use, cities experience "urban heat island" effects, so that temperatures are 1 to 5°C warmer in a city than in surrounding countryside, with the gradient most pronounced at night. Overheated urban environments will experience increased energy demand for air conditioning and refrigeration, creating a positive feedback loop toward more air pollution. While pandemics are likely to begin in the countryside, they will combust in cities of the Global South, where the consequences will be especially dire. As Tom Koch observes, "Historically it has always been [urban population] density combined with income inequalities that assures the evolution of pathogens that find humankind an inviting host. Poverty means crowded, substandard living conditions and a lack of appropriate healthcare that together assure communities ripe for microbial colonization."[25]

In "megacities" situated in zones prone to severe cyclonic storms and storm surges, severe flooding may occur, especially toward the middle of the century, as sea levels rise 30 to 42 cm.[26] Even small storm surges are likely to flood large portions of coastal cities, with large storm surges having the potential to precipitate a macrosystemic discontinuity.[27] Also of concern are the 30,000 largely anonymous "secondary" urban centers in the Global South, which face the same problems as megacities but lack the same national attention or international visibility.[28] Finally, because

fresh water flows are the single most important factor in the urban ecosystems, cities where available fresh water is the rate-limiting factor for a decent existence (for example, Mexico City, Delhi, Cairo, and Lima) are especially vulnerable to political unrest if water supplies dry up.[29]

Consensus on the Proper Scope of the State

Imagine If…

After a string of hurricanes hits South Florida over the course of two years, the government faces pressure from other parts of the country to abandon the Florida Keys rather than continue to rebuild and "throw away good money."

The last generation has witnessed a dramatic shift in the consensus on the proper scope of the state. Whether described as privatization, the Washington Consensus, liberalization, or "steer, don't row,"[30] the scope of the state has narrowed dramatically from the post-WWII heyday of statism. OECD countries are dismantling their welfare states; post-Communist states have retreated from "the commanding heights"; and in the Global South, structural adjustment programs have eviscerated the "developmental" state.[31] However, what seemed like an overwhelming historical direction in the 1990s has in recent years become contested. From Putin's Russia to Chavez's Venezuela to Chirac's France, resistance to the privatization or outsourcing of social services has been a growing political force in all parts of the world. Resistance to the privatization of water resources has been a particularly explosive issue, raising thorny questions about the definition of public versus private goods and how to rationally allocate a scarce good while ensuring minimal access and social equity.[32] In Bolivia, for example, resistance to water privatization has been the leading indicator in the rise of anti-liberal, neo-statist regimes.[33]

Climate change will shine a spotlight on this ideological debate. The capacity of private-sector institutions to cope with system discontinuities of the scope likely to result from climate change is dubious. Governments may soon face a choice of either becoming de facto insurers of the worst climate risks or else allowing large sectors of their population to become uninsured. This problem is particularly acute in the U.S., Berkeley political scientist Steven Weber points out, because the U.S. lacks a common political language for talking about how the state does and should socialize risk, as well as how (given state risk mitigations) individuals should be restrained from making antisocial choices. As Chris Walker of Swiss Re points out, if the state steps in to provide insurance to protect against climate change-driven storms, it will soon become clear that grandmothers in Albany are paying to insure the lifestyle choices of beachside condo-dwellers. How the public will react to this is uncertain: will there be demand for a state policy of sending market-driven price signals to owners and developers in high-risk areas, in which case development may become unfinanceable along the Gulf Coast and eastern seaboard? Or will there be a reaction against market-based mechanisms, as seems to be taking place elsewhere? Climate change may act as a forcing function in pushing for a resolution to this ideological tension. Depending on the result, such a resolution might have spillover consequences for how the public perceives other forms of social risk-sharing, such as the debate over national healthcare provision. Needless to say, if climate change has the potential to destabilize the consensus about the liberal state in the U.S., its potential to disrupt liberalizing policies in other countries is even greater.

Civil Order

From Iraq post-2003 invasion to the suburbs of Paris in 2005, a mix of natural disasters, official incompetence, socioeconomic inequality, and racism has made the fragility of civil orders, even in developed countries, painfully evident. While both the stability of the civil order and its ability to suddenly collapse are *prima facie* political occurrences, they are almost invariably precipitated by a witches' brew of causal factors, which can include climate or weather stress.

Imagine If…

A paralyzing dust storm sweeps through Cairo, exacerbating an already precarious supply of water and food. The government's inability to respond sparks riots in the streets and creates an opportunity for the Muslim Brotherhood to step in as the de facto provider to the people, rallying them around the incompetencies of the state.

