# Cities on Stilts: The Myth of Large Scale Climate Adaptation and the Limits of Sustainability

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**Cities on Stilts: The Myth of Large Scale Climate Adaptation and the Limits of Sustainability**

Patrick Parenteau

According to the Intergovernmental Panel on Climate Change (IPCC), the goal of climate policy is to "avoid the unmanageable and manage the unavoidable."[1] The key to avoiding the unmanageable is mitigation, defined as: "An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases."[2] Managing the unavoidable means adaptation, defined as: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."[3] Mitigation and adaptation are complementary strategies that can—at least in theory—work in harmony. However, finding the optimal mix of mitigation and adaptation is problematic. Mitigation and adaptation work at different spatial and time scales. Mitigation is global and long term while adaptation is local and shorter term. Those who will suffer the most from climate change, and are the least responsible for the emissions that cause it, are the ones who lack the financial and technical capacity to adapt. They are also the ones most in need of financial and technical assistance to grow carbon-free economies.

But there is a larger question: At what point does climate disruption become so "unmanageable" that adaptation is no longer a viable option for maintaining human civilizations? Put differently, at what point do we overshoot sustainable limits of the planet and condemn

[1] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), CLIMATE CHANGE 2007: SYNTHESIS REPORT, ch. 4 (2007), *available at* http://www.ipcc.ch/publications_and_data/ar4/syr/en/main.html.

[2] IPCC, CLIMATE CHANGE 2007: WORKING GROUP II: IMPACTS, ADAPTATION AND VULNERABILITY (2007), *available at* http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch18s18-1-2.html.

[3] *Id.*

future generations to, as one publication put it, a "hellish future?"[4] There are no simple answers. To hazard a guess one must first consider several factors: (1) the success or failure of mitigation policies so far; (2) the cumulative loading of carbon in the atmosphere; (3) the sensitivity of the climate system; (4) the effects of multiple positive feedback loops and the possibility of passing tipping points that would trigger runaway climate change; (5) the ability of social and political institutions to anticipate and respond to consequences such as sea level rise, extreme weather, food shortages, displaced populations, conflicts over water and other resources; and (6) the variability of impacts in different parts of the globe. The simple fact is that we have entered an era unknown in human history—dubbed the "Anthropocene" by climatologist Paul Crutzen.[5] Measuring any of these factors with any degree of certainty is extremely difficult, which leaves humanity relying instead on reasonable projections and best guesses. We know that the observable, measurable effects of a relatively slight increase (0.8°C, 1.4°F) in average global temperatures are considerably greater than what the IPCC projected in its Fourth Assessment.[6] For example, sea levels are rising 60% faster than projected.[7] A recent study from the Potsdam Institute concludes that sea levels rise two meters (6.6 feet) for every +1°C change. Everywhere

[4] Damian Carrington, *Climate Change Scientists Warn of 4C Global Temperature Rise*, GUARDIAN, Nov. 28, 2010.

[5] Paul Crutzen is one of the three chemists who shared the 1995 Nobel Prize for discovering the effects of ozone-depleting compounds. In a paper published in 2000, Crutzen and Eugene Stoermer, a professor at the University of Michigan, noted that humans now dominate a number of Earth's basic processes such as the nitrogen and carbon cycles. Paul J. Crutzen & Eugene F. Stoermer, *The "Anthropocene"*, 41 GLOBAL CHANGE NEWSL., 17 (2000), *available at* http://www.igbp.net/download/18.316f18321323470177580001401/1376383088452/NL41.pdf. Two years later, Crutzen published a paper in *Nature* in which he wrote: "The Anthropocene could be said to have started in the latter part of the eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane." Paul J. Crutzen, *Geology of Mankind*, 415 NATURE 23 (2002). The Anthropocene Working Group of the International Commission on Stratigraphy has been formed to consider whether a new epoch should be officially designated, and if so, how. Elizabeth Kolbert, *The Anthropocene Debate: Marking Humanity's Impact*, YALE ENVIRONMENT 360, May 10, 2010, http://e360.yale.edu/feature/the_anthropocene_debate__marking_humanitys_impact/2274/.

[6] Glenn Cherer, *IPCC Predictions: Then Versus Now*, DAILY CLIMATE—CLIMATE CENTRAL, Dec. 11, 2012, http://www.climatecentral.org/news/ipcc-predictions-then-versus-now-15340; Ben Block, *Climate Change Outpaces Predictions*, WORLDWATCH INSTITUTE, http://www.worldwatch.org/node/5990 (last visited July 19, 2013).

[7] Stefan Rahmstorf, Grant Foster, & Anny Cazenave, *Comparing Climate Projections to Observations up to 2011*, 7 ENVTL RES. LETTERS 044035 at 3 (2012), *available at* http://iopscience.iop.org/1748-9326/7/4/044035/pdf/1748-9326_7_4_044035.pdf.

one looks it seems climate change is accelerating: The Arctic is melting so fast that some scenarios predict it will be ice free in the summer by mid-century;[8] Antarctica is breaking apart and calving glaciers one-fourth the size of Rhode Island;[9] Greenland experienced a 97% surface melt in 2012;[10] and the rate of ocean acidification may be faster than at any time in the last 300 million years.[11] The list goes on.

The stated goal of the United Nations Framework Convention on Climate Change (UNFCCC), which 165 nations ratified, including the United States, is to avoid "dangerous anthropogenic interference with the climate system."[12] In 2009, the signatories to the Copenhagen Accord agreed that limiting the increase in *average* global temperature of 2°C (3.6°F) above pre-industrial levels would achieve this objective.[13] Some respected climate scientists, notably James Hansen and Kevin Anderson,[14] take the view that the +2°C target is too high, saying that it ignores the impacts of ocean acidification, and carries a high risk of dramatic sea level rise and mass extinctions of plants and animals.[15] Other scientists maintain that the

[8] IPCC WORKING GROUP I, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 5 (2014), *available at* http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf.

[9] George Hale, Letter, *Antarctic Glacier Calves Iceberg One-Fourth Size of Rhode Island*, NASA NEWS (JULY 11, 2013), http://www.nasa.gov/content/antarctic-glacier-calves-iceberg-one-fourth-size-of-rhode-island/; M.A. Depoorter et al., *Calving Fluxes and Basal Melt Rates of Antarctic Ice Shelves*, 502 NATURE 89 (2013), *available at* http://www.nature.com/nature/journal/vaop/ncurrent/full/nature12567.html.

[10] Alexander Robinson, Reinhard Calov & Andrey Ganopolski, *Multistability and Critical Thresholds of the Greenland Ice Sheet*, 2 NATURE CLIMATE CHANGE 429, 429 (2012) (concluding that "the Greenland ice sheet is more sensitive to long-term climate change than previously thought"). The scientists estimate that a temperature rise of 1.6°C could lead to rapid melting of the entire ice sheet which would raise sea levels by twenty feet or more. *Id.*

[11] IGBP, IOC, & SCOR, OCEAN ACIDIFICATION SUMMARY FOR POLICYMAKERS, 2 (2013), *available at* http://www.igbp.net/publications/summariesforpolicymakers/summariesforpolicymakers/oceanacidificationsummaryforpolicymakers2013.5.30566fc6142425d6c9111f4.html.

[12] U.N. Framework Convention on Climate Change, Art. 2, 1771 UNTS 107; S. Treaty Doc No. 102-38; U.N. Doc. A/AC.237/18 (Part II)/Add.1; 31 ILM 849 (1992), *available at* http://unfccc.int/essential_background/convention/items/2627.php.

[13] Note that this would allow much higher temperatures in the Arctic and northern latitudes.

