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4°C

Robin Kundis Craig

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J.B. Ruhl[*] and Robin Kundis Craig[+]

ABSTRACT

Conventional climate change wisdom tells governments to plan for a 2°C increase in global average temperature. However, increasingly robust science indicates that the planet is well on its way to at least 4°C of warming, possibly by the end of the 21st century or shortly thereafter. That much warming is a governance game changer, taking the multiple and interconnected complex systems that define U.S. society across thresholds and tipping points into cascades of transformational change. Critically, these systems potentially include the United States' system of government—the key system that must *successfully adapt to the coming changes in order for the country as a whole to have any chance of adapting peacefully, equitably, and productively to systemic transformation while still remaining a democracy.*

This Article seeks to push U.S. climate change adaptation policy toward an entirely new mode of governance necessary to meet the challenges ahead. It does so by making five novel arguments. First, it assembles recent scientific climate change studies to show that a 4°C warmer future is currently the planet's most likely trajectory. Second, it argues that being on that trajectory necessitates the dissociation of climate change mitigation and adaptation goals so that adaptation policy is free to address this more dire future. Third, it summarizes recent science to demonstrate that 4°C of warming poses a categorically different adaptation challenge than 2°C, as in situ adaptation becomes increasingly impossible, inducing both species and large numbers of people to migrate within U.S. boundaries. Fourth, to deal with these migrations and their attendant needs and consequences, this Article describes both a new mode of climate change adaptation, called "redesign" adaptation, and the governance tools available to coordinate, promote, and guide the equitable and productive resettlement of the United States. Finally, the Article argues that the United States, with strong leadership and funding from the federal government, needs to initiate anticipatory governance practices now *to facilitate redesign adaptation in the future, beginning with a new national foresight research program.*

[*] David Daniels Allen Distinguished Chair of Law, Vanderbilt University Law School.

[+] James I. Farr Presidential Endowed Professor of Law and University Distinguished Professor, University of Utah S.J. Quinney College of Law, Salt Lake City, UT (through June 30, 2021); Chaired Professor of Law, Gould School of Law, University of Southern California, Los Angeles (from July 1, 2021). We appreciate comments received on early drafts of this work during workshops conducted (online) by the U.C. Davis School of Law, University of Maryland Law School, Vanderbilt Law School, and Vermont Law School.

TABLE OF CONTENTS

INTRODUCTION

In March 2020, while the world's attention was focused on the coronavirus pandemic, an international team of 89 polar scientists from 50 organizations reported that Greenland and Antarctica are losing ice six times faster than they were in the 1990s.[1] Based on satellite data, the research team concluded that "[i]f the current melting trend continues, the regions will be on track to match the 'worst-case' scenario of the Intergovernmental Panel on Climate Change (IPCC) of an extra 6.7 inches (17 centimeters) of sea level rise by 2100."[2] One month later, in Siberia, "the small town of Verkhoyansk (67.5°N latitude) reached 100.4 degrees Fahrenheit, 32 degrees above the normal high temperature" and "likely the hottest temperature ever recorded in Siberia and also the hottest temperature ever recorded north of the Arctic Circle, which begins at 66.5°N."[3] All around the town, the Arctic tundra was burning.[4] This was not an anomaly, but rather the leading edge of a trend. Throughout the northern hemisphere, wildfire danger is expanding northward: before enflaming the Arctic in 2020, wildfire devastated large parts of Norway, Sweden, and Scotland in the summer of 2019.[5]

The accelerating ice loss and expanding wildfire zones are potential markers of what are known as tipping points—thresholds along a nonlinear pattern of system change that, once crossed, move the system into a new set of positive feedback dynamics that accelerate the pace of change and can be extremely difficult to reverse.[6] Scientists are increasingly concerned that we are dangerously close to passing these and many other irreversible climate change tipping points, especially with respect to the West Antarctic ice sheet, tropical coral reefs, the Amazon rain forest, and the Arctic boreal forest.[7] To add an additional chaotic possibility, once these and other systems tip, they might set off cascades of transformations in other natural systems.[8]

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[1] *Greenland, Antarctica Melting Six Times Faster Than in the 1990s*, NASA GLOBAL CLIMATE CHANGE (Mar. 16, 2020), https://climate.nasa.gov/news/2958/greenland-antarctica-melting-six-times-faster-than-in-the-1990s/.

[2] *Id*.

[3] Jeff Berardelli, "Arctic records its hottest temperature ever," CBS NEWS (updated June 23, 2020, 8:47 PM), https://www.cbsnews.com/news/arctic-hottest-temperature-ever/.

[4] *Id*.

[5] *Scotland, Norway and Sweden already severely affected by forest fires due to the dry weather in the north*, CTIF: INTL. ASS'N FIRE & RESCUE SERVS., (24 April 2019), https://www.ctif.org/news/scotland-norway-and-sweden-already-severely-effected-forest-fires-due-dry-weather-north.

[6] *See* Marten Scheffer, *Early-warning Signs for Critical Transitions*, 461 NATURE 53 (2009).

[7] Timothy M. Lenton, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen & Hans Joachim Schellnhuber , *Climate Tipping Points—Too Risky to Bet Against*, 575 NATURE 592, 592-95 (2019) (corrected April 9, 2020), https://www.nature.com/articles/d41586-019-03595-0). For example, there is evidence that the Greenland ice sheet is experiencing mass loss at accelerating rates and has "switch[ed] to a new dynamic state of sustained mass loss that would persist even under a decline in surface melt." Michalea D. King, Ian M. Howat, Salvatore G. Candela, Myoung J. Noh, Seongsu Jeong, Brice P. Y. Noël, Michiel R. van den Broeke, Bert Wouters & Adelaide Negrete, *Dynamic Ice Loss from the Greenland Ice Sheet Driven by Sustained Glacier Retreat*, 1 COMMUNICATIONS EARTH & ENV'T 1, 1 (2020) (corrected Sept. 4, 2020), https://doi.org/10.1038/s43247-020-0001-2.

[8] Lenton et al., *supra* note 7, at 593; Will Steffen, Johan Rockström, Katherine Richardson, Timothy M. Lenton, Carl Folke, Diana Liverman, Colin P. Summerhayes, Anthony D. Barnosky, Sarah E. Cornell, Michel Crucifix, Jonathan F. Donges, Ingo Fetzer, Steven J. Lade, Marten Scheffer, Ricarda

And yet, if you consult climate scientists' predictions from as recently as a decade ago, none of these climate change impacts are supposed to be happening yet.

No one can fault the scientists of a decade ago for underestimating the pace and intensity of climate change. They were and still are studying a rapidly moving target. For example, the peak annual atmospheric concentration of carbon dioxide (CO_2), the major driver of climate change, was 357 parts per million (ppm) in 1990, 367 ppm in 2000, 388 ppm in 2010, and 413 ppm in 2020. All of these levels are unprecedented in the past 800,000 years, and the highest, at over 400 ppm, has not been experienced by our planet for three million years.[9] In addition, knowledge and technologies also are improving as research observes climate change, in many cases revealing that projections were underestimating the pace of change.[10] It is thus no wonder that as researchers keep studying the ongoing changes in natural systems, they are finding that impacts are hitting harder and faster than previously expected.[11]

This trend has significant and potentially dire implications for governance and law. Climate change disruptions will extend not only to ecological systems, but to social systems as well, including systems of governance. It would be naïve to believe that governance in the United States will be immune; indeed, democratic systems of governance may be particularly unstable in the face of the relentless disruptions caused by climate change. Recognizing that this is a weighty claim in need of solid support, this Article does not mince words. It is long, detailed, and extensively referenced. We lean heavily on scientific findings reported in leading peer-reviewed journals,[12] the amalgam of which paints a picture of our nation's (and the world's) future that is nothing short of a policy nightmare. Getting the policies wrong—that is, failing to anticipate and adaptively plan for that future—presents an existential threat to democratic governance.

To be sure, policy disciplines have already grown far more sophisticated in their understanding of climate change governance compared to, say, the dawn of the 21st

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Winkelmann, and Hans Joachim Schellnhuber. *Trajectories of the Earth System in the Anthropocene*, 115 PNAS 8252, 8253-54 (2018), www.pnas.org/cgi/doi/10.1073/pnas.1810141115.

[9] Rebecca Lindsey, *Climate Change: Atmospheric Carbon Dioxide*, NOAA CLIMATE.GOV (Aug. 14, 2020), https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide; M. Willeit, A. Ganopolski, R. Calov & V. Brovkin, *Mid-Pleistocene Transition in Glacial Cycles Explained by Declining CO_2 and Regolith Removal*, 5(4) SCI. ADVANCES eaav7337 (2019), DOI: 10.1126/sciadv.aav7337.

[10] Michael Oppenheimer & Richard B. Alley, *How High Will the Seas Rise?*, 354 SCI. 1375 (2016) (noting that projections of sea level rise keep getting higher based on improved knowledge of dynamical processes).

[11] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SPECIAL REPORT ON THE OCEAN AND CRYOSPHERE IN A CHANGING CLIMATE 6-7, 9 (2019) [hereinafter 2019 IPCC OCEAN & ICE REPORT] ("Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850."); INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT 6-7 (2014) [hereafter 2014 IPCC SYNTHESIS REPORT] (noting that the global land temperature is rising twice as quickly as it should naturally).

[12] Although neither of us is a climate scientist, one of us holds a doctorate degree in ecological geography, the other is a trained science writer with a doctorate degree that explored the incorporation of science into literary descriptions of social and ecological change. Both of us regularly publish work in scientific journals, often as part of interdisciplinary teams including scientists from the natural and social sciences. We feel adequately equipped to collect, evaluate, and synthesize the available climate science for a policy audience.

century, and the severity of climate change is broadly motivating policy discourse. There is now widespread agreement that both mitigation—that is, efforts to reduce greenhouse gas emissions and the concentration of anthropogenic greenhouse gases in the atmosphere[13]—and adaptation—which encompasses efforts to adjust human behavior to climate change's unavoidable alterations[14]—must be *concurrent* governance efforts.[15] Moreover, those efforts must be cognizant of each other, because mitigation and adaptation strategies interact, sometimes working in tandem to produce co-benefits (e.g., water conservation generally reduces energy consumption), but sometimes involving trade-off conflicts (e.g., subsidizing biofuels at the expense of food security).[16] Finally, because both climate change mitigation and climate change adaptation require governance efforts at multiple scales, from local to international, coordination of these efforts is likely to become an increasingly important part of the overall climate change governance challenge.[17]

So far, so good. But here's the rub: *which* future should governments and other governance entities be coordinating about? Climate change adaptation inherently requires *present* governance institutions and arrangements to anticipate *future* conditions that are distant in time, in constant flux, riddled with uncertainty, and unlike any experienced in recorded human history. The conventional "predict and plan" mode of governance is stretched beyond its capacity under such conditions. Scholars in the planning and policy sciences thus have called for a new form of governance, which they call *anticipatory governance*, to reflect the challenge of formulating climate adaptation policy strategies that are built around a range of dynamic possible future scenarios and require constant monitoring and policy adjustment.[18] The crucial first step in anticipatory governance for climate change adaptation, therefore, is what range of scenarios to use.

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[13] 2014 IPCC SYNTHESIS REPORT, *supra* note 11, at 17.

[14] *Id*. at 19.

[15] *Id*. at 17.

[16] Mia Landauer, Sirkku Juhola & Maria Söderholm, *Inter=relationship between Adaptation and Mitigation: A Systemic Literature Review*, 131 CLIMATIC CHANGE 505, 505-17 (2015), https://doi.org/10.1007/s10584-015-1395-1 (summarizing research on mitigation and adaptation inter-relationships); Ayyoob Sharifi, *Co-benefits and Synergies between Urban Climate Change Mitigation and Adaptation Measures: A Literature Review*, 750 SCI. TOTAL ENV'T 141642, at 9-15 (2021), https://doi.org/10.1016/j.scitotenv.2020.141642 (focusing on the synergies); Ayyoob Sharifi, *Trade-offs and Conflicts between Urban Climate Change and Adaptation Measures: A Literature Review*, 276 J. CLEANER PROD. 122813, at 7-12 (2020), https://doi.org/10.1016/j.jclepro.2020.122813(focusing on the conflicts).