The key question here is the ratio between citizen expectations and government capacity. Citizens in the developed world tend to have much greater expectations of their government's ability to respond in the face of disaster. As extreme weather events become more frequent and more extreme, political institutions and leaders will be regularly tested to see if they meet expectations. If a developed-world government conspicuously fails to respond to a disaster in a way that meets citizen expectations, the collapse of civil order is likely to ensue very rapidly. While developed countries are likely to be able to restore order relatively quickly, in the longer term such collapses of order can undermine the legitimacy of both political leaders and political institutions. In the Global South, citizen expectations of government assistance in the face of disaster tend to be much lower than in the developed world, so the necessary response is less. But here too inadequate responses can prove devastating for governments. The poor response of the Pakistani government in the aftermath of the Bhola Cyclone of 1970, in which perhaps half a million people perished, was a major contributing factor that led to the violent splitting of East Pakistan (Bangladesh) from the rest of Pakistan in the spring of 1971.[34] It is worth emphasizing, moreover, that the only difference between the collapse of civil order and a failed state is whether order is eventually restored. Environmentally failed states are a nontrivial possibility.

Traditional Political Coalitions

For most of the twentieth century, the most common political pattern both within states and between states was a spectrum from "left" to "right," defined largely in terms of economic class sympathies and sympathies with collectivization. The major exception has been ethnic and nationalist political movements, which were often associated with racist or fascist ideologies. When environmentalists emerged as an important political force in Western states the 1970s and 1980s, these parties most frequently allied themselves with the left. With the ideological collapse of Communism in the 1980s, former communists and socialists often landed politically in green parties. Blaming environmental problems on companies rather than the state provided former leftists with a venue for continuing to attack capitalism—what post-unification Germans refer to as "watermelon" politics: green on the outside, red on the inside.

Imagine If…

Climate disruptions drive the formation of "Tea Leaf Coalitions" (blackshirts + greens) in Europe: nativist parties team up with environmentalists to keep immigrants out and to prevent the Global South from contributing to GHGs.

Because of the enormous collective risks associated with climate change, however, climate change may form the basis for a new set of political coalitions and oppositions that do not fit within the political paradigm described above. One possibility is that political coalitions and parties may be reformed around different attitudes to social risk-sharing, with one faction opting for having the state take an activist approach to mitigating a variety of "big" security risks (military, terrorist, environmental) and another coalition forming around allowing people to fend for themselves, with a less intrusive but also less protective state. The recent debate in the Sierra Club over the organization's stance on immigration presages such a formation,[35] as does the current debate in Europe about "repatriation" of immigrants.[36] A third possibility is that religious parties may form coalitions with Green parties, or adopt environmentalism as part of their political agenda.[37] For all these possibilities, headline environmental events related to weather disasters, perhaps attributed to climate change, could catalyze the formation of new political coalitions.

Insurance

Imagine If…

A major earthquake in California combined with flooding along the eastern seaboard pushes a major reinsurer to the brink of bankruptcy. As a major financial crisis takes shape, the U.S. Treasury and a coalition of financial institutions devise a bailout plan.

The insurance industry provides products for hedging against the risk of potential financial loss. Insurance works by measuring the rate at which losses take place for individuals for a given type of risk, and giving individuals personal (financial) protection from these risks in exchange for a payment based on the stochastic probability that the downside event will take place. By redistributing risk in both time and space, it allows for voluntary sharing of the risk associated with local or individual action. For our purposes it is important to recognize that there are both private and government forms of insurance. In the U.S., private companies for the most part provide personal insurance. However, the state is the formal insurer of many high-risk groups, and also acts as the insurer of last resort in the event of large disasters. Another key structural element of the insurance industry is that it is highly regulated industry, with the state (or, in the U.S., each individual state) regulating what kinds of coverage insurance companies can offer and at what prices. Insurance is enormously important, in part because without the socialization of risk, development becomes much more difficult. For example, a large hotel chain building a condo complex in the Bahamas or Miami cannot afford a total loss in the event of a hurricane; without insurance, it is much less likely to proceed with the investment. At the level of personal well-being, insurance also allows individuals to lead much more stress-free lives.

Climate change poses a series of interlocking challenges to the insurance industry. The first challenge is that insurance prices for events like floods, droughts, wind, hurricanes, and tornadoes are all based on historical data—in other words, on the past probability of events occurring in given locations. Climate change makes this historical data much less useful, as the risks for any given location for any of these events is likely to change, but by an unknown amount. Insurance companies do not know how to set the right prices, especially given that they must hedge against the possibility of a severe multiyear excursion (for example, hurricanes might take out the same Caribbean hotel five years running). If insurance companies no longer feel comfortable about the risk they are assuming, they may simply exit some markets. While the state may pick up the burden, there is no evidence that the state will be any better than insurance companies at evaluating the emergent risk profile. Unlike insurance companies, states cannot simply "exit the

market." This means states will inevitably face politically thorny decisions about whether to rebuild after disasters. Given the combination of political pressure in a media-saturated environment and the lack of adequate risk modeling skills, the chances that states will make financially poor decisions is very high.[38] Not coincidentally, coastal populations in the U.S. are expected to grow by 25 million during the next 30 years.[39]