[14] Kevin Anderson is Deputy Director of the Tyndall Centre for Climate Change Research in Great Britain. He is the co-author of *Beyond "Dangerous" Climate Change: Emission Scenarios for a New World*, published in the Philosophical Transactions of the Royal Society. Kevin Anderson & Alice Bows, *Beyond "Dangerous" Climate Change: Emission Scenarios for a New World*, 369 PHIL. TRANS. R. SOC. 20 (2010).

[15] James Hansen, Pushker Kharecha, & Makiko Sato, *Climate Forcing Growth Rates: Doubling Down on our Faustian Bargain*, 8 ENVTL. RES. LETTERS 011006 (2013).

+2°C metric marks the boundary between dangerous and catastrophic consequences.[16] The debate is largely academic. There is little evidence that the international community is prepared and willing to take on the kinds of monumental actions that would be necessary to reduce carbon emissions to achieve the +2°C target.

For example, the International Energy Administration (IEA) calculated that to have even a fifty-fifty chance of meeting the +2°C target, two-thirds of the world's remaining fossil fuel reserves would have to remain underground.[17] Enough oil, gas, and coal assets exist on the books of the major energy companies to exceed this threshold.[18] Expecting these companies to write off valuable assets is foolish. And there is little chance that governments will acquire them through purchase or condemnation. Besides, most fossil reserves are controlled by Saudi Arabia, Russia, and Iran—countries that are unlikely to forego fossil development.[19]

Crunch time is now. If we were serious about meeting the +2°C target, new investment in fossil fuel infrastructure would have to cease by 2015 to prevent a carbon lock-in that would create irreversible climate change.[20] Instead, we see a boom in oil and natural gas production from hydrofracking, pressure to build pipelines like Keystone XL to empty the Canadian tar sands, and a rush to drill in the newly ice-free Arctic. The problem is not, as some have feared, that we will run out of oil, or coal, or gas anytime soon [21] The problem is that we are running out

[16] Thomas E. Lovejoy, *The Climate Change Endgame*, N.Y. TIMES, Jan. 21, 2013.

[17] INTERNATIONAL ENERGY AGENCY, WORLD ENERGY OUTLOOK 2012: EXECUTIVE SUMMARY 3 (2012), https://www.iea.org/publications/freepublications/publication/English.pdf.

[18] *Unburnable Fuel*, ECONOMIST, May 4, 2013, *available at* http://www.economist.com/news/business/21577097-either-governments-are-not-serious-about-climate-change-or-fossil-fuel-firms-are.

[19] MIKE BERNERS-LEE & DUNCAN CLARK, THE BURNING QUESTION: WE CAN'T BURN HALF OF THE WORLD'S OIL, COAL AND GAS. SO HOW DO WE QUIT? 89–94 (2013).

[20] Fiona Harvey, *World Headed for Irreversible Climate Change in Five Years, IEA Warns*, GUARDIAN, Nov. 9, 2011, http://www.guardian.co.uk/environment/2011/nov/09/fossil-fuel-infrastructure-climate-change.

[21] INTERNATIONAL ENERGY AGENCY, MEDIUM TERM OIL MARKET REPORT, OVERVIEW (2013). IEA projects that global oil production capacity will grow by 8.4 million barrels a day between now and 2018—significantly faster than demand. Much of the increased production is coming from North America as a result of the breakthrough

of the atmospheric and oceanic capacity to absorb increasing carbon emissions. In other words, it is the cumulative emissions of CO2 that matter. In its Fifth Assessment, the IPCC adopted a "carbon budget" approach to evaluating the risks of climate change. Based on studies published over the past several years, the IPCC found that in order to have at least a 66% chance of limiting global warming to +2°C, no more than one trillion metric tons of carbon can be released into the atmosphere.[22] The IPCC report estimates that we've already used 531 billion tons of that budget as of 2011 by burning fossil fuels for energy and clearing forests for farming and myriad other uses. That means we only have about 469 billion tons left in our account. There are more than enough proven reserves of fossil fuels to exceed that number.[23] In short we are running out of atmosphere faster than we are running out of fossil fuels.

Although economic concerns are often raised as an objection to undertaking the stringent mitigation measures required to cap and begin a sustained effort to reduce carbon emissions, careful analysis shows that the economic benefits outweigh the costs.[24] As the Stern report and other analyses have shown the costs of inaction vastly outweigh the costs of strong mitigation.[25] In a survey of economists conducted by the Institute for Policy Integrity at NYU Law School, 84% of respondents agreed or strongly agreed that "the environmental effects of greenhouse gas

technologies of hydraulic fracturing and horizontal drilling that have opened vast deposits of oil and gas from North Dakota's Bakken formation and Alberta's tar sands. Similarly, our own Energy Information Agency projects ample natural gas and coal reserves through the end of this century. *See* U.S. ENERGY INFORMATION ADMINISTRATION, ANNUAL ENERGY OUTLOOK 2014 EARLY RELEASE OVERVIEW (2014), *available at* http://www.eia.gov/forecasts/aeo/er/executive_summary.cfm.

[22] IPCC WORKING GROUP I, *supra* note 8, at 21.

[23] CARBON TRACKER INITIATIVE, UNBURNABLE CARBON—ARE THE WORLD'S FINANCIAL MARKETS CARRYING A CARBON BUBBLE? 6–7 (2013), *available at* http://www.carbontracker.org/wp-content/uploads/downloads/2011/07/Unburnable-Carbon-Full-rev2.pdf.

[24] William D. Nordhaus, *Why the Global Warming Skeptics Are Wrong*, N.Y. REV. BOOKS, March 22, 2012, http://www.nybooks.com/articles/archives/2012/mar/22/why-global-warming-skeptics-are-wrong/; dana1981, *Nordhaus Sets the Record Straight—Climate Mitigation Saves Money*, SKEPTICAL SCI., March 2, 2012, http://www.skepticalscience.com/news.php?n=1325.

[25] NICHOLAS STERRN, STERN REVIEW ON THE ECONOMICS OF CLIMATE CHANGE http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm; Nordhaus, *supra* note 24.

emissions, as described by leading scientific experts, create significant risks to important sectors of the United States and global economies."[26] Realistically, the barriers to successful mitigation have more to do with politics, culture, and the entrenched power of the fossil fuel industry than economics or technological constraints.[27] When faced with the daunting difficulties of adopting a strong global climate treaties or meaningful national legislation, the United States has tended to shifts the discussion from mitigation and towards adaptation. The thinking seems to be that if there isn't the political will to do what's necessary to hold temperatures below +2°C, we'll have to learn to adapt. But adapt to what? Lots of questions emerge: Who must adapt and to what? How and when? What will it cost and who will pay? If +2°C is not a realistic target, what is and at what point does adaptation become prohibitively expensive or just plain impossible?

The effects of climate change that are visible so far—rising seas, melting ice caps, extended droughts, heavy precipitation, ocean acidification, ecosystem shift, etc.—are largely irreversible for at least a thousand years.[28] And the pace and scale of impacts are increasing. Even the most stringent mitigation efforts cannot avoid further damage to human and natural communities in the next few decades. As John Holdren, President Obama's Science Advisor, has said: "We have only three options: mitigate, adapt or suffer."[29]

Extreme events are driving policy. For example, in the wake of Super Storm Sandy, Mayor Bloomberg announced that New York City would embark upon a $20 billion plan to

[26] J. Scott Holladay, Jonathan Horne & Jason A. Schwartz, ECONOMISTS AND CLIMATE CHANGE (Institute for Policy Integrity, Policy Brief No. 5, 2009), http://resources.ofdan.ca/docs/EconomistsandClimateChange.pdf.