[17] *See, e.g.*, Elizabeth Burleson, *A Climate of Extremes: Transboundary Conflict Resolution*, 32 VERMONT L. REV. 477, 496, 501 (2008) (noting the agreement within both the United States National Academy of Sciences and the international community that coordination of climate change adaptation and mitigation is necessary).

[18] *See, e.g*., Karlijn Muiderman, Aarti Gupta, Joost Vervoort &Frank Biermann, *Four Approaches to Anticipatory Climate Governance: Different Conceptions of the Future and Implications for the Present*, 11 WIRES CLIMATE CHANGE e673, at 2 (2020), https://doi.org/10.1002/wcc.673; Ray Quay, *Anticipatory Governance: A Tool for Climate Change Adaptation*, 76 J. AM. PLANNING ASS'N 496, 498-99 (2010), DOI 10.1080/01944363.2010.508428. Anticipatory governance theory also has been influential in the nanotechnology realm. *See, e.g*., David H. Guston, *Understanding "Anticipatory Governance"*, 44 SOCIAL STUD. SCI. 218, 2019 (2014), DOI: 10.1177/0306312713508669. For more detail on anticipatory governance theory, *see infra* Part IV.C-D.

Until recently, the answer was straightforward, driven by a unified vison of the future based on a hardline goal for climate mitigation policy. The standard policy goal for the mitigation modality has been that we should be working relentlessly to contain the global average increase in temperature to 1.5°C above pre-industrial levels ideally, and to 2°C at worst (2.7°F to 3.6°F).[19] This is the mitigation goal of multiple organizations and international agreements. Under the 2015 Paris Accord, for example, nearly every signatory country pledged to keep global temperatures "well below" 2°C above pre-industrial levels and to "pursue efforts to limit the temperature increase even further to 1.5C."[20]

Adaptation policy has mostly followed mitigation policy's lead, built primarily around projections of measures needed to adjust to what the world will look like when it is 1.5° to 2°C warmer than pre-industrial times.[21] To be sure, adaptation *will* be necessary, even for that future. For example, the IPCC has spelled out in great detail the adaptations that would be required as a way of emphasizing the need to try to keep global warming to below 2°C.[22] Framed this way, adaptation policy has supported mitigation policy through their unified view of the future.

However, the 2°C as maximum assumption no longer works in the adaptation modality. As we detail in Part I, despite the continued international homage to this mitigation goal, most contemporary evaluations of the progress of climate change indicate that the increase in global average temperature will exceed 2°C, and probably

[19] "Global average temperature" refers to the average *surface* temperature of the entire planet. The IPCC, for example, traditionally defines global mean surface temperature ("GMST") using a weighted average of near-surface air temperatures over land ("SAT") and sea surface temperatures over the ocean ("SST"), INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, GLOBAL WARMING OF 1.5 °C, at 56 (2018) [hereinafter 2018 IPCC 1.5 °C REPORT]. Increases in this average temperature are a handy way to reference how much the planet as a whole has warmed, but—like most means—this average does not necessarily reflect the actual temperature conditions of any particular place or the warming that that place has experienced. The IPCC "defines 'warming', unless otherwise qualified, as an increase in multi-decade global mean surface temperature (GMST) above pre-industrial levels. Specifically, warming at a given point in time is defined as the global average of combined land surface air and sea surface temperatures for a 30-year period centered on that time, expressed relative to the reference period 1850–1900 … ." *Id*.

[20] *The Paris Agreement*, UNITED NATIONS CLIMATE CHANGE (as viewed Jan. 9, 2021), https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement#:~:text=Its%20goal%20is%20to%20limit,neutral%20world%20by%20mid%2Dcentury. For a history of the 2°C goal, see generally Yun Gao, Xiang Gao, & Xiaohua Zhang, *The 2℃ Global Temperature Target and the Evolution of the Long-Term Goal of Addressing Climate Change—From the United Nations Framework Convention on Climate Change to the Paris Agreement*, 3 ENGINEERING 272 (2017), https://doi.org/10.1016/J.ENG.2017.01.022; Mark New, Diana Liverman, Heike Schroder, & Kevin Anderson, *Four degrees and beyond: The potential for global temperature to increase four degrees and its implications*, 369 PHIL. TRANS. ROYAL SOC. A 6, 7-8 (2011), doi:10.1098/rsta.2010.0303.

[21] We review adaptation policy design in Part III, *infra*. For the most comprehensive survey of United States adaptation law and policy, see THE LAW OF ADAPTATION TO CLIMATE CHANGE: U.S. AND INTERNATIONAL ASPECTS (Michael B. Gerrard & Katrina Fischer Kuh eds. 2013) [hereinafter LAW OF ADAPTATION].

[22] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 5.

exceed 3°C, this century,[23] with increases continuing beyond 2100.[24] Given the trajectories of CO_2 atmospheric concentrations and anthropogenic emissions (not to mention additional emissions from the effects of climate change on ecosystems), the 2°C limit is likely achievable only if both the sensitivity of climate to CO_2 concentrations going forward is low[25] *and* either (1) technology developed in the next 50 years makes net negative emissions possible and globally substantial, or (2) global emissions peak rapidly and then fall for the next several decades at rates never before voluntarily achieved by any single nation.[26] As we explain in Part I, these are unrealistic assumptions, at best.

Given this likely trajectory, a dual-minded approach to climate change, politically difficult as it is, is necessary to simultaneously give the planet the best future possible (mitigation governance) while preparing humanity for the worst of the probable realities (adaptation governance). In other words, mitigation policy and adaptation policy can no longer operate under a unified view of the future. Rather, like Schrödinger's cat, governance entities must simultaneously resonate in two different climate futures—a mitigation modality aimed at a ceiling of 2°C and an adaptation modality prepared for an increase in global average temperature as high as 4°C.[27]

We both are committed to aggressive mitigation policy, and any failure to stay below 2°C warming should spur redoubled efforts to stabilize the planetary climate system at as small a temperature increase as possible. Nevertheless, we do not here engage the emerging debate over whether mitigation policy should continue to frame itself around the 1.5°-2°C goal.[28] Rather, our focus is on the need to begin thinking about the governance necessary to successfully adapt to a far warmer world—a 4°C future.

What the United States and other nations are doing to adapt to a 2°C future will not be enough for this warmer world. As we explain in Part II, research increasingly identifies warming of 2°C as a likely tipping point threshold for many ecological systems.[29] Evidence from the historical records and advanced modeling depict warming beyond 2°C as game changing, and the multiple crossings of multiple thresholds will require a different kind of adaptation.

Moreover, radical changes in the ecological systems will likely trigger tipping points in social systems, as well. As a startling example, at the extreme temperature increase of 7.5°C that could occur under a business-as-usual scenario with no mitigation, by 2070 one-third of the world's population would exist in an annual temperature range presently found on only 0.8% of the world's land mass, mostly in the Saharan desert, if

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[23] Celine Guivarch & Stephane Hallegatte, *2C or not 2C?*, 23 GLOBAL ENVT'L CHANGE 179, 180-86 (2013), https://doi.org/10.1016/j.gloenvcha.2012.10.006 (summarizing the growing perspective that 2ºC is not attainable).

[24] For a discussion of evidence supporting this assessment, *see infra* Part I.

[25] For detail on climate sensitivity, see *infra* Part I.C.

[26] Guivarch & Hallegatte, *supra* note 23, at 186.

[27] J.B. Ruhl, *Schrödinger's Climate*, JDSUPRA (May 19, 2020), https://www.jdsupra.com/legalnews/schrodinger-s-climate-32775/.

[28] The concern is that as the 2°C target loses credibility, adhering to it undermines international negotiations and, worse, would lead to insufficient mitigation measures. Guivarch & Hallegatte, *supra* note 23, at 179.

[29] Will Steffen et al., *supra* note 8, at 8253-54 & fig. 2.

they remained in situ.[30] It is unlikely they all would remain in situ, meaning that mass human (and other species) migration is a significant adaptation issue. Adaptation at every level of warming thus is best thought of as evolving in interdependent social-ecological systems, and this evolutionary dynamic will become more intense and rapid above 2°C. To be effective, adaptation thus cannot continue to be conceptualized as an incrementally linear extrapolation of current efforts if social-ecological systems undergo nonlinear change beyond 2°C.[31]

As suggested above, however, the unified vision binding adaption and mitigation policy together has kept adaptation policy and planning focused on a 2°C future. As we outline in Part III, this unified vision of a 2°C future has played out in adaptation policy in the United States and many other nations through three interconnected modes of adaptation deployed primarily at the local scale.[32] The first is, where practicable, to *resist* the impacts of climate change, such as by constructing hard sea walls to fend of rising sea levels. The second is to build the *resilience* of social-ecological systems to the harms of climate change, such as by improving urban capacity to respond to heat waves. The third mode is to *retreat* from unavoidable impacts, such as in areas where coastal resistance using sea walls is not practical. Using these "Three Rs," conventional adaptation policy is envisions the end product of as something close to life before warming and, importantly, in the same place.

As the prospect of holding temperature increase to under 2°C erodes, however, in situ adaptation using the Three Rs can no longer remain the presumed norm. Many human beings and the complex social-ecological systems in which they currently exist, including in the United States, will not be able to remain in their same configurations in the same locations in a "beyond 2°C" world.[33] As these risks become realities, the Three Rs are unlikely to be sufficient, and they may even be futile in some regions of the nation.[34] In short, moving past 2°C will require adding a fourth climate change adaptation mode—*redesign*. By "redesign," we mean transformational adaptation measures as radical as the pace and intensity of changing conditions beyond 2°C, measures that will be needed to reconfigure and relocate our nation's population distribution, land uses, infrastructure, economic and production networks, natural resource management, and other social, ecological, and technological systems.[35] The redesign adaptation mode anticipates, responds to, designs, and facilitates this relocation and reconception of population, infrastructure, agriculture, and other social-ecological system components.

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[30] Chi Xu, Timothy A. Kohler, Timothy M. Lenton, Jens-Christian Svenning, & Marten Scheffer *Future of the Human Climate Niche*, 117 PNAS 11350, 11350 (2020), https://doi.org/10.1073/pnas.1910114117.

[31] Mark Stafford Smith, Lisa Horrocks, Alex Harvey & Clive Hamilton, *Rethinking Adaptation for a 4°C World*, 369 PHIL. TRANS. OF THE ROYAL SOC'Y A 196, 196 (2011), https://doi.org/10.1098/rsta.2010.0277 ("Adapting to global warming of 4°C cannot be seen as a mere extrapolation of adaptation to 2°C; it will be a more substantial, continuous and transformative process").

[32] For descriptions of each, *see infra* Part II.A

[33] For a discussion of these and other likely impacts, see *infra* Part II.

[34] For a discussion of the growing body of research on this theme, se*e infra* Part III.

[35] For a discussion of the redesign adaptation mode, *see infra* Part III.C.

As much as the resist, resilience, and retreat adaptation modes have posed difficult governance challenges already,[36] the governance stakes in a 4°C world that requires the redesign mode of adaptation are potentially existential. Among the social systems subject to massive disruption and in need of adaptation, therefore, governance systems are of foremost concern. If redesign is not governed effectively, people will be more than angry with their governments. To avoid or minimize that disruption, engaging *now* in anticipatory adaptation to a world that will see more than a 2°C increase in global average temperature, while not costless, will give human societies like the United States the best chance of avoiding a breakdown in democratic governance.

The question this Article thus engages, perhaps quixotically, is: What does democratic governance of a 4°C world look like? We set out through this Article to begin a robust dialog about how governance in the United States can adapt to successfully cope with that scenario, where "success" means: (1) adapting to extreme climate change as a nation *without* transitioning our system of governance to either authoritarianism or tribalism; while (2) providing opportunities and support for those individuals and communities that otherwise face significant risks of being ignored, overrun, forgotten, left behind, or otherwise further marginalized; *and* (3) still striving to improve the resilience of the ecological components of the many social-ecological systems that we inhabit; *and* (4) building and retaining the capacity to continue adapting democratic governance to perpetually evolving social-ecological conditions. This is a tall order, to be sure, but if success in the face of daunting global conditions can be condensed to the goal of "staying in the game,"[37] these four conditions seem necessary.