The second challenge is that even if the insurance companies (or states) can figure out the right prices, insurance regulators may prevent them from actually setting those prices. As the frequency and force of Atlantic hurricanes increases, for example, setting the right price for hurricane insurance in coastal Florida may in effect become a prohibition to further development, and break the cycle of real estate appreciation for existing property owners—something likely to be extremely politically unpopular. But if regulators force insurance companies to keep prices artificially low, not only will this fail to send the right price signal to individuals considering investing or moving to the Gulf, but it will also eventually force insurers to exit the market. Insurers are calling on governments "to allow for adjustment of homeowners insurance rates and flood insurance rates, and to develop appropriate price and risk signals to consumers and businesses moving into his risk areas." As insurer Allianz warns (or perhaps threatens), "Insurers only exit markets as a last resort; however, if governments and regulators do not allow for more pricing flexibility [read: rate raises], exiting markets becomes the last resort."[40] Expect insurers to lobby heavily to limit development in coastal floodplains and other high-risk areas.

The third major risk factor for insurers is the risk of liability from climate change. Already there are American trial lawyers who see climate change as the next great class action opportunity. There are lawyers who plan to argue that if a company produces 1 percent of the world's emissions, it should be held liable for 1 percent of all global warming-related damages. If such litigation is successful, and if CO_2 and other GHGs are deemed "pollutants," it is the insurance industry that may end up having to pay these settlements. Regardless of who ends up paying, the prospect looms of decades of climate change-related litigation. If such lawsuits start to gain traction, it will greatly complicate any regulatory activity on climate change, as companies will no longer be willing to engage in anything that might be interpreted as a de facto admission of liability.

Tourism

Tourism is a huge business, by some accounts driving 10 percent of the world's economic activity. Over the coming decades, two major trends are expected. First, the rise of Asians as tourists is expected to be a huge phenomenon. Second, long-haul travel worldwide is expected to grow faster than intraregional travel.[41] In sum, many more people are going to be seeing much more of the world. Climate change is likely to play into this phenomenon at two levels.

Imagine If…

Rising temperatures (unappealing to European tourists) and a failing infrastructure devastate the Moroccan tourist industry, sparking an economic collapse. As Islamist political parties exploit the chaos, those with the means flee to Europe, while those left behind create a new locale for trans-border illicit trade.

At one level, locales become winners and losers. Low- and mid-latitude ski locations, where snowlines are expected to move up as much as 100 meters a decade, will be losers. Countries specializing in ecotourism, such as Costa Rica, Ecuador, Brazil, and East Africa, could be

threatened by the relocation or disappearance of the flora and fauna that attracts tourists. Parts of the Mediterranean—including North Africa, Spain, and Southern Italy—could become unpleasantly hot. Shifting rainfall patterns might take a more profound toll on the ability of these regions to support large numbers of tourists. People from hot countries are likely to opt out from going to places that are getting too hot, and tourism as a whole is likely to become more sensitive to climate change over time.[42]

For countries that are staking their development strategies on tourism (most notably, small island nations in the Caribbean and the Indian and Pacific oceans), the stakes are especially high. Ironically, these countries figure to be among the greatest losers in the reshuffling of tourism that climate change will produce. Warmer winters in North America and Europe will decrease demand for the sunny winter escapes. At the same time, the "beach product offering" is likely to become less attractive as the heat index rises, beaches erode, sea and coral quality decline, and vector-borne diseases increase. (Diseases may also be spread by international tourism, and the industry is uniquely vulnerable to shut-down in the face of local epidemics.) Insofar as tourism-based development strategies fail, it will increase push factors for immigrants seeking to leave these countries.

However, there is also a possible, more subtle effect that tourism may play for climate change. The growing number of global tourists will also constitute a set of people who, by the very act of seeing many parts of the world, will become increasingly conscious of the impact of climate change. Whether they return to the same location year after year and thus track longitudinal climate-induced changes to the local environment, or go to very different places where they will witness the uncanny worldwide echoes of climate change, these will be people who are increasingly globally conscious of climate change. The constituency for GHG abatement and impact mitigation is thus likely to grow.

The Global Pop-Politics of Rumors

A key uncertainty for the political economy of climate change is how the public, which will all but inevitably remain scientifically unenlightened on the subject, will react to the news of climate change. One possibility, which has been largely realized in the U.S., is an ongoing, mutually reinforcing mixture of apathy and ignorance. Another possibility, however, is paranoid overreactions of various sorts.