[27] *See, e.g.*, Rocky Mountain Institute, REINVENTING FIRE: BOLD SOLUTIONS FOR THE NEW ENERGY ERA (2011).

[28] Susan Solomon, Gian-Kasper Plattner, Reto Knutti & Pierre Friedlingstein, *Irreversible Climate Change Due to Carbon Dioxide Emissions*, 106 PROC. NAT'L ACAD. SCIS. 1704, 1704 (2009).

[29] John Holdren, Presidential Science Advisor, Remarks at National Climate Adaptation Summit (May 27, 2010), *available at* CLIMATE SCIENCE WATCH, *Text of remarks by Obama science adviser John Holdren to the National Climate Adaptation Summit*, May 28, 2010, http://www.climatesciencewatch.org/2010/05/28/text-of-remarks-by-obama-science-adviser-john-holdren-to-the-national-climate-adaptation-summit/.

make the city more "resilient" to climate change.[30] The plan involves building sea walls to protect the water front along with stricter building codes and floodplain regulation. Chicago has launched an aggressive "greening the cityscape" program to deal with heat waves, polluted runoff, floods, and air quality.[31] Seattle is leading the effort to develop a regional water planning program while investing heavily in green infrastructure.[32] Communities as small as Keene, New Hampshire are winning awards for adopting model climate-action and adaptation plans.[33] Adaptation planning at the local level is eminently sensible, but it would be a huge mistake to place undue faith in adaptation as a strategy for dealing with climate disruption at larger scales. Indeed, without aggressive mitigation, a magnitude of climate change is likely to be reached that makes adaptation impossible for some natural systems; while for most human systems it would involve very high social and economic costs. In short, we have to find ways to live within our carbon budget or risk incurring a debt that can never be repaid.

## I. THE PHYSICAL LIMITS OF ADAPTATION

According to a blockbuster report by the World Bank, the world is on a path to +4°C (8.1°F) increase this century (barring dramatic changes in the ways we use and produce energy, move goods and people, build communities, grow crops, manage forests and engage in many other activities).[34] In uncharacteristically blunt language, World Bank President Dr. Jim Yong Kim

[30] *See* NEW YORK CITY, PLANYC, http://www.nyc.gov/html/planyc2030/html/theplan/climate-change.shtml (last visited May 16, 2014). The plan sets out two overarching goals: (1) Reduce greenhouse gas emissions by more than 30%; and (2) Increase the resilience of our communities, natural systems, and infrastructure to climate risks.

[31] CHICAGO CLIMATE ACTION PLAN, ADAPTATION, http://www.chicagoclimateaction.org/pages/adaptation/11.php (last visited July 19, 2013).

[32] SEATTLE OFFICE OF SUSTAINABILITY AND ENVIRONMENT, CLIMATE ACTION PLAN, http://www.seattle.gov/environment/climate_plan.htm (last visited July 19, 2013).

[33] CITY OF KEENE, NEW HAMPSHIRE, ADAPTING TO CLIMATE CHANGE: PLANNING A CLIMATE RESILIENT COMMUNITY (2007), http://www.ci.keene.nh.us/sites/default/files/Keene%20Report_ICLEI_FINAL_v2_1.pdf.

[34] THE WORLD BANK, TURN DOWN THE HEAT: WHY A 4°C WORLD MUST BE AVOIDED (2012), http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf.

states in the foreword: "It is my hope that this report shocks us into action." Acknowledging the uncertainties that exist in predicting future conditions, the report takes a risk-based approach to its analysis and concludes:

> Without further commitments and action to reduce greenhouse gas emissions, the world is likely to warm by more than 3°C above the preindustrial climate. Even with the current mitigation commitments and pledges fully implemented, there is roughly a 20 percent likelihood of exceeding 4°C by 2100. If they are not met, a warming of 4°C could occur as early as the 2060s. Such a warming level and associated sea-level rise of 0.5 to 1 meter, or more, by 2100 would not be the end point: a further warming to levels over 6°C, with several meters of sea-level rise, would likely occur over the following centuries.[35]

The specific focus on sea level rise reflects the Bank's mission of assisting developing nations, many of which, like Bangladesh and island-nations like the Maldives and the Philippines, are facing extreme risks of inundation and salt water intrusion from sea level rise. Of course, climate-change impacts will not be limited to sea level rise. The World Bank's report paints a bleak picture of a +4°C world saying it "would be one of unprecedented heat waves, severe drought, and major floods in many regions, with serious impacts on human systems, ecosystems, and associated services."[36] Noting the particular risks to coral reefs and the entire marine ecosystem from the combined effects of global warming and acidification, the report observes:

> The regional extinction of entire coral reef ecosystems, which could occur well before 4°C is reached, would have profound consequences for their dependent species and for the people who depend on them for food, income, tourism, and shoreline protection. The observed and projected rates of change in ocean acidity over the next century are unparalleled in Earth's history.[37]

The ability of different marine organisms to adapt on their own to these rapid changes in ocean

[35] *Id*. at xiii.
[36] *Id*.
[37] *Id*. at xv; *see also* Bärbell Hönisch et al., *The Geological Record of Ocean Acidification*, 335 SCI. 1058 (2012).

chemistry is unknown, but humans could do little about it in any event. [38]

In a special report published by the British Royal Society, a series of articles by leading climate scientists describe what a +4°C world would be like.[39] Among the findings: tens of millions of people displaced by rising seas, elimination of farming in Sub-Saharan Africa, loss of tropical forests and marine ecosystems, and massive water shortages in India and Asia.[40] The penultimate finding: "In such a 4°C world, the limits for human adaptation are likely to be exceeded in many parts of the world, while the limits for adaptation for natural systems would largely be exceeded throughout the world."[41] The report urged the use of "all available mechanisms to reduce emissions to minimize the chance of high end climate change."[42] The report also noted that "responses that might be most appropriate for a 2°C world may be maladaptive in a +4°C world. . . . For example, a reservoir built to help communities adapt to moderate temperature increases may become dry if the temperatures continue to increase, or coastal protections designed for 2°C may prove futile at 4°C. This will require systems that are flexible and robust to accommodate a range of possible futures."[43] A robust strategy is one that performs well over a very wide range of alternative futures, like a well-balanced investment portfolio.

A 4°C world also raises the bar for the long-term financing of adaptation. With the global population expected to grow to nine billion by 2050, the challenges of adapting to a world of

[38] V.J. Fabry, B.A. Seibel, R.A. Feely & J.C. Orr, *Impacts of Ocean Acidification on Marine Fauna and Ecosystem Processes*, 65 ICES J. MARINE SCI. 414 (2008) (discussing widespread changes to marine ecosystems due to anthropogenic stressors).

[39] Carrington, *supra* note 4.

[40] Mark New, *Four Degrees and Beyond: the Potential for a Global Temperature Increase of Four Degrees and its Implications*, 369 PHIL. TRANS. ROYAL SOC'Y 4 (2010).

[41] Rachel Warren, *The Role of Interactions in a World Implementing Adaptation and Mitigation Solutions to Climate Change*, 369 PHIL. TRANS. ROYAL SOC'Y 217, 234 (2010).

[42] Mark New, Diana Liverman, Heike Schroder & Kevin Anderson, *Four Degrees and Beyond: The Potential for a Global Temperature Increase of Four Degrees and its Implications*, 369 PHIL. TRANS. ROYAL SOC'Y ABSTRACT (2010).

[43] *Id.* at 12–13.

steadily rising temperatures magnify enormously. If we cannot meet the basic needs for food, shelter, water, electricity, and health care for the seven billion people currently on the planet, it is hard to see how it will be possible to achieve these needs with an additional two billion people. The greater the warming, the more loss and damage that can be anticipated from the adverse effects of climate change.[44] Similarly, the less support for adaptation in terms of finance, technology and capacity, the more loss and damage will result.