To frame and spark such a dialog, this Article proceeds in four parts. Part I surveys the contemporary science showing why the 2°C goal is likely no longer feasible and a 4°C world is a real possibility. Part II leverages scientific projections of conditions at beyond 2°C to envision the 4°C world, including how it plays out across the United States, albeit recognizing there are key uncertainties in those projections. Part III outlines the current Three Rs adaptation policy modes and makes the case that, while they will continue to be necessary beyond 2°C, they will be insufficient to handle the scope and intensity of necessary adaptations. It then introduces the redesign modality of adaptation.

Building on this foundation, Part IV translates the foregoing into two policy typologies to facilitate design of law and policy for anticipatory governance of climate change adaptation for the 4°C world. One typology describes different redesign challenges based on three modes of change—linear, nonlinear, and cascading. The other typology outlines different possible governance responses, ranging from allowing private markets to guide adaptation to centralized top-down planning. Part IV then merges the two typologies to identify scenarios that must be anticipated when designing adaptation governance responses. This analysis leads to the conclusion that, for many redesign challenges, the United States may be best served by a coordinated national plan akin to

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[36] Mark T. Gibbs, *Why Is Coastal Retreat So Hard to Implement? Understanding the Political Risk of Coastal Adaptation Pathways*, 130 OCEAN & COASTAL MGMT. 107, 108-12 (2016), https://doi.org/10.1016/j.ocecoaman.2016.06.002 (describing the controversies surrounding the retreat mode).

[37] Joseph A. Tainter, *Social Complexity and Sustainability*, 3 ECOL. COMPLEXITY 91, 100 (2006), doi:10.1016/j.ecocom.2005.07.004.

the mobilization that occurred at the start of World War II. Part V concludes with suggestions for how a creation of a national science and policy research "foresight system" can begin to lay foundations for designing such an anticipatory national planning initiative.

Put bluntly, if the mounting body of science pointing in the direction of moving beyond 2°C proves to be correct, it would behoove our nation to have begun envisioning how to "stay in the game" well before we cross the 2°C threshold. To do otherwise—to count on the description herein of what lies ahead turning out to be wrong, or on society to design effective solutions on the fly if it turns out to be right—is a gamble we consider not worth taking.

I. EMBRACING 4°C: WHY 2°C IS TOO CONSERVATIVE FOR ANTICIPATORY ADAPTATION GOVERNANCE

As noted in the Introduction, this Article's science-based central premise is that it is highly unlikely that the world will achieve its "below 2°C" goals for global average warming. This Part defends that premise, providing an overview of the science regarding the world's likely climate change future. It begins with the planet's current temperature and atmospheric greenhouse gas concentration status, as well as an overview of trends. It then explores the more complicated issue of what humans would have to do to keep global average temperature below 2°C, recognizing that such projections are made in a context of uncertainty and best-guesses but nevertheless concluding that any such efforts are unlikely to succeed.

A. Where Are We Now? The Current Increase and Trends in Global Average Temperature

The year 2019 was the second hottest year on record, at least at the moment we are composing this Article.[38] In that year, global average temperature was already 1.15°C (2.07°F) above the pre-Industrial average.[39] In other words, the planet is already more than 76% of the way to being 1.5°C warmer, on average, or 57.5% of the way to being 2°C warmer.

More ominously, "[t]he global annual temperature has increased at an average rate of 0.07°C (0.13°F) per decade since 1880 and over twice that rate (+0.18°C / +0.32°F) since 1981."[40] At the current rates of increase, global average temperatures will be 1.5°C warmer than pre-industrial levels by 2040[41] and 2°C warmer by roughly 2067. However, the rates of warming are also still accelerating, and "[e]stimated anthropogenic

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[38] Rebecca Lindsey & LuAnn Dahlman, *Climate Change: Global Temperature*, NOAA CLIMATE.GOV (Aug. 14, 2020), https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature.

[39] *Id.*

[40] *Id.*

[41] In 2018, for example, the IPCC concluded that "[g]lobal warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. 2018 IPCC 1.5°C REPORT, *supra* note 19, at 4.

global warming is currently increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade due to past and ongoing emissions (*high confidence*)."[42]

As bad as that story is, global average temperature increases are not always the most relevant numbers for climate adaptation governance. As the IPCC observed in 2018, "Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher in the Arctic."[43] Of particular relevance, temperatures over land surfaces, where most people live, are increasing faster than global average temperature, which is moderated by the ocean's capacity to absorb heat.[44] The IPCC reported in 2019 that mean land surface air temperature "has risen considerably more than the global mean surface (land and ocean) temperature" and has already reached 1.53°C.[45] Vividly illustrating this effect, in 2019 the *Washington Post* compiled multiple data sources to produce a map showing that over one-fifth of the globe has already experienced a 2°C rise, and *all* of the United States west of the Mississippi River plus a large swath of the Southeast has already experienced a 1.5°C rise.[46] Much of the terrestrial world, in other words, has already exceeded the more ambitious of the world's climate change mitigation goals.

B. Can We Stay Below 2°C? Carbon Budgets, Coronavirus, and Uncertainty

Given where conditions stand now, how realistic is the 2°C ceiling mitigation goal? This depends on three factors: (1) the prospect of substantially and rapidly reducing global net emissions; (2) the total additional emissions that can be accepted before atmospheric carbon dioxide concentrations push temperatures past 2°C; and (3) the range of uncertainty in both those calculations. Based on current models, none of these factors bodes well for meeting the 2°C climate mitigation goal.[47]

1. Emissions Cuts Sufficient to Halt Warming Are Unlikely

Reducing anthropogenic greenhouse gas emissions, while a necessary first step, is not enough to immediately stop climate change. Carbon dioxide lingers in the atmosphere for a long time—on the order of centuries.[48] Climate change will be an issue as long as atmospheric CO_2 concentrations remain high, trapping more heat close to the

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[42] *Id.*

[43] *Id.*

[44] *Id.*

[45] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SPECIAL REPORT: CLIMATE CHANGE AND LAND 9 (Aug. 2019) [hereinafter 2019 IPCC LAND REPORT].

[46] Chris Mooney & John Muyskens, *2°C: Beyond the Limit*, WASH. POST (Sept 11, 2019), https://www.washingtonpost.com/graphics/2019/national/climate-environment/climate-change-world/?itid=lk_inline_manual_1&itid=lk_inline_manual_1&itid=lk_interstitial_manual_6.

[47] For a similar assessment, leading to the conclusion that extensive private institution responses will be needed in addition to public governance, see MICHAEL P. VANDENBERGH & JONATHAN M. GILLIGAN, BEYOND POLITICS: THE PRIVATE GOVERNANCE RESPONSE TO CLIMATE CHANGE 37-63 (2017) (after an assessment of policy and climate science, concluding "We are pessimistic about the possibility of meeting the 2°C goal."). While we agree that private institutions will play an important role in climate mitigation and adaptation, our focus herein is on public adaptation governance.

[48] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 5.

Earth's surface. Reversing the process significantly enough to quickly change the planet's warming processes will require herculean efforts by the world's nations over the next two to three decades—an unlikely future recently made more unlikely by the fact that nations are likely to prioritize economic and social recovery as the coronavirus pandemic eventually recedes.

Two simultaneous phenomena during the coronavirus epidemic make this point real. First, as a result of the Spring 2020 global lockdowns during the pandemic, the world experienced "one of the biggest single drops in modern history in the amount of carbon dioxide humans emit. Over the first few months of 2020, global daily CO_2 emissions averaged about 17 percent lower than in 2019. At the moments of the most restrictive and extensive lockdowns, emissions in some countries hovered nearly 30 percent below last year's averages . . . ."[49] Nevertheless, in May 2020, the world hit a record 418 parts per million atmospheric concentration of carbon dioxide. Without the coronavirus-induced drop in emissions, it would only have been roughly 418.4 parts per million.[50] The seemingly huge drops in emissions had only a small effect on *slowing*—and did not come anywhere close to *reversing*—the buildup of atmospheric greenhouse gas concentrations. Researchers now conclude that the significant emissions cuts during COVID-19 mean that the planet will be only 0.005 to 0.015°C cooler in 2030 than it otherwise would have been if the pandemic had not occurred.[51]

Thus, even at the height of coronavirus restrictions, we were still putting carbon dioxide into the atmosphere faster than it could cycle back out. As a result, "even though emissions have dropped, CO_2 is still going into the atmosphere and it will still accumulate there, just as it has since humans started burning vast amounts of fossil fuels."[52] As one scientist put it, "The buildup of CO_2 is a bit like trash in a landfill. As we keep emitting, it keeps piling up."[53] Only radical reductions in the "trash" can stop the "landfill" from rising further.

Reducing the "trash" will require unprecedented political, social, economic, and technological transformations. In the IPCC's analysis, for example:

> In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions [must] decline by about 45% from 2010 levels by 2030 (40–60% interquartile range), reaching net zero around 2050 (2045–2055 interquartile range). For limiting global warming to below 2°C CO_2 emissions are projected to decline by about 25% by 2030 in most pathways (10–30% interquartile range) and reach net zero around 2070 (2065–2080 interquartile range).[54]

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[49] Alejandra Borunda, "Plunge in carbon emissions from lockdowns will not slow climate change," NAT'L GEO. (May 20, 2020), https://www.nationalgeographic.com/science/2020/05/plunge-in-carbon-emissions-lockdowns-will-not-slow-climate-change/#close.

[50] *Id*.

[51] Piers M. Forster, Harriet I. Forster, Mat J. Evans, Matthew J. Gidden, Chris D. Jones, Christoph A. Keller, Robin D. Lamboll, Corinne Le Quéré, Joeri Rogelj, Deborah Rosen, Carl-Friedrich Schleussner, Thomas B. Richardson, Christopher J. Smith, and Steven T. Turnock, *Current and future global climate change impacts from COVID-19*, 10 NATURE CLIMATE CHANGE 913, 913 (2020), https://doi.org/10.1038/s41558-020-0883-0.

[52] Borunda, *supra* note 49.

[53] *CO_2 Levels Reach Record High*, THE WEEK, June 26, 2020, at 19.

[54] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 12.

In other words, to make a real difference, "[e]missions must fall 7.6 percent—in line with the worst-case lockdown scenario for 2020—*every year this decade* to ensure the 1.5°C cap, unless other means are found to remove carbon from the atmosphere… ."[55] If past performance is any guide, the world is unlikely to sustain these pandemic-driven emissions cuts, which were for all practical purposes forced upon societies.[56]

In the context of this Article, it is also worth noting that achieving the 1.5°C mitigation goal requires significant societal transformations, although lesser in magnitude and complexity than what we foresee as becoming necessary on the adaptation side at 3°C to 4°C.[57] As the IPCC expounded,

> Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban infrastructure (including transport and buildings), and industrial systems (high confidence). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options.[58]

The most critical of these social transitions is weaning energy production and consumption off of fossil fuels.[59] As the Pathways to Deep Decarbonization project outlines,[60] a three-pronged strategy must be adopted for an energy transition scenario to succeed in reducing greenhouse gas emissions at levels and in time frames needed to contain climate change to a 2°C scenario: "(1) highly efficient end use of energy in buildings, transportation, and industry; (2) decarbonization of electricity and other fuels; and (3) fuel switching of end uses to electricity and other low-carbon supplies."[61] These

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[55] *Global CO_2 emissions could fall 7 percent in 2020 due to Covid-19, study shows*, FRANCE24 (May 20, 2020, 09:38), https://www.france24.com/en/20200520-co2-emissions-could-fall-7-percent-in-2020-due-to-covid-19-study-shows (emphasis added) (referring to Corinne Le Quere et al., *Temporary Reduction in Daily Global CO_2 Emissions During the COVID-19 Forced Confinement*, 10 NATURE CLIMATE CHANGE 647 (2020), https://doi.org/10.1038/s41558-020-0797-x).