There is a historical precedent for this worry. As Stewart Brand observes, during the 1950s, nuclear weapons or nuclear testing were blamed in some quarters for every sort of freak event. For the conspiracy-minded, everything untoward was traceable to the bomb. Freak snowstorm in October? *Must be those nuclear tests!* Five legged frogs in the local pond? *Those nuclear tests!* Outbreak of a long-absent disease? *Those tests!* It is distinctly possible that climate change—and, even more importantly,

Imagine If…

Climate change creates an influx of "participation science," where amateurs become the leading purveyors of information related to the human impact of climate change. ClimatePulse.com, a user-generated online site that styles itself a "wikipedia of ecosystems," becomes the "authority" on climate impacts, providing a heady mix of scientific half-truths and doomsday reporting on the local impacts of climate change. As it morphs into an organizational platform for transnational environmental activists, the site becomes one of the most frequently visited pages in the developed world.

any policy efforts designed to mitigate climate change—could come to occupy a similar place the cultural imagination: a bogey, this time reverberating not just in the U.S., but through the echo chamber of a globalized popular culture. If this takes place, it will add an additional layer of complexity to any political efforts to develop rational and fair, cost-benefit measured, technocratic responses to climate change.

Since the 1950s, pop culture has become much more volatile and fast-moving, in no small part because of the advent of new mass and social media, including the internet, video-sharing, podcasting, and the handheld devices for creating, distributing, and consuming information. What has emerged is a global popular culture of paranoia, ripe for exploitation by political opportunists. That climate change is likely to unfold in a series of excursions from the mean will serve to continually mask the broader trend—and a paranoid culture of half-wisdom and rumor-mongering could amplify these excursions. For example, climate change skeptics could use a five- to 10-year global cooling excursion to debunk climate science in the media. This possibility should especially concern those wishing to construct rational long-term policies appropriate for GHG emissions abatement and impact mitigation plans. If such a surprising global climate excursion toward cooling by chance took place just as global politicians put together a workable global GHG abatement plan, opportunists might seize the excursion as an excuse to dismiss the need for abatement. Others might blame the sudden random cooling on the excesses of the abatement regime itself, not realizing that the abatement could not possibly yet have had any effect on the weather. The chance that the political will to enforce an abatement scheme might unravel in the face of such an unluckily timed climate excursion is unlikely, but far from inconceivable.

Finally, as awareness of climate-related disasters unfolds, global public consciousness about climate change will grow, but not necessarily in a linear fashion or in response to facts. Public opinion will depend not on the actual threat of climate change, but rather on the *perception* of the threat of climate change. This perception may move very quickly in response to an acute crisis, and may stabilize at a very different crisis level. This may take place differently in different countries, and anger at the U.S. may rise if the U.S. continues to be perceived as indifferent even in the face of unfolding, interlocking global climate change disasters. At some point, the U.S. may no longer be able to be effective in “de-linking” climate change from other multilateral issues, including trade talks and security negotiations.

Conclusion: Security and Analytic Implications

This paper has presented a variety of potential impacts of climate change. It is possible to classify the security implications of climate change into three general categories:

1. *Impacts that constrain U.S. freedom of action and operations.* These constraints can emerge because of changes to the U.S. strategic position, or that change popular U.S. political attitudes. They may also be a result of novel challenges from new, climate change-driven political formations outside the U.S. For the systems examined in this paper, the global rumor mill, a changing consensus on the scope of the state, or new national or transnational environmental coalitions may all pose new constraints on U.S. freedom of action and operations.
2. *Impacts that pose novel challenges for action.* These challenges arise largely because of acute systems disruptions. Such acute crises may force the U.S., as a global leader, to act in situations that it might otherwise have preferred to ignore. For example, a major local crisis in water availability, or a collapse in civil order, or the implosion of one or more major cities are all likely to demand U.S. response.
3. *Impacts that impose new kinds of costs and requirements for preemptive action.* Forestalling the worst effects of anthropogenic climate change demands long-range planning. Abatement of the underlying driver, namely GHG emissions, is an obvious imperative, but also one that does not solve the potentially near-term challenges discussed in this paper. The U.S. may need to adopt a "preemptive" approach to forestall the worst effects of collapsing ecosystems, water systems, or radical restructuring of the global insurance industry.

Cascading Failures May Produce Major System Discontinuities

In thinking about the systemic impact of climate change, it is important to focus not just on the individual systems that may be disrupted, but also on how disruptions may cascade or reverberate between different systems. Because of the synergies in the highly integrated macrosystem, the convergence of systemic stresses and climate change may produce simultaneous nonlinearities across multiple systems that risk overloading the macrosystem as a whole, creating the possibility of catastrophic failure. Theories of revolution show that it is the simultaneity of impacts and stresses on a macrosystem that produces collapses.