Climate Interactive, a website developed and maintained by a team of experts at MIT, provides a handy simulation tool called the *Climate Scoreboard* that allows users to track progress towards meeting climate-stabilization targets negotiated through the United Nations Framework Convention on Climate Change process.[45] The Scoreboard automatically reports, on a daily basis, whether proposals in the treaty process commit countries to enough greenhouse gas emissions reductions to achieve widely expressed goals, such as limiting future warming to 1.5 to 2.0°C (2.7 to 3.6°F) above pre-industrial temperatures. Under the "business as usual" scenario, the Scoreboard projects global temperatures to increase to 4.9°C by 2100. Even if all the commitments under existing international agreements and proposals were met, the temperature would still hit a 4.5°C increase by 2100.

There are very real limits to how far human systems and ecosystems can adapt to a +4°C world. This is true particularly for rises in temperature and sea levels, ocean acidification, loss of

[44] At the COP 19 meeting in Warsaw the issue of "loss and damage" received a lot of attention in the press and in the talks. "Loss and damage" refers to repairable damage or permanent loss due to the impacts of climate change, including severe weather events and slow-onset events such as sea-level rise and temperature rise. Loss may be economic or noneconomic; examples of noneconomic loss include loss of life, culture, livelihood, ecosystems, or territory. "Residual loss and damage" refers to loss and damage that occurs despite mitigation and adaptation efforts. Low-lying island nations, for example, fear the eventual complete loss of country and culture. In the end the delegates agreed to establish the Warsaw Mechanism on Loss and Damage. Though some wanted a separate fund the agreement calls for the new mechanism to be folded into the Green Fund for adaptation. *See* UNFCCC Work Programme on Loss and Damage, http://www.lossanddamage.net/unfccc-work-programme.

[45] Climate Interactive, The Climate Scoreboard, http://climateinteractive.org/scoreboard (last visited July 19, 2013).

biodiversity, salinization, and desertification. Because such processes worsen over time—often at large scale—adaptation gradually becomes less possible. As temperatures and sea levels rise, territory will become uninhabitable and unproductive. Soil moisture levels will decrease to the point that cultivation of crops is no longer viable in entire regions such as Sub-Saharan Africa. Groundwater sources in coastal areas will become too saline to provide drinking water. Melting glaciers will critically reduce water supplies to hundreds of millions of people. Adaptation will become impossible on low-lying islands, in settlements close to sea level, and in the most arid regions. This will lead to the permanent loss of lands, livelihoods, and cultural resources. What happens to the vast numbers of people affected by these conditions is a huge humanitarian and global security issue with no analog in international law. The legal status of these "climate refugees" is uncertain to say the least. The term 'climate refugee' is not an officially recognized category under existing international law.[46] There are no frameworks, no conventions, no protocols and no specific guidelines that can provide protection and assistance for people crossing international borders because of climate change; and while existing international humanitarian law may apply in some cases of environmental displacement, the existing rights guaranteed to refugees—specifically those of international humanitarian assistance and the right of return—do not apply.[47]

The prospect of large-scale climate-induced migrations is causing alarm among international human rights advocates.[48] The potential for population displacement for hundreds of millions of people—a number that is increasing as the climate warms—has generated a sense

[46] Roger Zetter, *Legal and Normative Frameworks*, 32 FORCED MIGRATION REV. 63 (2009), *available at* http://www.fmreview.org/FMRpdfs/FMR31/62-63.pdf.

[47] Benjamin Glahn, '*Climate Refugees*'? *Addressing the International Legal Gaps—Part I*, INT'L BAR NEWS, (June 2009), http://www.ibanet.org/Article/Detail.aspx?ArticleUid=B51C02C1-3C27-4AE3-B4C4-7E350EB0F442.

[48] Margit Ammer, *Climate Change and Human Rights: The Status of Climate Refugees in Europe*, Ludwig Boltzmann Institute of Human Rights (May 2009), http://bim.lbg.ac.at/en/admigrationasylum/climate-change-and-human-rights-the-status-climate-refugees-europe.

that urgent international action is needed. Many policy-makers, researchers, and academics are suggesting that the international community must put in place new kinds of international legal norms to cope with the coming population shifts. Some advocate either amending the 1951 Refugee Convention or creating a new convention for this new category of migrants; others recommend aggregating existing legal mechanisms and producing something similar to the 1998 Guiding Principles on Internal Displacement, but for environmental migrants.[49]

In sum, given the changing nature of the global climate, adaptation will always be insufficient, as it requires a continuous learning process towards a constantly moving boundary.

## II. THE ECONOMIC LIMITS OF ADAPTATION

Economic logic dictates that climate policy must combine elements of both mitigation and adaptation, but getting the right mix is critical. Mitigation policies typically face rising marginal costs. Each additional unit of mitigation is likely to cost more than the previous unit. Costs rise rapidly as the extent of abatement becomes more ambitious. Some adaptation will be low cost (i.e., installing a window fan) whereas some adaptation actions might be high cost (i.e., building sea walls). An optimal policy would combine low-cost mitigation strategies and low-cost adaptation strategies. Either policy alone would not be a workable approach.

The costs and benefits of adaptation are likely to be unevenly distributed among sectors, socioeconomic groups, and countries. Whereas mitigation serves a global public good, adaptation can both be private and public and the scope of its benefits will seldom extend beyond local and national borders. Governments may be unwilling to fund measures where the costs of adaptation exceed the costs of impacts averted (e.g., costs of protecting small coastal areas from

[49] Benjamin Glahn, '*Climate Refugees'? Addressing the International Legal Gaps—Part II*, INT'L BAR NEWS (August 2009), http://www.ibanet.org/Article/Detail.aspx?ArticleUid=3E9DB1B0-659E-432B-8EB9-C9AEEA53E4F6.

sea level rise).

At a macro level, mitigation is more cost effective than adaptation. According to a major study by the International Institute for Environment and Development, the net present value (of climate change impacts in the IPCC's "A2" scenario[50] is $1,240 trillion with no adaptation, but *only* $890 trillion with adaptation.[51] However, in the "aggressive abatement" case, which corresponds to the +2°C target of 450–500 ppm (concentration of carbon dioxide in the atmosphere) the mean net present value of climate change damage is only $410 trillion, or $275 trillion with adaptation.[52] So stabilizing at 450 ppm (we just crossed the 400 PPM threshold[53]) reduces net present value impacts by $615 to $830 trillion. But the abatement net present value cost is only $110 trillion, yielding a six-to-one savings or better.

Keep in mind that these figures are based on a "worst case" scenario that assumes we will not exceed 850 ppm this century. However, actual emissions have been rising so fast that we are well on the way to 1000 ppm or worse,[54] meaning that the costs of adaptation would be much greater—though by how much is unknown. Whatever the actual amount, it is well beyond the capacity and willingness of the global community to finance large-scale adaptation in developing countries. In the Copenhagen Accord, the wealthier nations pledged to create a mitigation and adaptation fund of $100 billion by 2020.[55] The fund is badly undersubscribed.[56] But even if it

[50] The A2 scenario is at the higher end of the SRES emissions scenarios but not the highest. *See* United Nations Environment Program, IPCC Special Report on Emissions Scenarios (2000), http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/.

[51] MARTINE PARRY ET AL., ASSESSING THE COSTS OF ADAPTING TO CLIMATE CHANGE: A REVIEW OF THE UNFCCC AND OTHER RECENT ESTIMATES (2009), *available at* http://pubs.iied.org/pdfs/11501IIED.pdf.