[56] New et al., *supra* note 20, at 8-9 (summarizing various lines of research indicating that the emissions cuts required to stay below 2°C of warming are virtually impossible). *See also* Peter Christoff, *Introduction: Four Degrees or More?*, *in* FOUR DEGREES OF GLOBAL WARMING: AUSTRALIA IN A HOT WORLD (Peter Christoff, ed.) at 1 (Routledge 2014) (noting that "there is widespread agreement that current mitigation efforts . . . will lead to global average warming of 4°C or more from pre-industrial levels by the end of this century . . .").

[57] *See* Frank W. Geels, Benjamin K. Sovacool, Tim Schwanen, & Steve Sorrell, *Sociotechnical Transitions for Deep Decarbonization*, 357 SCI. 1242, 1242-44 (2017), DOI: 10.1126/science.aao3760.

[58] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 15.

[59] For extensive discussions and references on this theme, see John C. Dernbach, *Legal Pathways to Deep Decarbonization: Postscript*, 48 ENVT'L L. REP. 10875, 10881-84 (2018); Michael B. Gerrard, *Legal Pathways for a Massive Increase in Utility-Scale Renewable Generation Capacity*, 47 ENVTL. L. REP. 10591, 10592 (2017); J.B. Ruhl & James Salzman, *What Happens When the Green New Deal Meets the Old Green Laws*, 44 VT. L. REV. 693, 701-13 (2020).

[60] *See* JAMES H. WILLIAMS ET AL, PATHWAYS TO DEEP DECARBONIZATION IN THE UNITED STATES (2014), https://usddpp.org/downloads/2014-technical-report.pdf.

[61] *Id*. at xv (emphasis added). *See also* THE WHITE HOUSE, MID-CENTURY STRATEGY FOR DEEP DECARBONIZATION 7 (2015) (aiming to "transition[ ] to a low-carbon energy system, by cutting energy

changes will require rapid and massive national initiatives. On the energy production side, for example, estimates using a "high renewables" reference case frame a range of between 1,350 and 2,500 gigawatts of new wind and solar renewable power generating capacity that must come online in the United States between today and 2050 to meet Paris Accord goals—an amount roughly 15 to 30 times the present wind and solar generating capacity.[62] However, there is no evidence that global greenhouse gas emission levels have peaked and turned the corner.[63] Report after report issued in 2019 confirmed that there is little to suggest that emission reduction goals set through various international and domestic institutions are on track to be achieved.[64] Even the most climate-progressive states and cities in the United States are falling behind.[65]

Although we know what needs to be done, making the energy transformation and other necessary social changes needed to wrestle emissions under control requires overcoming "the interlinked mix of technologies, infrastructures, markets, regulations, and use practices that together deliver societal functions."[66] The resistance to change has become a sobering reality, as estimates of the massive technology and social transformation campaigns needed to stabilize climate made as recently as 2004 were soon

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waste, decarbonizing the electricity system and deploying clean electricity and low carbon fuels in the transportation, buildings, and industrial sectors") (emphasis omitted), https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf. There is growing concern that even these initiatives, if achieved, will not suffice, and that carbon dioxide removal technologies must be developed to facilitate net negative emissions. *See An Equitable Path to Net-Zero Emissions*, NATURE, Dec. 5, 2019, at 7; *Negative Emissions: The Chronic Complexity of Carbon Capture*, ECONOMIST, Dec. 7, 2019, at 22.

[62] *See* WHITE HOUSE, *supra* note 61, at 4 (estimating an additional 30 GW per year between 2016 and 2035, totaling 600 GW, and then an additional 60 GW per year between 2035 and 2050, totaling 750 GW, for an estimated total of 1,350 additional GW); WILLIAMS ET AL., *supra* note 60, at vii (estimating an additional 2,500 GW, representing 30 times the current capacity).

[63] WHITE HOUSE, *supra* note 61, at 4.

[64] U.N. ENVIRONMENT PROGRAMME, EMISSIONS GAP REPORT 2019, at xiv-xv (2019) (noting that global greenhouse gas emissions rose on average 1.5 % annually over the past decade and "[t]here is no sign of GHG emissions peaking in the next few years"); ROBERT WATSON ET AL., FEU-US, THE TRUTH BEHIND THE CLIMATE PLEDGES i (2019), https://feu-us.org/behind-the-climate-pledges/ ("An analysis of current commitments to reduce emissions between 2020 and 2030 shows that almost 75 percent of the climate pledges are partially or totally insufficient to contribute to reducing GHG emissions by 50 percent by 2030, and some of these pledges are unlikely to be achieved.").

[65] For U.S. states, see CITIZENS BUDGET COMM'N, GETTING GREENER: COST EFFECTIVE OPTIONS FOR ACHIEVING NEW YORK STATE'S GREENHOUSE GAS GOALS 1-2 (2019), https://cbcny.org/sites/default/files/media/files/REPORT_GettingGreener_120602019.pdf (identifying obstacles to achieving emission reduction goals); NEXT 10, CALIFORNIA GREEN INNOVATION INDEX 4 (2019) ("California will reach its 2030 and 2050 goals in 2061 and 2157, respectively— representing a 31-year and a 107-year delay."), https://www.next10.org/sites/default/files/2019-10/2019-california-green-innovation-index-final.pdf. For U.S. cities, see Sam Markolf, Ines M.L. Azevedo, Mark Muro, & David G. Victor, *Pledges and Progress: Steps Toward Greenhouse Gas Emissions Reductions in the 100 Largest Cities Across the United States*, BROOKINGS INSTITUTE (Oct. 20, 2020), https://www.brookings.edu/research/pledges-and-progress-steps-toward-greenhouse-gas-emissions-reductions-in-the-100-largest-cities-across-the-united-states/ (two-thirds of US cities that have adopted emissions reduction targets are falling short of meeting them); Jeffrey Brainard, *News in Brief: U.S. Cities Labor to Cut Emissions*, 370 SCI. 508, 509 (2020), DOI: 10.1126/science.370.6516.508 (same).

[66] Geels et al., *supra* note 57, at 1242.

after shown to fall significantly short of what will be needed.[67] More recent proposed "roadmaps" to deep decarbonization outline no less than herculean policy efforts and technological breakthroughs, none of which is yet even on the horizon.[68] The world's continuing inability to tackle these transformations on the mitigation side gives credence to our concerns for 4°C adaptation governance.

2. Carbon Budgets Also Suggest that the 2°C Mitigation Goal Is Unrealistic

Atmospheric CO_2 concentrations indicate that the planet already is committed to warming that exceeds 2°C, and even the coronavirus pandemic was insufficient to keep those concentrations from continuing to increase. Other metrics tell a similar tale. For example, another way to think about the 1.5°C/2°C climate mitigation goal is to ask how much of a carbon budget we have left—that is, how much more CO_2 can we add to the atmosphere and still have a reasonable chance of keeping warming to less than 1.5° or 2°C above pre-industrial levels? The IPCC, for example, stated in 2018 that accumulated anthropogenic carbon emissions to that point were unlikely sufficient to push global average warming past 1.5°C within this century.[69] However, those emissions did not stop, or reach "net zero,"[70] in 2018, raising the issue of how much more leeway humanity has. Carbon budget estimates mean little in the abstract: what does one gigatonne (billion tonnes, or Gt) really mean in terms of human activity? To put the following discussion of estimates in perspective, in 2019 global energy-related emissions of carbon dioxide flattened after two years of increases to 33 Gt,[71] but the total global emissions still increased, reaching 36.81 Gt.[72] As a rough rule of thumb, the IPCC estimates total global CO_2 emissions to be 42 Gt per year, give or take 3 Gt (i.e., 39-45 Gt per year).[73]

Even within the uncertain and probability-based world of climate change projections, carbon budgets deserve a place of honor for lack of certainty and variability. As a result, the following discussion seeks to "ballpark" best-case and worst-case estimates. Nevertheless, the bottom line is clear: A business-as-usual world will eat up even the 2°C carbon budget within a few decades.

According to the IPCC in 2014, as of 2011, in order to have a two-thirds chance of staying below a 2°C increase in global average warming, a total of 1000 gigatonnes more of carbon dioxide or its equivalent, give or take a couple hundred gigatonnes, can

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[67] Steven J Davis, Long Cao, Ken Caldeira, & Martin I Hoffert, *Rethinking Wedges*, 8 ENVTL. RESEARCH LETT. 01101, at 1-2 (2013), doi:10.1088/1748-9326/8/1/011001; *see also generally* Eli Kintisch, *Climate Study Highlights Wedge Issue*, 339 SCI. 128, 128-29 (2013), DOI: 10.1126/science.339.6116.128 (summarizing the study).

[68] *See*, *e.g.*, Johan Rockström et al., *A Roadmap for Rapid Decarbonization*, 355 SCI. 1269, 1270-71 (2017), DOI: 10.1126/science.aah3443.

[69] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 5.

[70] *Id*.

[71] *Global CO_2 Emissions in 2019*, INTL. ENERGY AGENCY (Feb. 11, 2020), https://www.iea.org/articles/global-co2-emissions-in-2019.

[72] Zeke Hausfather, *Analysis: Global fossil-fuel emissions up 0.6% in 2019 due to China*, CARBON BRIEF (Dec. 4, 2019), https://www.carbonbrief.org/analysis-global-fossil-fuel-emissions-up-zero-point-six-per-cent-in-2019-due-to-china.

[73] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 12.

be added to the atmosphere—*ever*.[74] Keep in mind, first, that the 2°C goal is *not* guaranteed even if that budget is met; indeed, the odds of losing are twice as bad as in Russian Roulette. Second, even within the IPCC's constraints, the actual number of gigatonnes might be 12.0% lower—or 8.6% higher—than its median estimate.

Even so, leaving all the caveats aside, and using the IPCC's median limit of 2900 Gt total, humanity had 1000 Gt left at the end of 2011 to have a 66% chance of keeping global warming to 2°C. Assuming roughly 40 Gt per year, by the end of 2019, humans had already emitted another 320 Gt.[75] That left 680 Gt to go. At the 40 Gt pace, we will miss even our two-thirds chance of staying below 2°C by around 2036. The IPCC's 2018 carbon budget, which focused on the 1.5°C goal, was only slightly more favorable, suggesting that the world in 2018 might be able to emit only 420 Gt more of carbon dioxide to have a two-thirds chance of staying below 1.5ºC. That allows roughly 10 more years under business as usual, or until somewhere between 2028 and 2030.[76]
Individual carbon budget studies exhibit even more variation. Between 2016 and 2018, experts produced nine different studies trying to calculate humanity's remaining carbon budget to keep global average temperature increases below 1.5°C. Assessments of these nine studies concluded that "the remaining carbon budget to limit warming to 'well below' 1.5°C might have already been exceeded by emissions to-date, or might be as large as 15 more years of emissions at our current rate."[77] In short, at best the budget is used up by 2033. Even if a slim budget remains, however, the CO_2 emissions committed from existing fossil fuel power plants and those currently planned, permitted, and under construction (which are mostly in China and India) will alone consume the entire CO_2 budget that remains to limit warming to 1.5°C.[78] Worse still, another study concluded that even if *all* fossil fuel emissions were immediately halted, "current trends in global food systems would prevent the achievement of the 1.5°C target and, by the end of the century, threaten the achievement of the 2.0°C target."[79] Thus, business-as-usual in energy and food alone could doubly blow past the 2.0°C mitigation target.

To complicate matters still further, the foregoing carbon budget analyses are limited to anthropogenic emissions, which are not the only source of greenhouse gasses. As climate change forces ecological systems across nonlinear thresholds of

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[74] 2014 IPCC SYNTHESIS REPORT, *supra* note 11, at 10.

[75] This figure is based on the assumed 40 gigatonnes per year multiplied by eight years.

[76] 2018 IPCC 1.5°C SPECIAL REPORT, *supra* note 19, at 12.

[77] Zeke Hausfather, *Analysis: How much 'carbon budget' is left to limit warming to 1.5C?,* CARBON BRIEF (April 9, 2018), https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c.