For example, consider the interplay of the collapse of civil order and the dynamics of urbanization. If a climate change-induced system disruption reduces the ability of the government to deliver political goods (Katrina being an obvious example), it also reduces political legitimacy and halts economic activity, thus driving local populations to rely upon primary loyalties (families, neighborhoods, religious organizations, gangs, etc.) for daily survival. This dynamic in the political system is often (and will increasingly be) played out in urban settings—physical spaces that require intensive external flows of goods and services to survive, and that are also highly (and increasingly) interconnected and networked via transport and telecommunications infrastructure. Collapsing civil order within urban settings will offer extreme economic rewards in the form of smuggling and black markets; indeed, these may be the only functioning markets, making virtually everyone in these spaces a "bad actor." Those unwilling or unable to profit from the chaos will radiate outward through refugee flows, exporting social conflicts to adjacent

locales. Finally, because of the sheer complexity of megacities, they will be very difficult to reorder once destabilized, and may continue in chaos until they depopulate themselves.[43]

Imagine Cascading Disruptions Across Multiple Systems…

As local wells run dry or are contaminated by arsenic, residents of Xian, China, increasingly rely on the local mafia to provide water, which has been siphoned from the few remaining functional pipelines. *Disrupted systems: traditional political coalitions, water availability, consensus on state scope.*

As the Yucatan peninsula is devastated by alternating floods and droughts, the Mexican government fails to respond and thousands perish. In the wake of the disasters, Zapatistas reignite their revolutionary agenda, destabilizing the central government and sparking a massive outflux of refugees toward the U.S. *Disrupted systems: civil order, urban forms, consensus on state scope.*

A new airborne virus spreads through Turkey, forcing border closures and the collapse of all tourism and trade. The press reports that the virus was released by European Jews to thwart Turkey's admission into the EU, when in fact the virus was admitted through a cargo shipment from Africa. Conspiracy claims spark riots among Muslims around the world. *Disrupted systems: civil order, urban forms, ecosystems.*

Analytic Opportunities

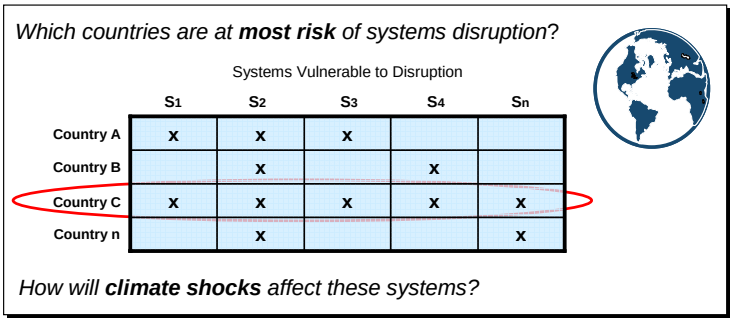
The approach presented in this paper is useful to for understanding how climate change may affect their territory or who want to forecast which regions or types of countries/economies are most vulnerable to climate change.

Using this approach, it is possible to examine which local systems are particularly susceptible to the known disruptions of climate change, and ask what the interaction effects will be if that already-at-risk system is further disrupted by a severe climate event or climate excursion. This framework can also be used to forecast which areas are particularly vulnerable to climate change by asking: which regions are suffering from multimodal systemic stress? Diagnosing which places are most likely to suffer most from climate change begins with locating those regions with the largest number of disrupted systems. Most vulnerable will be places where, for example, the state has low response capacity, *and* the local or hinterland ecosystem is out of kilter, *and* urbanization is taking place with few social services, *and* the water supply has hit its limit. In such places, with such multiply-stressed systems, the freak storm or prolonged drought could very well launch a profound, cascading crisis.

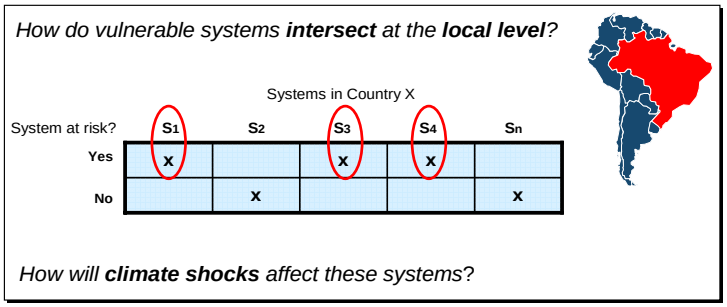
One useful avenue for further analysis would be to construct a quantitative model that formulates the interrelationships and feedback loops connecting various systems that may be in a state of disruption, or vulnerable to climate shocks, or both. Such a model could be fed data about specific countries, regions, or cities to construct a "Climate Change Vulnerability Index," modeled after indexes such as Transparency International's Corruption Index,[44] *Foreign Policy*'s Failed States Index,[45] or the United Nation's Human Development Index.[46] As with these other indexes, the purpose would not be to predict the exact chances of bad things happening, but rather to galvanize public attention and to spur interdisciplinary thinking. The most effective Vulnerability Index would make clear that even countries or regions ranking "low" in *relative* vulnerability might yet be highly vulnerable in an *absolute* sense.