[52] *Id.* at 19.

[53] Justin Gillis, *Heat-Trapping Gas Passes Milestone, Raising Fears*, N.Y. TIMES, May 10, 2013.

[54] Carbon dioxide (CO2) emissions from fossil fuel burning and cement production increased by 2.1% in 2012, with a total of 9.7 billion tons of carbon emitted to the atmosphere, 58% above 1990 emissions (the Kyoto Protocol reference year). Emissions are projected to increase by a further 2.1% in 2013. GLOBAL CARBON PROJECT, GLOBAL CARBON BUDGET, http://www.globalcarbonproject.org/carbonbudget/13/hl-full.htm (last visited May 16, 2014).

[55] Althena Ballesteros, *From Copenhagen to Cancun: Climate Finance*, WORLD RESOURCES INSTITUTE, June 04, 2010, http://www.wri.org/blog/copenhagen-cancun-climate-finance.

were fully funded it wouldn't even qualify as a down payment on what would be needed to adapt to life in a +4°C world.

Further, spending on mitigation and adaptation are not equivalent. Mitigation spending will go to things like new energy systems, new public transit systems, new agricultural systems. It will yield innovation, higher productivity, new jobs, less pollution, and improved quality of life. Adaptation spending is pure cost, a net loss that displaces other productive investments.

## III. THE SOCIAL LIMITS OF ADAPTATION

Perhaps even more important than physical or economic constraints are the potential social limits on adaptation. Unlike the millions of species facing extinction from climate change in this century,[57] humans at least have some choices to make. But how and when people will react is a subject of intense debate. A recent commentary in *Nature Climate Change* may shed some light on the subject. The authors introduce a framework for thinking about adaptation that is actor-centered and risk-based. They pose several provocative questions: whether there are social limits to adaptation; where the limits might lie; who they would affect; and what the consequences of reaching such limits might be.[58] The authors develop a typology of risk described as follows:

> [A]ctors will implicitly or explicitly place risks to their valued objectives into one of three categories involving different types of response: acceptable risks are risks deemed so low that further efforts in risk reduction (adaptation) are not justified; tolerable risks relate to situations where adaptive, risk-reduction efforts are required for risks to be kept within reasonable levels; and intolerable risks are those which fundamentally threaten a private or social norm—threatening, for instance, public safety, continuity of traditions, a legal standard or a social contract—despite adaptive action having been taken. On reaching an intolerable

[56] Liane Schalatek, Neil Bird, & Jessica Brown, *Where's the Money? The Status of Climate Finance Post-Copenhagen*, Climate Finance Policy Brief No.1, HEINRICH BOLL STIFTUNG (2012), http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/5844.pdf.

[57] Ilya M.D. Maclean & Robert J. Wilson, *Recent Ecological Responses to Climate Change Support Predictions of High Extinction Risk*, 108 PROC. NAT'L ACAD. SCI. 12337 (2011).

[58] Kristin Dow et al., *Limits to Adaptation*, 3 NATURE CLIMATE CHANGE 305 (2013).

> risk level, we normally expect a discontinuity of behavior in order to avoid the risk, whether this is a homeowner's decision to move, or a forester selling off land, as the alternative is increasing losses. The question of what is acceptable, tolerable or intolerable remains with the individual actors, as they shape collective responses.[59]

For an example of individual risk assessment, the authors cite the case of a rice farmer in South Asia. They posit a scenario where rice yields decline 10% with every degree of nighttime temperature over 26°C. Initially the farmers can take some cost-effective adaptive responses to cushion the impact as temperatures rise, but at some point farming becomes a losing proposition, the risks become intolerable, and the farmer is forced to quit.

Scaling up the problem to the community level, the authors cite the familiar example of the Norse Greenlanders, who established a thriving settlement around Disko Bay that lasted for over four hundred years and then disappeared in the face of the "Little Ice Age." Though a number of factors were involved, recent analysis of marine sediments suggests that climate change played a major role in the collapse.[60] The *Nature Climate Change* authors suggest the collapse of the Viking settlement presents a historical example of a society that failed to adapt to climate change. The message from this article is that climate researchers need to develop better methods to predicting and anticipate adaptation limits; and policymakers need to start making plans for managing the consequences of exceeding those limits. In mapping the risks of climate change, the space between what might be considered acceptable and what becomes intolerable is not all that great.

There is also an ethical dimension to consider. Those with the most economic or political

[59] David Roberts, *The Limits of Climate Adaptation are Social, Not Physical or Economic*, GRIST, Apr. 29, 2013, http://grist.org/climate-energy/understanding-the-social-limits-of-adaptation/.

[60] Sofia Ribeiro et al., *Climate Variability in West Greenland During the Past 1500 Years: Evidence from a High-Resolution Marine Palynological Record from Disko Bay*, 41 BOREAS 68 (2012).

power will also be the ones most buffered against risk. As the last to be adversely affected by risks, they will be the least inclined to take adaptive action, especially if it's expensive. And because they are also the ones with the most political influence, they will be able to delay collective action even as climate risks are ravaging the more vulnerable. Think Maldives, Bangladesh, Sudan, Kivalina—all communities at imminent risk from sea level rise, flooding and other effects of climate change.

Finally, there is the issue of deeply held values and beliefs that influence how people perceive, interpret, and think about risks and risk management, what information and knowledge they value, what concerns have salience and so on. Individuals look at new problems, tasks, and solutions through the lens of their preexisting values, preferences, beliefs, norms, and experiences. Research in risk perception, cognitive psychology, and people's values and beliefs suggests this cultural lens colors general belief about society and the environment. Cognitive filters shape our perceptions, constrain our attitudes about options (and others involved in the process), and influence our decisionmaking processes.[61]

The global scale of the climate change issue means that the benefits of taking local action are uncertain and the effect of climate change may be experienced as a slow onset phenomenon exacerbating existing problems rather than a dramatic change generating new action. Some uncertainties can be quantified, but many simply cannot, meaning that there is some level of irreducible ignorance in our understanding of future climate conditions. Different approaches to characterizing such uncertainty—narratives, quantitative, alternative scenarios, or probabilistic descriptions—can have quite different effects on the types of adaptation decisions that are made,

[61] *See* W. Neil Adger et al., *Are There Social Limits to Adaptation to Climate Change?* 93 CLIMATIC CHANGE 335 (2009).

or not made.[62]

## IV. THE ILLUSION OF ECOSYSTEM ADAPTATION

According to the 2005 Millennium Ecosystem Assessment report, 60% of the world's ecosystems are now degraded, and the extinction rate is now 100 to 1,000 times higher than the "background" rate of long spans of geological time.[63] Climate change is expected to have significant influences on terrestrial biodiversity at all system levels, including species-level reductions in range, size and abundance, especially among endemic species. One in 10 species could face extinction by the year 2100 if current climate change impacts continue.[64] Without mitigation, something on the order of 60% of plants and 40% of animals are likely to lose more than half of their present range by the 2080s.[65] Without mitigation, large-range contractions can be expected even among common and widespread species, amounting to a substantial global reduction in biodiversity and ecosystem services by the end of this century. The degree to which individual species can adapt (and biodiversity maintained) in the face of this unprecedented loss of habitat is unknown and perhaps unknowable until it is too late to do anything about it. Prompt and stringent mitigation, on the other hand, could substantially reduce range losses and buy several decades to increase the likelihood of successful climate-change adaptation.