[78] Dan Tong, Qiang Zhang, Yixuan Zheng, Ken Caldeira, Christine Shearer, Chaopeng Hong, Yue Qin & Steven J. Davis, *Committed Emissions from Existing Energy Infrastructure Jeopardize 1.5°C Climate Target*, 572 NATURE 373, 373 (2019), https://doi.org/10.1038/s41586-019-1364-3. China, which accounts for 28% of global emissions, relies on coal for 58% of its energy consumption and 66% of its electric power generation, and has at least 100 gigawatts of coal generation capacity under construction, announced in 2020 that it would reach zero net emissions before 2060, but many experts were skeptical it could make such a U-turn. *See* Dennis Normile, *China's Bold Climate Pledge Earns Praise—But Is it Feasible?*, 370 SCI. 17, 17-18 (2020), DOI: 10.1126/science.370.6512.17.

[79] Michael A. Clark et al., *Global Food System Emissions Could Preclude Achieving the 1.5°C and 1.5°C Climate Change Targets*, 370 SCI. 705, 705-08 (2020), DOI: 10.1126/science.aba7357.

transformation (discussed in Part II), historically sequestered greenhouse gases will be released. As scientists reported in *Nature* in late 2019:

> The world's remaining emissions budget for a 50:50 chance of staying within 1.5 °C of warming is only about 500 gigatonnes (Gt) of CO_2. Permafrost emissions could take an estimated 20% (100 Gt CO_2) off this budget, and that's without including methane from deep permafrost or undersea hydrates. If forests are close to tipping points, Amazon dieback could release another 90 Gt CO_2 and boreal forests a further 110 Gt CO_2. With global total CO_2 emissions still at more than 40 Gt per year, the remaining budget could be all but erased already.[80]

This ecological contribution to climate change only gets worse as we move past 2°C, as "huge swaths of the world's tropical forests will begin to lose more carbon than they accumulate. Already, the hottest forests in South America have reached that point."[81] In addition, Arctic lakes have been observed releasing large bubbles of methane—enough to fuel pillars of flame over the water's surface when set alight—since at least 2018.[82] These lakes, looking eerily like the *MacBeth* witches' bubbling cauldron, may be the first signs that Arctic feedback loops are now in motion, accelerating greenhouse gas emissions, climate change, and any chance of staying within the carbon budget for even 2°C.[83] In the Arctic Ocean itself, new research indicates that lunar and tidal cycles play important roles in methane gas release, leading to underestimates of how much of this greenhouse gas the Arctic is currently emitting.[84] Looking more broadly than just direct human-generated emissions, therefore, we probably have already consumed the 2°C budget regardless of whether anthropogenic emissions are controlled.

C. Where Are We Going? Committed Warming and Projections for Global Average Temperatures

Predicting future increases in global average temperature by necessity requires making educated guesses about how a variety of variables, both human and planetary, will actually play out in the future. These variables include the rate at which and extent to which the energy system is decarbonized (i.e., the conversion to renewable and nuclear power), human population growth, patterns of consumerism, when and to what extent the ocean's capacity to absorb carbon dioxide will slow or stop, the extent to which melting ice will accelerate warming by exposing dark surfaces, and many more. The variety of guesses that climate modelers make goes a long way to explaining the variety of

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[80] Lenton et al., *supra* note 7 (citations omitted).

[81] Elizabeth Pennisi, *Tropical Forests Store Carbon Despite Warming*, 368 SCI. 813, 813 (2020), DOI: 10.1126/science.368.6493.813.

[82] Chris Mooney, *Arctic Cauldron*, WASH. POST (Sept. 22, 2018), https://www.washingtonpost.com/graphics/2018/national/arctic-lakes-are-bubbling-and-hissing-with-dangerous-greenhouse-gases/.

[83] *Id*.

[84] Nabil Sultan, Andreia Plaza-Faverola, Sunil Vadakkepuliyambatta, Stefan Buenz & Jochen Knies, *Impact of tides and sea-level on deep-sea Arctic methane emissions*, 11 NATURE COMMUNICATIONS art. 5087, at 1-2 (Oct. 9, 2020), https://doi.org/10.1038/s41467-020-18899-3.

predictions that exist about how warm the planet will become—and how fast. Nevertheless, most scenarios agree that the planet is well on its way to a 4ºC increase in global average temperature, which could occur as soon as 50 years from now.

The IPCC, for example, most consistently compares four scenarios.[85] Its business-as-usual scenarios tend to suggest that the world could reach 4°C by the end of this century.[86] In 2017, researchers using a different methodology published their projections in *Nature*, concluding that by 2100 "[t]he likely range of global temperature increase is 2.0-4.9°C, with a median of 3.2°C . . . ."[87]

The breadth of that range is attributable to uncertainty regarding how fast and how much our climate responds to changes in atmospheric greenhouse gas concentrations—known as climate sensitivity.[88] The benchmark for assessment is the expected range of increase in temperature at 560 ppm, which is double the pre-industrial concentration and roughly 145 ppm above the current level.[89] One of the first assessments, a 1979 study by the National Research Council, produced a broad range of 1.5℃ to 4.5℃.[90] Recent efforts to tighten the range do not bode well. The most comprehensive study, published in 2019, weaves together contemporary warming trends, the latest understanding of climate system feedback loops and other dynamics, and studies of ancient climates.[91] The study concludes that at 560 ppm the likely (66% chance) warming range is between 2.6℃ and 3.9℃.[92] The study was unable to rule out that the sensitivity could be above 4.5°C per doubling of carbon dioxide levels, although this is not likely.[93] In other words, barring rapid global political, social, and technological transformations of the breadth and depth discussed above, we will be fortunate to limit temperature rise to 2.6℃, just as likely to reach 3.9℃, and the possibility of reaching 4.0℃ or higher cannot be ignored.

Importantly for adaptation governance, however, warming doesn't stop in 2100, nor is 560 ppm a naturally-imposed ceiling on concentrations. In May 2020, "the concentration of carbon dioxide in the atmosphere crept up to about 418 parts per million. It was the highest ever recorded in human history and likely higher than at any point in

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85 2014 IPCC SYNTHESIS REPORT, *supra* note 11, at 8 (bold emphasis added).

86 *Id*. at 9 fig. SPM 5(a), 12 fig. SPM 7; *see also* New et al., *supra* note 20, at 9-10 (noting that, in a series of model runs, "[a]ll but two of the models reach 4◦C before the end of the twenty-first century, with the most sensitive model reaching 4◦C by 2061, a warming rate of 0.5◦C per decade. All the models warm by 2◦C between 2045 and 2060. This supports the message that an early peak and departure from a business-as-usual emissions pathway are essential if a maximum temperature below 4◦C is to be avoided with any degree of certainty."); Christoff, *supra* note 56, at 1 (noting that "there is widespread agreement that current mitigation efforts . . . will lead to global average warming of 4°C or more from pre-industrial levels by the end of this century . . .").

87 Borunda, *supra* note 49.

88 S. C. Sherwood et al., *An Assessment of Earth's Climate Sensitivity Using Multiple Lines of Evidence*, 58 REVS. GEOPHYSICS e2019RG000678, at 2 (2019), https://doi.org/ 10.1029/2019RG000678.

89 *Id*. at 2.

90 *Id*.

91 *Id*. at 1 *See also* Paul Voosen, *Earth's Climate Destiny Finally Seen More Clearly*, 369 SCI. 354, 354-55 (2020), DOI: 10.1126/science.369.6502.354
(summarizing the study).

92 Sherwood et al., *supra* note 88, at 1.

93 *Id*.

the last three million years."[94] The increasing concentration of carbon dioxide already accumulated in the atmosphere—the planet's response to which constitutes an important source of uncertainty regarding how fast the planet will warm—represents "committed warming," a future of global average temperature increases even if all new emissions cease tomorrow (unless technology is developed to actively draw CO_2 back out of the atmosphere on massive scale). According to the National Oceanic and Atmospheric Administration (NOAA), the last time carbon dioxide concentrations were over 400 ppm (three million years ago), "temperature was 2°–3°C (3.6°–5.4°F) higher than during the pre-industrial era, and sea level was 15–25 meters (50–80 feet) higher than today."[95] Given the delays involved in atmospheric dynamics, humans thus probably have already committed the planet to a future that blows right by the 2°C warming goal. Moreover, for more than a decade now, the CO_2 concentration in the atmosphere has been increasing roughly 2.3 ppm per year.[96] At that rate, the concentration will be roughly 485 ppm by 2050 and at the doubling threshold of 560 ppm by around 2080. From there, by 2100 the 2.0℃ mitigation target will be a historical footnote.

II. ANTICIPATING 4°C: WHAT DOES THE WORLD LOOK LIKE BEYOND 2°C?

Climate change is, well, *change*—an expression of all the accumulated extra energy (mostly in the form of heat) working on the planet's various physical, chemical, and biological systems at all scales simultaneously. Envisioning governance of the United States at 4ºC requires policymakers and adaptation planners to imagine *not* a future stable state of being in a hotter world but rather a continual and accelerating *process* of discontinuous and often unpredictable transformation. Indeed, even leaving the coronavirus pandemic to the side for the moment, Americans are already experiencing an accelerating pace of natural disasters and extreme inconveniences, lurching from wildfires to hurricanes to drought to "Polar Vortex" winters to severe flooding.[97] Species are already migrating poleward and higher in altitude (terrestrial) or deeper in depth (marine), which is rearranging ecosystems, perturbing food webs (including humans'), and changing fisheries world-wide, among other disruptions to natural systems upon which humans depend.[98]

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[94] Borunda, *supra* note 49.

[95] Lindsey, *supra* note 9.

[96] *Id*.

[97] *See* Bill McKibben, *How Fast Is the Climate Changing?: It's a New World, Each and Every Day*, THE NEW YORKER (Sept. 3, 2020), https://www.newyorker.com/news/annals-of-a-warming-planet/how-fast-is-the-climate-changing-its-a-new-world-each-and-every-day(describing the wildfire and hurricane combinations in late August and early September 2020).

[98] For a collection of research studies on this theme, see Steven L Chown, *Marine Food Webs Destabilized*, 369 SCI. 770, 770-71 (2020), DOI: 10.1126/science.abd5739; Jay R. Malcolm, Adam Markham, Ronald P. Neilson & Michael Garaci, *Estimated Migration Rates Under Scenarios of Global Climate Change*, 29 J. BIOGEOGRAPHY 835, 836, 838-42 (2002); Marten Scheffer, Steve Carpenter, Jonathan A. Foley, Carl Folke & Brian Walker, *Catastrophic Shifts in Ecosystems*, 413 NATURE 591, 591-96 (2001); Brett R. Scheffers et al., *The Broad Footprint of Climate Change from Genes to Biomes to People*, 354 SCI. 719, 719-20 (2016), DOI: 10.1126/science.aaf7671.

These experiences will only get worse, challenging the abilities of governance institutions to provide—or perhaps even define—the sense of stability necessary for social-ecological systems to productively adapt to their new reality. To paint a more vivid picture of that challenge, in this section we summarize the scientific evidence of looming nonlinear change to the planet and the limits of human adaptive capacity, then use that background to envision conditions in the United States under a 4°C scenario.