Further, constructing scenarios on how systems may react and interact in the face of climate change (and weather excursions from the mean) would help to identify vulnerabilities at a local and regional level that may otherwise remain unseen. Scenarios would help determine the linchpins within systems that are particularly vulnerable for disruption, providing insight into where additional resilience and contingency planning is required. Scenarios are not just about doom and gloom; there also shed light on unforeseen opportunities that, if acted on, could have a lasting mitigating impact, and help better prepare the U.S.—and the planet—for the catalytic climate events that are inevitably in our future. As Thomas Homer-Dixon elegantly asks, "What kind of trouble is our civilization likely to encounter ahead? How can we cope, and how might we take advantage of opportunities that arise for civilization's renewal?"[47]

Transnational



Regional /Country



About Global Business Network and the Monitor Group

Global Business Network

Founded in 1987 and a member of the Monitor Group since 2000, GBN specializes in helping organizations adapt and compete more effectively and more responsibly in the face of mounting uncertainty—whether it's uncertainty about their future, the future of their industry, or the future of the world at large. A pioneer in the evolution and application of scenario thinking, GBN's consulting and training services focus on strategy, decision-making, innovation, visioning and alignment, and organizational and leadership development.

The principal authors of this GBN white paper were Nils Gilman, Doug Randall, and Peter Schwartz. Contributors include Derek Bothereau, Stewart Brand, Rebecca Otto, and Steven Weber. Copies are available at http://www.gbn.com/climatechange.

The Monitor Group

Monitor Group has 28 offices worldwide and offers a portfolio of strategic consulting services to clients who seek to grow top-line revenue, shareholder value, and individual and organizational capabilities. The firm works with the world's foremost business experts and thought leaders to help major multinational companies, governments and philanthropic institutions develop specialized capabilities in areas including competitive strategy, marketing and pricing strategy, innovation, national and regional economic competitiveness, non-profit management, technology/e-business, organizational design and development, and scenario planning. Monitor Group's separate merchant banking division consists of investment funds (both venture capital and private equity) as well as an M&A advisory service.

Endnotes

[1] One of the most notable studies of the historical impacts of climate change is H. H. Lamb, *Climate, History and the Modern World* (Routledge, 1995). An important recent study of climate change's future impacts is Frank Ackerman and Elizabeth Stanton, "Climate Change: The Costs of Inaction" (11 October 2006): http://www.foe.co.uk/resource/reports/econ_costs_cc.pdf. This report estimates that *direct economic damages due to climate change could reach $20 trillion annually by 2100*, the equivalent of 6 to 8 percent of expected global economic output. This price tag excludes the cost of biodiversity loss, human cultural losses, or the collapse of the North Atlantic thermohaline circulation. The report also points out that while most climate models suggest that global warming is likely to have little net impact on global agriculture to 2050, thereafter, high emissions scenarios predict dire effects on global agriculture, including in the northern hemisphere.

[2] For detail on SRES A2, see http://www.geo.vu.nl/~ivmadapt/fb_scenario.htm.

[3] It is worth noting that the SRES A2 scenario strongly resembles in both its climate and socioeconomic assumptions the United Nations Environment Programme's (UNEP) third Global Environmental Outlook (GEO-3) "Security First" scenario. Putting "security" first (specifically, ahead of markets, policy, and sustainability agendas) reflects the current set of political priorities for the post-9/11 U.S. (see http://unep.org/geo/pdfs/The%20GEO-3%20Scenarios.PDF, p. 33). The GEO-3 scenarios were themselves developed based on integrated global and regional scenarios created by the Global Scenario Group (GSG). "Security First" was based on GSG's "Barbarization" scenario. In the Barbarization scenario, social and environmental problems overwhelm market and policy response, creating a Hobbesian world where either countries and regions descend into unbridled conflict, institutional disintegration, and economic collapse, or elites in "fortresses" use authoritarian repression to keep the impoverished masses in line. See Paul Raskin, et al. "Global Scenarios in Historical Perspective": www.maweb.org/proxy/Document.326.aspx.

[4] Adapted from IPCC II: http://www.grida.no/climate/ipcc_tar/wg2/009.htm#tabspm1.