Of course, species can and do adapt and there is some evidence this is happening in response to the climate changes we have seen thus far.[66] But for many species and unique

[62] CHARLOTTE L. MORGAN, LIMITS TO ADAPTATION: A REVIEW OF LIMITATIONS RELEVANT TO THE PROJECT "BUILDING RESILIENCE TO CLIMATE CHANGE—COASTAL SOUTHEAST ASIA" (2011).

[63] ECOSYSTEMS AND HUMAN WELL BEING BIODIVERSITY SYNTHESIS 4, a*vailable at* http://www.maweb.org/documents/document.354.aspx.pdf (last visited May 16, 2014).

[64] Ilya M.D. Maclean & Robert J. Wilson, *Recent Ecological Responses to Climate Change Support Predictions of High Extinction Risk*, 108 PNAS 12337 (2011).

[65] R. Warren et al., *Quantifying the Benefit of Early Climate Change Mitigation in Avoiding Biodiversity Loss*, 3 NATURE CLIMATE CHANGE 678 (2013).

[66] For example, polar bears are spending more time on land and eating snow geese eggs and caribou rather than

habitats—like coastal salt marshes, prairie potholes, coral reefs, alpine systems, and the arctic—adaptation, whether natural or "assisted" by humans, is not a promising strategy. Because the pace of climate change is so rapid, the way species typically adapt (e.g., migration) is, in most cases, simply not possible given the pace and scale of change. Global change is simply too pervasive and occurring too quickly. According to a study published in *Ecology Letters*, most land animals will not be able to evolve quickly enough to adapt to the dramatically warmer climate expected by 2100 and will simply go extinct.[67]

Moreover, climate change is happening at the same time that species and ecosystems are under tremendous stress from many other human activities. Conversion of land for human uses (e.g., urban settlements, farming, harvesting of forests) can interfere directly with seed dispersal and cause changes in the composition of forested ecosystems.[68] Natural and manmade barriers, such as roads, cities, bodies of water, and agricultural land may block migration of species. Pollution and habitat degradation may impair the health of particular species, making them less able to withstand stresses from climate change. Alpine ecosystems may simply run out of room as alpine temperatures migrate above the mountaintops. Fragmentation of ecosystems and competition from introduced exotic species may make it impossible for species to migrate to suitable areas in response to climatic shifts. The Reality and the Rhetoric of Adaptation **[is this meant to be a new section heading?]**

Comment [PP1]: Yes

The capacity to adapt does not mean that effective action will be taken in time to reduce vulnerabilities to climate change. Given the documented impacts associated with climate change

their preferred prey of ringed seals. Sindya N. Bhanoo, *Polar Bears Turn to Snow-Goose Egg Diet*, N.Y. TIMES, Jan. 24, 2014.

[67] Ignacio Quintero & John J. Wiens, *Rates of Projected Climate Change Dramatically Exceed Past Rates of Climatic Niche Evolution Among Vertebrate Species*, 16 ECOLOGY LTRS. 1095 (2013).

[68] Joel D. Scheraga & Anne E. Grambsch, *Risks, Opportunities, and Adaptation to Climate Change*, 10 CLIMATE RESEARCH 85 (1998).

in the United States to date, and the prospect of much worse things to come, one might expect to see a robust application of adaptation strategies. According to the Second National Climate Assessment,[69] these are the new realities:

1. Global warming is unequivocal and primarily human-induced.
2. Climate changes are underway in the United States and are projected to grow.
3. Widespread climate-related impacts are occurring now and are expected to increase.
4. Climate change will stress water resources.
5. Crop and livestock production will be increasingly challenged.
6. Coastal areas are at increasing risk from sea level rise and storm surge.
7. Threats to human health will increase.
8. Climate change will interact with many social and environmental stresses.
9. Thresholds (e.g., temperature tolerances of some organisms) will be crossed, leading to large changes in climate and ecosystems.
10. Future climate change and its impacts depend on choices made today.

Yet, according to the Center for Climate and Energy Solutions, only fifteen states have adopted adaptation plans (another four are in process).[70] Most of what we have seen can be characterized as reactive (as opposed to proactive) adaptation.[71] In areas of the country like the Southwest, where climate change has already had a dramatic effect on water supplies, and where

[69] Globalchange.Gov, Assess the U.S. Climate, http://www.globalchange.gov/what-we-do/assessment (last visited July 25, 2013).

[70] Center for Climate and Energy Solutions, Climate Adaptation Plans, http://www.c2es.org/us-states-regions/policy-maps/adaptation (last visited July 25, 2013).

[71] Reactive adaptation occurs after the initial impacts of climate change become evident; proactive adaptation occurs before the impacts are obvious. Buying air conditioners is an example of a reactive strategy to heatwaves. Investing in green infrastructure to reduce the heat island effect in cities is an example of a proactive strategy.

the major reservoirs on the Colorado River have reached record low levels,[72] one would expect to see states scrambling to prepare for the "permanent dustbowl" that scientists have predicted for mid-century.[73] According to a study by the National Center for Atmospheric Research, within a half century much of the United States (and large parts of the rest of the world) could experience devastating drought at levels far worse than the 1930s Dust Bowl.[74] Yet the affected states have been slow to react. For example, the Arizona Drought Preparedness Plan adopted in 2004 does not factor climate change into future conditions.[75] The Colorado Statewide Water Supply Investigation report, which projects demands and supplies through 2030, notes that the projections may be affected by climate change but does not use climate forecasts in projecting availabilities and does not recommend the use of such forecasts in planning.[76] In New Mexico, which already faces declining groundwater levels and over-appropriated streams, the State Water Plan, published in December 2003, does not even mention climate change.[77] In sum, although the desert Southwest is squarely in the bulls-eye of climate change, adaptation efforts have been slow and tentative.

The federal government is not doing much better. Federal agencies manage over 600 million acres of land—almost 30 percent of the land area of the United States—and more than 150,000 acres of protected waters including 13 marine sanctuaries. These agencies are charged under multiple statutes with stewardship over these public resources. The natural resources under

[72] Felicity Berringer, *Lake Mead Hits Record Low Level*, N.Y. TIMES, Oct. 18, 2010.

[73] Alan Zarembo & Bettina Boxall, *Permanent Drought Predicted for Southwest*, L.A. TIMES, Apr. 6, 2007, http://www.livingrivers.org/archives/article.cfm?NewsID=765.

[74] Aiguo Dai, *Drought under Global Warming: A Review*, 2 WILEY INTERDISCIPLINARY REV.: CLIMATE CHANGE 45 (2011).

[75] ARIZONA DEPARTMENT OF WATER RESOURCES, ARIZONA DROUGHT PREPAREDNESS PLAN (2004), *available at* http://www.azwater.gov/AzDWR/StatewidePlanning/Drought/ADPPlan.htm.

[76] COLORADO WATER CONSERVATION BOARD, STATEWIDE WATER SUPPLY INITIATIVE—2010, *available at* http://cwcb.state.co.us/water-management/water-supply-planning/pages/swsi2010.aspx.

[77] NEW MEXICO OFFICE OF THE STATE ENGINEER, STATE WATER PLAN (2008), *available at* http://www.ose.state.nm.us/publications_state_water_plans.html.

their care, heavily used by Americans at over 600 million visits per year, are seriously threatened by climate change. Yet, despite a constant stream of announcements about climate adaptation planning on public lands, little progress has been made on the ground.