A. Coming to Grips with Nonlinear Change

The tendency among nonscientists when thinking about global warming is to think in linear terms: if X amount of damage occurs with 1°C of warming, then 2X damage will occur at 2°C of warming, 3X at 3°C, and so on. That would be bad enough, but a fundamental truth about a rapidly warming planet is that the impacts from a steadily increasing mean global average temperature are *nonlinear*, and in two senses. First, the amount of change occurring is often geometric, with each increment of warming multiplying and accelerating, rather than simply adding, impacts. Second, at some point the changes become transformative, fundamentally altering social-ecological systems into new states of being. To make matters even more chaotic, different systems transform at different temperatures. Some, like Arctic and coral reef social-ecological systems, are already transforming.[99] Others, like mangrove social-ecological systems, currently face far less risk.[100] It does not take much—the decline of a top-level predator because of temperature or the expansion of another predator's range—to throw ecological systems into cascade transformations.[101]

Thus, as the IPCC has emphasized, even the difference between 1.5°C and 2°C is important when thinking about future adaptation governance.[102] For example, temperature extremes at specific locations change more rapidly than the global average, so that "extreme hot days in mid-latitudes warm by up to about 3°C at global warming of 1.5°C and about 4°C at 2°C, and extreme cold nights in high latitudes warm by up to about 4.5°C at 1.5°C and about 6°C at 2°C."[103] Thus, the 0.5°C change in global average temperature from 1.5°C to 2°C makes the hottest days a full 1°C hotter and the hottest nights 1.5°C hotter—an example of geometric impacts.[104] Half a degree Celsius also

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[99] *See* 2018 IPCC 1.5°C REPORT, *supra* note 19, at 11 fig. SPM.2. Between 1950 and 2000 the average air temperature on the Antarctic Peninsula increased by 4°C. Antarctic contribution to SLR since 1992 is about 8mm. That will accelerate if temps keep rising. Robin E. Bell & Helene Seroussi, *History, Mass Loss, Structure, and Dynamic Behavior of the Antarctic Ice Sheet*, 367 SCI. 1321, 1321-25 (2020), DOI: 10.1126/science.aaz5489.

[100] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 11 fig. SPM.2.

[101] *See* Elizabeth Pennisi, *An Ecosystem Goes Topsy-turvey as a Tiny Fish Takes Over*, 369 SCI. 1154, 1154-55 (2020), DOI: 10.1126/science.369.6508.1154; Douglas B. Rasher et al., *Keystone Predators Govern the Pathway and Pace of Impacts In a Subarctic Marine Ecosystem*, 369 SCI. 1351, 1351-54 (2020), DOI: 10.1126/science.aav7515.

[102] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 7.

[103] *Id*.

[104] *See also* New et al., *supra* note 20, at 10 ("The broadly constant ratio of local climate change to global temperature change implies that these local changes are amplified in a 4ºC world; for example, a local change of 3ºC in a +2ºC world (1ºC greater than the global average) becomes 7.5ºC in a +4ºC world (3.5ºC above the global average).").

makes a dramatic difference to the Arctic: "With 1.5°C of global warming, one sea ice-free Arctic summer is projected per century. This likelihood is increased to at least one per decade with 2°C global warming."[105] Here, a 0.5°C difference in the increase in global average temperature leads to a ten-fold increase in impacts. Similarly, as global average temperature increases arithmetically, a geometrically accelerating percentage of species are affected: "Of 105,000 species studied, 6% of insects, 8% of plants and 4% of vertebrates are projected to lose over half of their climatically determined geographic range for global warming of 1.5°C, compared with 18% of insects, 16% of plants and 8% of vertebrates for global warming of 2°C (medium confidence)."[106]

These nonlinear trajectories continue past 2°C, making a world at 4°C one in which the risks associated with natural disasters and ecological failure are global in scope and unimaginably intense compared to the present. For example, a recent comprehensive study of 30 different impacts of climate change concluded that:

> the global average chance of a major heatwave increases from 5% in 1981–2010 to 28% at 1.5 °C and 92% at 4°C, of an agricultural drought increases from 9 to 24% at 1.5°C and 61% at 4°C, and of the 50-year return period river flood increases from 2 to 2.4% at 1.5°C and 5.4% at 4°C. The chance of a damaging hot spell for maize increases from 5 to 50% at 4°C, whilst the chance for rice rises from 27 to 46%.[107]

These increasing risks are, obviously, likely to be costly to human life and to economies. While not at the heart of where the worst damage will occur, the United States is by no means out of harm's way, and projections suggest that climate change will subject it to substantial hits to economic activity and surges in mortality.[108] For all practical purposes, planning and policy in such an environment will need to assume that debilitating heatwaves, drought, crop failure, floods, and other harms are the new normal.[109]

An important reason why conditions get so much worse beyond 2°C is that more and more biophysical systems begin crossing tipping points as temperatures keep rising.[110] Many ecosystems are already crossing transformational tipping point thresholds

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[105] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 8.

[106] *Id*.

[107] N. W. Arnell, J. A. Lowe, A. J. Challinor & T. J. Osborn, *Global and Regional Impacts of Climate Change at Different Levels of Global Temperature Increase*, 155 CLIMATIC CHANGE 377, 377 (2019), https://doi.org/10.1007/s10584-019-02464-z.

[108] Solomon Hsiang et al., *Estimating Economic Damage from Climate Change in the United States*, 356 SCI.1362, 1364-65 (2017), DOI: 10.1126/science.aal4369 (Above 1°C their model suggests losses of 1.2% US GDP per 1°C of warming. Mortality is the largest incremental factor above 2.5°C); William A. Pizer, *What's the Damage from Climate Change?*, 356 SCI. 1330, 1330-31 (2017), DOI: 10.1126/science.aan5201 (estimating that 3°C leads to a loss of 2% of US GDP, and 6°C is 6% loss).

[109] For an in-depth, accessible explanation of how rising temperatures lead inevitably to more intense, frequent, and long-lasting droughts, see Toby R. Ault, *On the Essentials of Drought in a Changing Climate*, 368 SCI. 256, 256-60 (2020) (corrected April 24, 2020), DOI: 10.1126/science.aaz5492.

[110] As New et al. explain:

at 1.0°C of warming,[111] but the number of those systems undergoing transformations accelerates by 2°C and continues to expand from there:

> Approximately 4% (interquartile range 2–7%) of the global terrestrial land area is projected to undergo a transformation of ecosystems from one type to another at 1°C of global warming, compared with 13% (interquartile range 8–20%) at 2°C (medium confidence). This indicates that the area at risk is projected to be approximately 50% lower at 1.5°C compared to 2°C (medium confidence).[112]

One way to look at these estimates is that the number of ecosystems transforming approximately triples with each 1°C of warming. If that relationship holds, then at 3°C about 39% of ecosystems will be transforming, and somewhere before 4°C of warming *all of them will be*.[113]

We are well on the way there. Pervasive shifts in forest vegetation are already occurring and are likely to accelerate under future global changes.[114] Most at risk are tropical forests, which are already exhibiting nonlinear, unpredictable trajectories of change in structure and diversity.[115] Diverse terrestrial and marine species are exhibiting poleward range extensions and changes in abundance and distribution.[116] Rising carbon reduces the nutrients in plants, which is already dwindling terrestrial insect populations.[117] All herbivores are at risk if this trend continues. In many systems,

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> There are a range of other potential thresholds in the climate system and large ecosystems that might be crossed as the world warms from 2°C to 4°C and beyond. These include permanent absence of summer sea ice in the Arctic, loss of the large proportion of reef-building tropical corals, melting of permafrost at rates that result in positive feedbacks to greenhouse gas warming through CH_4 and CO_2 releases and die-back of the Amazon forest. While the locations of these thresholds are not precisely defined, it is clear that the risk of these transitions occurring is much larger at 4◦C—and so the nature of the changes in climate we experience may well start shifting from incremental to transformative.

New et al., *supra* note 20, at 10-11 (citations omitted).

[111] *See* King et al., *supra* note 7.

[112] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 8.

[113] Precise projections of which systems cross thresholds at which temperature regimes have proven elusive, suggesting that policy should not assume there are "safe operating spaces" below specified levels of temperature rise. *See* Helmut Hillebrand et al., *Thresholds for Ecological Responses to Global Change Do Not Emerge from Empirical Data*, 4 NATURE ECOL & EVOLUTION 1502, 1502-09 (2020), https://doi.org/10.1038/s41559-020-1256-9.

[114] Nate G. McDowell et al., *Pervasive Shifts in Forest Dynamics in a Changing World*, 368 SCI. 964, eaaz9463, at 1-3 (2020), DOI: 10.1126/science.aaz9463.

[115] Harald Bugmann, *Tree Diversity Reduced to the Bare Essentials: Tropical Forest Dynamics Can Be Explained by Merely Two Functional Trait Axes*, 368 SCI. 128, 128-29 (2020), DOI: 10.1126/science.abb7020.

[116] This effect has been documented since the late 1990s. *See, e.g.*, Camille Parmesan et al., *Poleward Shifts in Geographical Ranges of Butterfly Species Associated with Regional Warming*, 399 NATURE 579, 579-83 ((1999), https://doi.org/10.1038/21181.

[117] Elizabeth Pennisi, *Carbon Dioxide Increase May Promote 'Insect Apocalypse': Study Links Low-Nutrient Plants to Fewer Grasshoppers*, 368 SCI. 459, 459 (2020), DOI: 10.1126/science.368.6490.459.

nonlinear effects accelerate the pace of transformation.[118] Projections suggest that shifts in Earth ecosystems are likely to occur over "human" timescales of years and decades, meaning the collapse of large vulnerable ecosystems, such as the Amazon rainforest and Caribbean coral reefs, may take only a few decades once triggered.[119]

Although other systems will take longer to transform, once they cross thresholds of nonlinear change the transformation will for all practical purposes be irreversible. For example, under a sustained warming scenario, a threshold for the integrity of the Antarctic ice shelves, and thus of the stability of the ice sheet, seems to lie between 1.5°C and 2°C. Crossing these thresholds implies commitment to large ice sheet changes and sea level rise that may take thousands of years to be fully realized and may be irreversible on longer time scales.[120] Similar concerns are coming from research on ocean circulation systems.[121] In short, almost everywhere researchers explore, they are finding evidence of a changing world increasingly dominated by accelerating nonlinear effects, tipping point thresholds, and likely irreversible trajectories of transformation. Beyond 2°C, the world is likely to look nothing like the complexes of social-ecological systems we currently are used to,[122] including in the United States.

Of course, we cannot be certain about what the 4°C world will look like and just how different it will be. For a sense of that, however, we can turn to paleoclimate records.[123] For instance, *drops* in global average temperature of 4°C from pre-industrial levels have led to ice ages.[124] In the other direction, during much of the Paleocene and early Eocene, when global average temperatures were roughly 7°C warmer than now, "the poles were free of ice caps, and palm trees and crocodiles lived above the Arctic

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[118] Eric Sanford et al., *Widespread Shifts in the Coastal Biota of Northern California During the 2014-2016 Marine Heatwaves*, 9 SCI. REPS. art. 4216, at 6-12 (2019), https://doi.org/10.1038/s41598-019-40784-3.

[119] Gregory S. Cooper, Simon Willcock & John A. Dearing, *Regime Shifts Occur Disproportionately Faster in Larger Ecosystems*, 11 NATURE COMM. art. 1175, at 7 (2020), https://doi.org/10.1038/s41467-020-15029-x.

[120] Frank Pattyn & Mathieu Morlighem, *The Uncertain Future of the Antarctic Ice Sheet*, 367 SCI. 1331, 133135 (2020), DOI: 10.1126/science.aaz5487; *see also* Jason P. Briner et al., *Rate of Mass Loss from the Greenland Ice Sheet Will Exceed Holocene Values this Century*, 586 NATURE 70, 70-74 (2020), https://doi.org/10.1038/s41586-020-2742-6; Ian Joughin, Richard B. Alley, & David M. Holland, *Ice Sheet Response to Oceanic Forcing*, 338 SCI. 1172, 1172-76 (2012), DOI: 10.1126/science.1226481.

[121] Thomas F. Stocker, *Surprises for Climate Stability*, 367 SCI. 1425, 1425-26 (2020), DOI: 10.1126/science.abb3569.

[122] New et al., *supra* note 20, at 6 ("In some cases, such as farming in sub-Saharan Africa, a +4◦C warming could result in the collapse of systems or require transformational adaptation out of systems, as we understand them today.").

[123] *See* Jessica E. Tierney et al., *Past Climate Informs Our Future*, 370 SCI. 680, eaay3701, at 7 (2020), DOI: 10.1126/science.aay3701 (noting that improved geochemical and statistical techniques are providing more reliable projections from paleoclimate models); Thomas Westerhold et al., *An Astronomically Dated Record of Earth's Climate and its Predictability Over the Last 66 Million Years*, 369 SCI. 1383, 1383-87 (2020), DOI: 10.1126/science.aba6853 (describing new techniques and results).