[5] Paul R. Epstein and Evan Mills, eds., "Climate Change Futures: Health, Ecological and Economic Dimensions" (November 2005): http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf, p. 18. See also David Easterling, et al., "Climate Extremes: Observations, Modeling, and Impacts," *Science* (22 September 2000).

[6] See the important paper by Jose A. Rial, et al., "Nonlinearities, Feedbacks and Critical Thresholds within the Earth's Climate System," *Climatic Change* 65 (2004).

[7] For example, a major volcanic eruption might temporarily slow or even reverse global warming for five or 10 years. Even as global cooling ensued, GHGs would continue to accumulate, eventually returning the climate to the place suggested by the trendline.

[8] Eugene Linden, The Winds of Change: Climate, Weather, and the Destruction of Civilizations (Simon and Schuster, 2006), p. 256.

[9] Perhaps the best known example is the collapse and closure of the Grand Banks cod fishery in the 1980s. See Jeremy B. C. Jackson, "Historical Overfishing and the Recent Collapse of Coastal Ecosystems," *Science* (27 July 2001); see also Richard L. Haedrich, Lawrence C. Hamilton, "The Fall and Future of Newfoundland's Cod Fishery," *Society and Natural Resources* 13:4 (2000).

[10] Jane Lloyd, "The Link Between Environment and Disease," http://www.un.org/Pubs/chronicle/2006/issue1/0106p68.htm.

[11] "Biological systems are constantly responding to disturbance; however, the time scales necessary for natural selection are generally much longer than a few decades during which the climate could be changed. In such cases, biological systems might accommodate minor (or slowly occurring) perturbations in a smooth continuous fashion, although even minor changes in climate can be disruptive for some ecosystems and species. However, many of the world's ecosystems are stressed by a variety of disturbances, including pollution, invasion of exotic species, and fragmentation (or isolation) of habitats. Such conditions, coupled with the relatively rapid rate of anticipated climate change, will likely erode a system's resiliency and reduce its chances for successful adaptation." (William E. Easterling, et al., "Coping with Global Climate Change: The Role of Adaptation in the U.S.": http://www.pewclimate.org/docUploads/Adaptation.pdf, p. 4.)

[12] "Gradual Change Can Push Ecosystems into Collapse," *Environmental News Network* (12 October 2001). See also Marten Scheffer et al., "Catastrophic shifts in ecosystems," *Nature* (11 October 2001).

[13] IUCN, "Biological Diversity of Dryland, Mediterranean, Arid, Semi-Arid, Savanna, and Grassland Ecosystems" (June 1999): http://www.iucn.org/themes/pbia/wl/docs/biodiversity/sbstta4/dryland.pdf.

[14] "Continued warming and more extreme weather patterns are likely to have a marked and adverse effect in the distribution and quality of drinking water worldwide. Water shortages and water-related illnesses could become more widespread and more frequent, putting enormous pressure on watersheds, water delivery systems, and health care systems. Agricultural impacts could be severe, especially as irrigation needs rise due to warmer global temperatures, and hydroelectric power could be severely compromised in many nations. Water shortages could lead to intense competition and more violent conflicts, as demand rises, aquifers and surface water bodies become depleted, and changes in the hydrological cycle make water supplies more varied and unpredictable" (quoted in Paul Epstein and Evan Mills, eds., "Climate Change Futures: Health, Ecological, and Economic Dimensions," *op cit.*, p. 89).

[15] Peter H. Gleick, "Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020" (2002): http://www.pacinst.org/reports/water_related_deaths/water_related_deaths_report.pdf.

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[17] OECD, "Water and Violent Conflict" (2005): http://www.oecd.org/dataoecd/26/5/35785565.pdf

[18] "Synthesis of the 4th World Water Forum" (2006): http://www.worldwatercouncil.org/fileadmin/wwc/World_Water_Forum/WWF4/synthesis_sept06.pdf, p. 42.

[19] IPCC, 2001. Working Group II, ch. 11: http://www.grida.no/climate/ipcc_tar/wg2/427.htm. The U.N. estimates that by 2050 more than 2 billion people will live in water-scarce areas: http://www.acunu.org/millennium/Global_Challenges/chall-02.html.

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[21] In the tropics, intestinal diseases typically peak during the rainy season, with floods and droughts increasing risk. Major causes of diarrhea linked to heavy rainfall and contaminated water supplies are: cholera, cryptosporidium, E.coli infection, giardia, shigella, typhoid, and viruses such as hepatitis A: http://www.who.int/globalchange/climate/en/chapter5.pdf. See also Robert W. Sutherst, "Global Change and Human Vulnerability to Vector-Borne Diseases," *Clinical Microbiology Reviews* 17 (2004), which reviews the highly complex ways that increased heat, increased or decreased moisture, urbanization, land use, trade and travel, and endocrine hormone disrupters interact with one another to change disease vectors.