In January 2001, the Department of Interior issued a directive to the Forest Service, the Fish and Wildlife Service, the Bureau of Land Management, the National Park Service and other federal resource management agencies to analyze potential climate change effects in their management plans and activities.[78] According to a 2007 report by the Government Accountability Office (GAO), the resource managers have simply ignored that directive.[79] Specifically the GAO found that "resource managers have limited guidance about whether or how to address climate change and, therefore, are uncertain about what actions, if any, they should take. In general, resource managers lack specific guidance for incorporating climate change into their management actions and planning efforts."[80] In a separate report investigating federal infrastructure investments in roads and bridges, wastewater systems, and power plants that are vulnerable to climate change, GAO found that

> Decision makers have not systematically considered climate change in infrastructure planning for various reasons, according to representatives of professional associations and agency officials who work with these decision makers. For example, more immediate priorities—such as managing aging infrastructure—consume time and resources, limiting decision makers' ability to consider and implement climate adaptation measures. Difficulties in obtaining and using information needed to understand vulnerabilities and inform adaptation decisions pose additional challenges.[81]

[78] Secretarial Order 3289: Addressing the Impacts of Climate Change on America's Water, and other Natural and Cultural Resources (2009), http://www.doi.gov/whatwedo/climate/cop15/upload/SecOrder3289.pdf.

[79] U.S. GOVERNMENT ACCOUNTABILITY OFFICE, CLIMATE CHANGE: AGENCIES SHOULD DEVELOP GUIDANCE FOR ADDRESSING THE EFFECTS ON FEDERAL LAND AND WATER RESOURCES, GAO-07-863 (Aug 7, 2007), http://www.gao.gov/products/GAO-07-863.

[80] *Id.* at 8.

[81] U.S. GOVERNMENT ACCOUNTABILITY OFFICE, CLIMATE CHANGE: FUTURE FEDERAL ADAPTATION EFFORTS COULD BETTER SUPPORT LOCAL INFRASTRUCTURE DECISION MAKERS, GAO-13-242 (2013), http://www.gao.gov/products/GAO-13-242.

In November 2013 President Obama took a number of actions aimed at strengthening the nation's ability to plan for and adapt to climate change. On November 1, he issued an Executive Order (EO) titled "Preparing the United States for the Impacts of Climate Change."[82] Among other things, the EO directs federal agencies to "identify and seek to remove or reform barriers that discourage investments or other actions to increase the Nation's resilience to climate change while ensuring continued protection of public health and the environment;" and to "reform policies and Federal funding programs that may, perhaps unintentionally, increase the vulnerability of natural or built systems, economic sectors, natural resources, or communities to climate change related risks." The EO creates the Council on Climate Preparedness and Resilience comprised of over 30 federal agencies; and also directs the heads of the Departments of Defense, the Interior, and Agriculture, the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and other agencies to work with the Chair of the Council on Environmental Quality (CEQ) and the Director of the Office of Management and Budget (OMB) to "complete an inventory and assessment of proposed and completed changes to their land- and water-related policies, programs, and regulations necessary to make the Nation's watersheds, natural resources, and ecosystems, and the communities and economies that depend on them, more resilient in the face of a changing climate." Obama also created the Interagency Climate Change Adaptation Task Force led by the CEQ. Finally, President Obama ordered the creation of a high-level task force aimed at bolstering the roles of state and local governments in national preparation for the impacts of climate change. The 24-member task force includes the governors of seven states and Guam and 18 officials from local and tribal governments.

[82] Exec. Order, *Preparing the United States for the Impacts of Climate Change*, Nov. 1, 2013, *available at* http://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change.

The Task Force will face skepticism in some quarters regarding the urgency of addressing the climate challenge. The majority of states have yet to seriously engage the adaptation planning process.[83] North Carolina actually passed a law banning the state from basing coastal policies on the latest scientific predictions of how much the sea level will rise.[84] New Jersey Governor Chris Christie publicly dismissed the idea that climate change had anything to do with Sandy, the largest storm in the history of the Atlantic, and rejected calls for better coastal planning to prepare for the next super-storm.[85] In questioning whether there was sufficient proof that Sandy was "caused" by climate change, the Governor missed the point. As Kevin Trenberth, Distinguished Senior Scientist at the National Center for Atmospheric Research, has said "All weather events are affected by climate change because the environment in which they occur is warmer and moister than it used to be."[86] Climate change amplifies the effects of extreme weather, just like steroids amplify the prowess of a batter. Asking whether a given storm was caused by climate change is like asking which home run that Barry Bonds hit was caused by steroids. The point is that there is a large body of scientific evidence demonstrating that climate change will increase both the likelihood and severity of storms like Sandy.[87]

[83] *See* GEORGETOWN CLIMATE CENTER, STATE AND LOCAL ADAPTATION PLANS, http://www.georgetownclimate.org/adaptation/state-and-local-plans?page=1 (last visited May 16, 2014).

[84] Patrick Gannon, *Sea-level Rise Bill Becomes Law*, STAR NEWS ONLINE, Aug. 1, 2012; http://www.starnewsonline.com/article/20120801/ARTICLES/120809970/-1/business?Title=Perdue-does-not-sign-or-veto-sea-rise-level-bill.

[85] Sarah Gonzalez, *Christie: No Proof Climate Change Caused Sandy*, WNYC, May 20, 2013; http://www.wnyc.org/blogs/transportation-nation/2013/may/20/gov-christie-rejects-nj-transit-needed-prepare-climate-change-ahead-sandy/.

[86] Kevin E. Trenberth, *Framing the Way to Relate Climate Extremes to Climate Change*, 115 CLIMATIC CHANGE 283 (2012).

[87] IPCC SPECIAL REPORT, MANAGING THE RISKS OF EXTREME WEATHER EVENTS AND DISASTERS TO ADVANCE CLIMATE ADAPTATION, SUMMARY FOR POLICY MAKERS 5–7 (2012).

## V. THE RISKS OF MALADAPTATION

Maladaptation is defined by the IPCC as "a change in natural or human systems that leads to an increase rather than a decrease in vulnerability."[88] Actions are maladaptive when they increase emissions of greenhouse gases. For example, greater reliance on energy-intensive air conditioners in response to the health impacts of heat-waves; or greater use of snowmaking at ski resorts.[89] Actions are maladaptive if, relative to alternatives, they reduce incentives to adapt. For example, promoting water conservation through marginal cost pricing structures and recycling programs is a better approach to dealing with more frequent and intense droughts than constructing expensive, energy intensive desalination plants that contribute yet more carbon to the atmosphere.[90] Actions are maladaptive if, relative to alternatives, they set paths that limit future choices through major capital investments in energy and water supply systems. Maladaptation can also occur as a result of underestimating the degree of sea level rise and storm surge leading to risky development in areas not adequately protected by land-use ordinances and building codes. Damage may simply be transferred from one place to another as in the case of a dike or levee that redirects wave energy to another section of the coast. Some measures may increase the vulnerability of those that are at high risk, such as those occupied by minority groups or low-income households.

[88] IPCC, 2001 CLIMATE CHANGE REPORT, Annex B. Glossary of Terms, http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf.

[89] For example to insure that there would be sufficient snow for the Winter Olympics in Sochi, arrangements were made to store 16 million cubic feet of snow under insulated blankets and to operate hundreds of snow-making guns around the clock to keep them that way. Porter Fox, *The End of Snow?* N.Y. TIMES SUNDAY REV., Feb. 7, 2014.

[90] On January 24, 2014, California Governor Jerry Brown declared a drought emergency and issued a statewide water conservation order requiring a 20% cutback in water use across the board. Lisa Fernandez, *Gov. Brown Declares Drought Emergency for California*, NBC SAN DIEGO, Jan 28, 2014, *available at* http://www.nbcsandiego.com/news/california/Gov-Jerry-Brown-Orders-Drought-Emergency-for-California-240818091.html?akmobile=o. Calling it "the worst drought California has ever seen," Governor Brown launched the Save Our Water Campaign and issued a series of directives to state agencies to facilitate water transfers, conserve groundwater, and protect aquatic resource. *See* http://www.saveourh20.org/.