[124] *How Is Today's Warming Different from the Past?*, NASA EARTH OBSERVATORY (June 10, 2010), https://earthobservatory.nasa.gov/features/GlobalWarming/page3.php.

Circle."[125] In one of the most comprehensive analyses, Nolan et al. concluded that without substantial mitigation efforts, all global terrestrial ecosystems are at risk of major transformation in composition and structure.[126]

Stepping back, what does all this mean for humans? In somewhat clinical terms, the IPCC has outlined the impacts of nonlinear change beyond 2°C. For example, the IPCC calculates that both permafrost degradation and food supply instability enter the realm of very high risk—"[v]ery high probability of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks"—at 2°C. Dryland water scarcity and wildfire damage become very high risk at 3°C and vegetation loss and tropical crop yield declines at about 3.5°C, but soil erosion does not become very high risk until around 5°C.[127] For wildfire damage, for example, our current 1°C increase in global average temperature means a longer fire season; at 2.5°C, 50% more of the Mediterranean region is at risk of wildfire; and at about 4.3°C, 100 million more people are at risk from wildfire.[128] With respect to food security, the planet moves from infrequent, locally important spikes in food prices at 1°C to "periodic food shocks across regions" at 3.2°C to "sustained food supply disruptions globally" at about 4.3°C.[129] The list goes on.

While alarming, these projections do not provide much sense of what life would be like for humans under extreme conditions. For that, several authors have used available scientific evidence to sketch out narratives in what might be termed scientific speculation. For example, as early as 2008, Mark Lynas conjured progressive visions of the world as global average temperatures increase from 1ºC to 6ºC.[130] At 4ºC, places like Bangladesh and New Jersey will rapidly be losing land mass and coastal cities around the world—including Mumbai, Shanghai, London, Venice, New York, and New Orleans—"may become fortified islands, largely below sea level and under siege from all sides by the advancing waters."[131] At the same time, food security becomes an international crisis as the world's "breadbaskets" fail in rapid succession, often replaced by deserts,[132] while lands recently freed of ice and snow, like Canada and Russia, prove unequal to the task of replacing them.[133] Lynas concludes that "all of these regions will be hemorrhaging people in the biggest human migration ever seen, with hundreds of millions on the move in search of food and water"[134] and "that mass starvation will be a permanent danger for much of the human race in the four-degree world … ."[135]

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125 Michon Scott & Rebecca Lindsey, *What's the Hottest Earth's Ever Been?*, NOAA CLIMATE.GOV (June 18, 2020), https://www.climate.gov/news-features/climate-qa/whats-hottest-earths-ever-been.

126 *Id*.

127 2019 IPCC LAND REPORT, *supra* note 45, at 16-17 fig. SPM.2.

128 *Id*.

129 *Id*.

130 MARK LYNAS, SIX DEGREES: OUR FUTURE ON A HOTTER PLANET (National Geographic 2008).

131 *Id*. at 187.

132 *Id*. at 195.

133 *Id*.

134 *Id*.

135 *Id*. at 196.

More recently, asking "Will your grandchildren live in cities on Antarctica?," Frank Jacobs more optimistically envisions a traumatic but ultimately successful human migration to the poles.[136] In contrast, for Gaia Vince of *The Guardian*, 4°C means "[d]rowned cities; stagnant seas; intolerable heatwaves; entire nations uninhabitable … and more than 11 billion humans. A four-degree-warmer world is the stuff of nightmares and yet that's where we're heading in just decades."[137]

While these visions differ in the details, they agree on several big points relevant to adaptation governance. First, humans will be migrating *en masse*, probably mostly toward the poles as middle latitudes become increasingly uninhabitable.[138] Second, food insecurity escalating to mass starvation will become a real problem for almost everyone as both terrestrial and marine food systems fail.[139] Third, sea level rise, melting ice and increasing numbers of increasingly severe storms will transform the coasts, where humanity has been concentrating itself, exacerbating migration pressures.[140] Fourth, the rest of the biosphere will be suffering disproportionately both from climate change itself and from humanity's attempts to adapt and survive—the sixth global mass extinction of species will be well underway, exacerbated by increasing loss of habitat as a result both of changing physical parameters and of new human settlement.[141] Finally, while *Homo sapiens* is unlikely to go extinct, human suffering is likely to increase dramatically. Under any conditions, mass migration is generally accompanied by poor sanitation, poor nutrition, nonexistent health care, and rampant disease; to that, climate change will add heat stress and significantly reduced resources (e.g., food) and capacity for relief efforts. Governments and governance systems need to be prepared, or we can certainly add war, famine, disease, and increased inequalities into the narrative.

B. Acknowledging Potential Limitations on Humanity's Adaptative Capacity

Having established the probability of planetary transformation, another potential complication for adaptation governance is that humans might not be as adaptable to a warmer world as they like to believe. Consider first that while the planet has repeatedly supported a thriving biosphere at a global average temperature 5°C to 8°C hotter than

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[136] Frank Jacobs, *What the World Will Look Like 4°C Warmer*, BIG THINK (May 22. 2017), https://bigthink.com/strange-maps/what-the-world-will-look-like-4degc-warmer.

[137] *E.g*., Gaia Vince, "The heat is on over the climate crisis. Only radical measures will work," THE GUARDIAN (May 18, 2019, 11.00 EDT), https://www.theguardian.com/environment/2019/may/18/climate-crisis-heat-is-on-global-heating-four-degrees-2100-change-way-we-live.

[138] For more detailed discussion of human migration, see *infra* Parts III.C and IV.A.

[139] Vince, *supra* note 137. *See* also Éva Plagányi, *Climate Change Impacts on Fisheries*, 363 SCI. 930, 930-31 (2019), DOI: 10.1126/science.aaw5824 (concluding that there has already been a 4% decline in global productivity of marine fisheries between 1930 and 2010).

[140] Vince, *supra* note 137

[141] *Id*.

today, humans, *as a species*, have never experienced those temperatures.[142] Adapting to a 4°C *hotter* world, therefore, is literally *not* in our DNA.

Nor, possibly, are humans as temperature-flexible as we might like to believe. Developing the concept of the "human climate niche," Xu et al. emphasize that, despite all our advances in technology, even "today, humans, as well as the production of crops and livestock . . . are concentrated in a strikingly narrow part of the total available climate space."[143] They further conclude that temperature is that main determinant of where people live[144] and that humanity's temperature preferences have not changed for at least 8000 years.[145] These researchers suggest that "[t]his distribution likely reflects a human temperature niche related to fundamental constraints."[146]

If human thriving does depend on occupancy of this fundamental temperature niche, the implications for climate change adaptation are profound. Warming now is occurring ten to twenty times faster than when the planet was emerging from its ice ages,[147] giving both humans and ecosystems far less time to move to the temperature zones that allow them to continue to survive.[148]

C. Imagining the United States When the World Is 4°C Warmer

What will a 4°C warmer United States look like? In the summer of 2020, ProPublica and the *New York Times* partnered to address that very question.[149] The project vividly illustrated that the United States in a 4°C world looks quite different from the United States at 2°C. Defining a "suitable zone" as the area of the nation in the sweet spot of Xu et al.'s "human climate niche,"[150] the zone covers most of the heart of the nation today, moves northward under a moderate emissions scenario, converging around the Great Lakes, and almost completely shifts into Canada under a high emissions scenario.[151] Putting these maps into descriptive words, Abraham Lustgarten of the *New Your Times* observes that

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[142] *Id*.

[143] Xu et al., *supra* note 30, at 11350.

[144] *Id*.

[145] *Id*. at 11350-51.

[146] *Id*. at 11350.

[147] Scott & Lindsey, *supra* note 125.

[148] Urbanization also is a driver of rising population heat exposure, compounding the effects of climate-induced heat exposure. *See* Ashley Mark Broadbent, Eric Scott Krayenhoff, &Matei Georgescu, *The Motley Drivers of Heat and Cold Exposure in 21st Century US Cities*, 117 PNAS 21108, 21108-10 (2020), https://doi.org/10.1073/pnas.2005492117; Kangning Huang, Xia Li, Xiaoping Liu, & Karen C Seto1*Projecting Global Urban Land Expansion and Heat Island Intensification through 2050*, 14 ENVT'L RES. LETT. art. 114037, at 1-3 (2019)., https://iopscience.iop.org/article/10.1088/1748-9326/ab4b71.

[149] *See* Abrahm Lustgarten, *How Climate Migration Will Reshape America*, THE N.Y. TIMES MAG. (Sept. 15, 2020), https://www.nytimes.com/interactive/2020/09/15/magazine/climate-crisis-migration-america.html; Al Shaw, Abrahm Lustgarten, & Jeremy W. Goldsmith, *New Climate Maps Show a Transformed United States*, PROPUBLICA (Sept. 15, 2020), https://projects.propublica.org/climate-migration/.

[150] *See* Xu et al, *supra* note 30.

[151] *See* Shaw et al., *supra* note 149.

> Buffalo may feel in a few decades like Tempe, Ariz., does today, and Tempe itself will sustain 100-degree average summer temperatures by the end of the century. Extreme humidity from New Orleans to northern Wisconsin will make summers increasingly unbearable, turning otherwise seemingly survivable heat waves into debilitating health threats. Fresh water will also be in short supply, not only in the West but also in places like Florida, Georgia and Alabama, where droughts now regularly wither cotton fields.[152]

There are two important policy points to draw from this bleak scenario. First, these changes will mean different things across the nation's already varied climate. For example, "large increases in heavy precipitation have [already] occurred in the Northeast, Midwest, and Great Plains, where heavy downpours have frequently led to runoff that exceeded the capacity of storm drains and levees, and caused flooding events and accelerated erosion," while Alaska is already experiencing melting permafrost that with both destabilize infrastructure and accelerate climate change.[153] Increased competition for water—both among humans and between humans and ecosystems—is likely in the Southeast, Caribbean, Great Plains, Hawaii, the Pacific Island Territories, and especially the Southwest, which also faces increasing risks of catastrophic wildlife.[154] The nation's coasts are increasingly at risk from sea-level rise and worsening storm surge, especially in the Gulf of Mexico, and Southeast.[155] Worsening—and life-threatening—heatwaves are a risk everywhere.

Second, although the direct impacts of sea level rise, drought, heat, and other threat factors may be uneven across the nation and across economic sectors, no region or sector can be complacent that it will avoid disruption. Climate-induced impacts in one region or sector undoubtedly will have knock-on effects elsewhere. For example, increasingly unlivable temperatures in some regions, lack of potable water in other regions, and the invasion of the sea in coastal regions are likely to drive significant internal migrations within the United States' borders, meaning every region of the nation is affected.[156] Regional and sectoral interactions from this and other impacts, such as crop failures and water scarcity, will only be more intensive and far reaching in a 4°C world.[157] Likewise, the United States will feel effects from around the globe as well, where in all cases social-ecological system conditions worsen as temperatures rise.[158]

One need not fully accept all projections the ProPublica/*New York Times* project produced to appreciate that the United States in a 4°C world would join the ranks of

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[152] Lustgarten, *supra* note 149.

[153] U.S. GLOBAL CHANGE RESEARCH PROGRAM, CLIMATE CHANGE IMPACTS IN THE UNITED STATES: THE THIRD NATIONAL CLIMATE ASSESSMENT 9 (2014) [hereinafter 2014 U.S. CLIMATE IMPACT REPORT].

[154] *Id*. at 11.

[155] *Id*.

[156] *See* Lustgarten *supra* note 149. Domestic internal migration is likely to be prevalent in many nations. François Gemenne, *Climate-induced Populations Displacements in a 4°C+ world*, 369 PHIL. TRANS. ROY. SOC. A 182, 182-83 (2011), doi:10.1098/rsta.2010.028.

[157] *See* Rachel Warren, *The Role of Interactions in a World Implementing Adaptation and Mitigation to Climate Change*, 369 PHIL. TRANS. ROYAL SOC'Y A 217, 219-33 (2011), https://doi.org/10.1098/rsta.2010.0271.