[22] John Reid, "Water Wars: Climate Change may Spark Conflict," *The Independent* (28 February 2006): http://www.globalpolicy.org/security/natres/water/2006/0228list.htm.

[23] "Environment: Scientists Raise Alarm as Man-Made Deserts Spread" (20 June 2006): http://www.rferl.org/featuresarticle/2006/6/FA3B660C-FFAF-4C63-9B10-014423E0041C.html.

[24] Joel E. Cohen, "Human Population Grows Up," *Scientific American* (September 2005).

[25] While the Black Death killed an estimated one-third of Europeans in the 1340-50s, it killed more than 80 percent of Europe's urban population. In general, see Tom Koch, *Cartographies of Disease: Maps, Mapping, and Medicine* (Esri Press, 2005).

[26] U.K. Climate Impacts Program, "Updates to regional net sea-level change estimates for Great Britain" (2006). If the Western Antarctic Ice Sheet collapses, it will cause a 5-6 meter sea level rise, radically changing coastlines and potentially impacting 500-600 million people worldwide. Even assuming that the collapse unfolds over a 500-year time span, the effects will begin to be felt in coastal areas already by 2050. One model estimates that by mid-century worldwide land losses could be as high as 10,000 square kilometers annually, with 125,000 people displaced annually. R. J. Nicholls, et al., "Global Estimates of the Impact of the Collapse of the West Antarctic Ice Sheet," *Climatic Change* (2005): http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/annex6.pdf.

[27] R. J. Nicholls, "Coastal Megacities and Climate Change," *Geojournal* 37:3 (1995).

[28] Eugene Linden, "The Exploding Cities of the Developing World," *Foreign Affairs* 75:1 (1996), p. 55.

[29] On megacity biochemistry, see Ethan H. Decker, et al., "Energy and Material Flow through the Urban Ecosystem," *Annu. Rev. of Energy Environ.* 25 (2000).

[30] On "steer, don't row," see David Osborne and Ted Gaebler, *Reinventing Government* (Plume, 1991).

[31] Daniel Yergin, *The Commanding Heights* (Free Press, 2002).

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[33] See William Finnegan, "Leasing the Rain," *New Yorker* (8 April 2002): http://www.newyorker.com/fact/content/articles/020408fa_FACT1?020408fa_FACT1.

[34] See the useful interview with former Medecines Sans Frontiers President Rony Brauman in MSF internal newsletter (February 2006): http://www.msf.fr/documents/base/2006-02-01-Messages139VA.pdf, p. 11.

[35] Brad Knickerbocker, "A 'Hostile' Takeover Bid at the Sierra Club," *The Christian Science Monitor* (20 February 2004): http://www.csmonitor.com/2004/0220/p01s04-ussc.html.

[36] Dan Bilefsky and Ian Fisher, "Across Europe, Worries on Islam Spread to Center," *New York Times* (11 October 2006): http://www.statesman.com/news/content/news/stories/world/10/11/11eurmuslims.html.

[37] Stephanie Simon, "Evangelicals Ally with Democrats on Environment," *Los Angeles Times* (19 October 2006): http://www.latimes.com/news/nationworld/nation/la-na-warming19oct19,0,3197792.story.

[38] A Swiss Re-sponsored project paints one picture: "As commercial insurability declines, demands emerge to expand existing government-provided insurance for flood and crop loss, and to assume new risks (for example, for wildfires and windstorms). Cash-strapped governments, however, find that claims interfere with balancing their budgets and in turn limit their coverage, with the result that more ultimate losses are shifted back to the individuals and businesses impacted by climate change" (quote in Paul Epstein and Evan Mills, eds., "Climate Change Futures: Health, Ecological, and Economic Dimensions," *op. cit.*, p. 100. Other scenarios can be imagined: perhaps the public will sanction large-scale hikes in taxes to cover major system discontinuities, or they may require insurance operators to offer subsidized rates, leading in effect to nationalization of insurance.

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[43] See John Robb, Brave New War: The Next Stage of Terrorism and the End of Globalization (Wiley, forthcoming 2007).

[44] http://www.transparency.org/policy_research/surveys_indices/cpi.

[45] http://www.foreignpolicy.com/story/cms.php?story_id=3098.

[46] For the 2005 report, see http://hdr.undp.org/reports/global/2005/pdf/presskit/HDR05_PKE_HDI.pdf.

[47] Thomas Homer-Dixon's new book considers the interplay of crises that have pushed modern civilization to the brink of collapse (Thomas Homer-Dixon, *The Upside of Down: Catastrophe, Creativity, and the Renewal of Civilization* (Island Press/Shearwater, 2006).