The Maginot Line is often cited as the classic case of maladaptation. Built at enormous cost to repel a WWI style invasion, it utterly failed when the Germany army in WWII simply skirted the line and caught the French forces off guard and unprepared. The world is facing a number of Maginot Line decisions. When confronted with the uncertainty in climate information, a reasonable reaction might be to ask climate scientists to improve knowledge and understanding, and to provide, as soon as possible, more reliable forecasts of future conditions. Unfortunately, even though knowledge will improve, uncertainty will remain inherent to adaptation decisionmaking. The processes of adaptation to climate change in both human and natural systems are highly complex and dynamic, often entailing many feedbacks and dependencies on existing local and temporal conditions. In many cases, decisions, such as the replacement of existing infrastructure, cannot simply be delayed in the hope that more certain information will become available. What is needed instead is an approach that is more robust to the number of scenarios that may play out and more inclusive in terms of the people who may be affected and those who will have to pay for the measures. It is more like an optimal approach that combines the best practices of mitigation and adaptation. Climate resilience is more than adaptation. As defined by the IPCC, adaptation means an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, an adjustment that moderates harm or exploits beneficial opportunities. Resilience, on the other hand, refers to the capacity over time of a system, organization, community, or individual to create, alter, and implement multiple adaptive actions. Resilience is a combination of activities that reduces risks and vulnerability to those risks and provides a safety net or recovery path. Resilience might be possible only by increasing the overall strength of a system by removing or reducing other stressors unrelated to climate change. For example, coral reef organisms have some ability to

acclimate to seasonal differences in temperature; however they have little capacity to acclimate to temperatures more that 2–3°C above their annual mean summer maxima. Corals currently under stress from other factors such as poor water quality may also not be able to adapt as well to increases in temperature than corals not experiencing these stressors, leading to a great amount of uncertainty about how coral reef systems as a whole will adapt to climate change in the future

## VI. GEO-ENGINEERING: THE HAIL MARY PASS

Desperate times call for desperate measures. Frustrated at having their persistent warnings for over three decades ignored by the public, political leaders, and by the slow pace and uncertain outcomes of negotiations under the UNFCCC process, a number of distinguished scientists are calling for enhanced research and experimentation on a number of radical techniques to re-engineer the climate system to offset the impacts of global warming. As it relates to climate change, geo-engineering falls into two categories: solar radiation management and carbon dioxide removal.[91] The former involves reflecting solar radiation back into space. The latter is aimed at removing carbon dioxide from the atmosphere and storing it.

Some ideas, like launching billions of tiny mirrors into space to reflect the sun, or fertilizing the oceans with iron to absorb carbon (as if the oceans needed more), are way outside the box.[92] Others, like building a flotilla of massive vessels to ply the oceans spraying saltwater to lighten the clouds and increase the albedo effect, pose all kinds of problems of efficacy, unintended consequences, and governance issues.[93] Still others, like planting zillions of artificial trees to soak up the carbon, have been demonstrated at a pilot scale but are nowhere near

[91] David Suzuki & Ian Hanington, *Is Geoengineering a Silver Bullet for Climate Change?, at* http://www.davidsuzuki.org/blogs/science-matters/2013/08/is-geoengineering-a-silver-bullet-for-climate-change/ (Aug. 22, 2013).

[92] Andrew Moseman, *How Geoengineering Works: 5 Big Plans to Stop Global Warming*, POPULAR MECHANICS, Oct. 1, 2009.

[93] *Id.*

commercial application.[94] The technique that has drawn the most attention is injecting sulfates into the stratosphere to create a blanket effect to cool the earth. Inspired by the Mt. Pinatubo eruption in 1991 which resulted in a 1°F reduction in global temperatures, some scientists are eager to test the idea on a broader scale.[95] The idea of pouring vast amounts of sulfur dioxide into the atmosphere to combat climate change may seem strange when considering the monumental efforts and money the United States, Europe, and other industrialized nations invested into installing scrubbers on powerplants to abate the acid rain damage to aquatic ecosystems and other cultural resources. But that simply underscores the desperation felt by the scientific community. Al Gore has said it is "insane, utterly mad and delusional in the extreme" to turn to geo-engineering projects to avoid a climate catastrophe [96]

A full examination of the geo-engineering debate is beyond the scope of this paper. Questions of efficacy, governance, unintended consequences, cost, and equity loom large. Yet it must be acknowledged that these ideas are being pursued without any over-arching framework for evaluation or regulation. That is almost certainly not conducive to either good science or sound public policy.[97]

## VII. CONCLUSION

Having squandered several decades that could have been spent implementing cost-effective and pro-active measures to address climate change, we are now faced with the daunting task of having to fast track more stringent mitigation efforts that will only become more costly as time

[94] David Biello, *400 PPM: Can Artificial Trees Help Pull CO2 from the Air?,* SCI. AM., May 16, 2013.
[95] DAVID KEITH, A CASE FOR CLIMATE ENGINEERING (2013).
[96] Suzzane Goldenburg, *Al Gore Says Use of Geo-Engineering to Head off Climate Disaster is Insane*, GUARDIAN, Jan. 14, 2014.
[97] For more background, see *Geoengineering: Challenges and Global Impacts*, a report of a seminar held on July 15, 2009, that explored approaches to managing climate change based on strategic engineering of the environment on a global scale. Institute of Physics The Royal Academy of Engineering, http://www.rsc.org/images/geoengineering_tcm18-179077.pdf.

passes.[98] At the same time, society will be saddled with increasing response costs to the ravages of extreme weather events and the reality of coping with the unavoidable consequences of our past neglect.[99] But it would be a grave mistake to shift the focus entirely to adaptation in the vain hope that we can somehow adapt our way out of the hole we have dug for ourselves and future generations—not to mention all the other life forms on earth. Mitigation should remain the number one priority. The scientists have crunched the numbers and provided a prescription for climate stabilization: to avoid potentially catastrophic consequences that will exceed the limits of adaptation, we must find ways to limit the cumulative loading of carbon in the atmosphere to less than one trillion metric tons by 2050.[100] Whether we as a global society can find the courage and resolve to do what needs to be done remains to be seen. As Elizabeth Kolbert has said, "It may seem impossible to imagine that a technologically advanced society could choose, in essence, to destroy itself, but that is what we are now in the process of doing."[101]

[98] G. Luderer et al., *Economic Mitigation Challenges: How Further Delay Closes the Door for Achieving Climate Targets*, 8 ENVTL RESEARCH LTRS. 031033 (2013). The authors conclude that delaying climate policy would triple short-term mitigation costs. Global economic growth would be cut back by up to 7% within the first decade after climate policy implementation if the current international stalemate is continued until 2030—compared to 2% if a climate agreement is reached by 2015.

[99] A 2005 study by the Multihazard Mitigation Council shows that each dollar spent on mitigation saves society an average of four dollars in damages avoided. MULTIHAZARD MITIGATION COUNCIL, NATURAL HAZARD MITIGATION SAVES: AN INDEPENDENT STUDY TO ASSESS THE FUTURE SAVINGS FROM MITIGATION ACTIVITIES (2005), *available at* http://www.nibs.org/?page=mmc_projects#nhms.

[100] David Biello, *How Much Is Too Much?: Estimating Greenhouse Gas Emissions*, SCI. AM., Apr. 29, 2009, http://www.scientificamerican.com/article.cfm?id=limits-on-greenhouse-gas-emissions.

[101] Elizabeth Kolbert, FIELD NOTES FROM A CATASTROPHE: MAN, NATURE, AND CLIMATE CHANGE 189 (2006).