[158] *See* IPCC LAND REPORT, *supra* note 45, at 8-9.

nations perceived today as most at risk in a 2°C world.[159] At 4°C, the United States' comparable wealth will not be enough to stop the "suitable zone" from exiting northward. Welcome, United States, to a club no nation wishes to join.

As the ProPublica/*New York Times* project most emphasizes, the most significant consequence of the high emissions scenario for the United States is *internal* domestic human migration.[160] At 2°C, we and other northern hemisphere developed nations are the sought-after refuge for the hard-hit developing world. At 4°C, we may still be, but there is likely to be significant migration within the United States, away from coastal regions, away from intolerably hot regions, and away from regions with no sustainable potable water supply. Ironically, as Lustgarten observes, "here in the United States, people have largely gravitated toward environmental danger, building along coastlines from New Jersey to Florida and settling across the cloudless deserts of the Southwest."[161] Under extreme climate change, the gravitational pulls will be reversed.

What that means for different regions of the nation is likely to be a mixed bag. In one influential study, geographer Mathew Hauer meticulously modeled the impacts of sea level rise (SLR) on coastal communities and estimated demand for relocation to be as high as 13 million people.[162] His main point, however, is that they are moving somewhere inland, meaning inland communities will have to adapt as well.[163] Fan et al. find that this inter-regional migration likely will also redistribute economic fortunes as a result of rising wages and land prices in the in-migration regions.[164] Other studies make predictions about domestic migration responses to heat and natural disasters, often finding nonlinear effects.[165]

The magnitude and impacts of domestic climate-induced inter-regional migration have been largely ignored in adaptation planning in the United States (and elsewhere), the spotlight being instead on cross-border international migration.[166] New modalities of adaptation governance will be necessary to cope with its impacts and the many other transformations occurring in a 4°C world.[167] We turn to that theme in the next Part.

III. ADAPTING TO 4°C: REORIENTING ADAPTATION POLICY FOR ANTICIPATORY REDESIGN

Climate change adaptation policy took a back seat to mitigation policy until a decade ago, when it became clear that severe and protracted harms would occur even if

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[159] Lustgarten, *supra* note 149.

[160] Shaw et al., *supra* note 149; Lustgarten, *supra* note 149.

[161] Lusgarten, *supra*, note 149.

[162] Mathew E. Hauer, *Migration Induced By Sea-level Rise Could Reshape the US Population*, 7 NATURE CLIMATE CHANGE 321, 321-25 (2017), https://doi.org/10.1038/nclimate3271.

[163] *Id*.

[164] Qin Fan, Karen Fisher-Vanden, & H. Allen Klaiber, *Climate Change, Migration, and Regional Economic Impacts in the United States*, 5 J. ASSOC. ENVTL. RESOURCE ECON. 643, 644-45 (2017).

[165] *Id*. at 643-44.

[166] *See* Gemenne, *supra* note 156, at 187-88

[167] W. Neil Adger et al., *Urbanization, Migration, and Adaptation to Climate Change*, 3 ONE EARTH 396, 396 (2020), https://doi.org/10.1016/j.oneear.2020.09.016.

the (at that time) 1.5°C goal could be achieved.[168] Indeed, in some policy circles speaking of adaptation was forbidden, lest its potential for alleviating harm suppress support for aggressive, costly mitigation policy.[169] The inevitability of rising sea levels, hotter climates, bigger storms, and other conditions eventually forced adaptation into the policy discussion, and it is now seen as an essential partner of mitigation policy for both human communities and conservation resources.[170] Adaptation policy[171] now focuses on key drivers, including: (1) coastal flooding; (2) inland flooding; (3) weather event disruption of electrical, emergency and other key infrastructure systems; (4) extreme heat; (5) food insecurity; (6) water shortages; (7) marine ecosystem degradation; and (8) terrestrial and inland water ecosystem disruption.[172]

Nevertheless, adaptation policy has largely centered around the 1.5°-2°C scenario,[173] although more recently cities in the United States have begun to include a high emissions scenario in their adaptation plans.[174] The 1.5°-2°C scenario is not pleasant by any stretch, but it is not nearly as disruptive and difficult to manage as the 4°C scenario described in Part II. In this Part we match up the current adaptation policy model against the 4°C scenario. We conclude the current model is not up to the challenge, in large part because progressively increasing temperatures geometrically, rather than arithmetically, increase the disruptions to social-ecological systems from climate change. In particular, domestic inter-regional migration in the United States will disrupt the population landscape, with cascading consequent impacts. As a result, we propose that a new framing is needed in order to prepare for adaptation beyond 2°C, a framing we call *redesign*.

A. Resistance, Resilience, and Retreat

Although there are different formulations and terminologies, current climate change adaptation policy can be sorted into three modes: *resistance* (also known as protect, fortify, or defend), *resilience* (also known as adjustment, accommodate, manage, or transform), and *retreat* (also known as move, resettlement, relocation, or avoidance).[175]

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[168] For a history of the emergence and development of adaptation policy and research, see J.B. Ruhl, *Climate Change Adaptation and the Structural Transformation of Environmental Law*, 40 ENVT'L L. 363, 365-75 (2010). *See also* Xueqing Shan, *Coordinating Local Adaptive Strategies Through a Network-Based Approach*, 29 DUKE ENVT'L L. & POL'Y F. 183, 187 (2018).

[169] Ruhl, *supra* note 168, at 366-70.

[170] *Id*.

[171] Jacobs, *supra* note 136.

[172] Eli Kintisch, *In New Report, IPCC Gets More Specific About Warming Risks*, 344 SCI. 21, 21 (2014), DOI: 10.1126/science.344.6179.21. *See also* GLOBAL COMMISSION ON ADAPTATION, ADAPT NOW: A GLOBAL CALL FOR LEADERSHIP ON CLIMATE RESILIENCE 3 (2019) (identifying human, environmental, and economic imperatives to adapt quickly), *available at* https://gca.org/reports/ [hereinafter ADAPT NOW].

[173] *See* Warren, *supra* note 157, at 218-19.

[174] *See* Missy Stults & Larissa Larsen, *Tackling Uncertainty in US Local Climate Adaptation Planning*, 40 PLANNING RESEARCH 416, 420, 425 (2020), https://doi.org/10.1177/0739456X18769134.

[175] Ruhl, *supra* note 168, at 387-89 (using the terms resist, transform, move); *see also* Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, in LAW OF ADAPTATION, *supra* note 21, at 239 (using the terms resistance, adjustment, and retreat); Trip Pollard, *Damage Control: Adapting Transportation to a Changing Climate*, 39 WM & MARY ENVT'L L. & POL'Y REV. 365, 378 (2015) (listing the various terms); Mark Scott et al., *Climate Disruption and Planning: Resistance or Retreat?* 21 PLANNING THEORY &

These are not necessarily mutually exclusive, and in many contexts may need to be deployed simultaneously—e.g., even if Miami eventually needs to use retreat as part of its strategy, its population needs to be protected and resilient during the time it takes to move and then in their resettled part of the city.[176] Nevertheless, the "Three Rs" are distinct in terms of their core orientations to an adaptation response.

1. Resistance

Resistance polices focus on building infrastructure and other mostly technological defenses to climate change impacts in order to protect human communities.[177] Resistance has long been a core policy approach to natural hazards in the United States. Classic examples include seawalls along coastal areas and dams and levees along flood-prone rivers.[178] It is no surprise, therefore, that resistance strategies are prominent in many local and regional climate change adaptation plans.[179] Resistance strategies are less likely to be effective for conservation lands, however, where climate change will directly alter ecological resources and processes in ways that would be difficult if not impossible to prevent.[180]

Resistance policies have been criticized from a number of perspectives, even in the purely disaster-prevention context. One is that they encourage development in the protected area, exposing more people and capital to risk if the infrastructure fails.[181] Another is that they are expensive and thus most likely to be used to protect affluent and politically powerful populations.[182] Resistance strategies often take the form of "hard" infrastructure, which almost inevitably come with significant environmental impacts, from interruption of sand and sediment flows to blocked animal migration pathways to altered habitat.[183] This conventional approach conflicts with the growing advocacy for natural or "green" approaches, such as enhancing coastal wetlands.[184] For 4°C climate

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PRACTICE 125, 130 (2020), https://doi.org/10.1080/14649357.2020.1704130 (using a variety of these terms).

[176] Jeroen C. J. H. Aerts et al., *Evaluating Flood Resilience Strategies for Coastal Megacities*, 344 SCI. 473, 473-75 (2014), DOI: 10.1126/science.1248222 (evaluating different mixes of strategies); Audrey Baills, Manuel Garcin, & Thomas Bulteau, *Assessment of Selected Climate Change Adaptation Measures for Coastal Areas*, 185 OCEAN & COASTAL MGMT. 105059, at 3, 7 (2020), https://doi.org/10.1016/j.ocecoaman.2019.105059 (outlining a broad array of strategies and criteria for evaluating selection).

[177] Ruhl, *supra* note 168, at 386; Verchick & Scherega, *supra* note 175, at 235-37.

[178] Scott et al., *supra* note 175, at 130.

[179] Aerts et al., *supra* note 176, at 474; Baills et al., *supra* note 176, at 3.

[180] Katherine R. Clifford et al., *Navigating Climate Adaptation on Public Lands: How Views on Ecosystem Change and Scale Interact with Management Approaches*, 66 ENVT'L MGMT. 614, 615-16 (2020), https://doi.org/10.1007/s00267-020-01336-y.

[181] Scott et al., *supra* note 175, at 126-27; Robin Kundis Craig, *Coastal Adaptation, Government-Subsidized Insurance, and Perverse Incentives to Stay*, 152 CLIMATIC CHANGE 215, 220-24 (2019), https://doi.org/10.1007/s10584-018-2203-5.

[182] Scott et al., *supra* note 175, at 127.

[183] Verchick & Scherega, *supra* note 175, at 240-41.

[184] *Id*. at 250-251; *see generally also* Siddharth Narayan et al., *The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences*, 11 PLOS ONE e0154735 (2016), DOI: 10.1371/journal.pone.0154735 (assessing the befits of coastal resoration); Niki L. Pace, *Wetlands or*

adaptation, all of these objections to resistance strategies remain, with the added disincentive that the scale of necessary deployment presents staggering economic costs.[185] Resistance strategies, while likely necessary for many communities (at least in the short term), thus must be carefully planned.

2. Resilience

Climate resilience policies are designed to facilitate a community's capacity to cope with climate change where impacts cannot be avoided or effectively resisted.[186] For example, there is no conceivable way a city could prevent ambient air temperatures from rising or halt sea level rise, but it could subsidize air conditioning to make indoor conditions more hospitable and adopt building and planning codes that integrate heat-conscious and flood-conscious design. Resilience policy goes beyond technology and response management, however, as social and economic system capacities also contribute to a community's overall resilience not only to climate change but also to other disruptions.[187] Such strategies can range from new forms of training to the conscious diversification of industry and other forms of income.

Like resistance strategies, enhancing resilience capacity, particularly through technology and response management strategies, has long been a focus of public policy independent of climate change.[188] Building architecture in earthquake-prone areas and homes elevated on stilts in coastal areas offer technology examples, and the Federal Emergency Management Agency is a management example. Like resistance, therefore, climate resilience strategies are a natural extension of past policy and have played a major role thus far in climate adaptation policy.[189] Moreover, some new forms of resilience strategies are likely to be necessary for a 4°C future, from adaptive training in the health care sector in response to emerging health threats[190] to crop diversification in

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Seawalls—Adapting Shoreline Regulation to Address Sea Level Rise and Wetland Preservation in the Gulf of Mexico, 26 J. LAND USE & ENVTL. L. 327, 330-41 (2011).

[185] For example, using a moderate emissions scenario, a recent study estimates that adequately protecting coastal communities from sea level rise would cost over $400 billion over the next 20 years. CENTER FOR CLIMATE INTEGRITY, HIGH TIDE TAX: THE PRICE TO PROTECT COASTAL STATES FROM RISING SEAS 1 (June 2019), *available at* https://www.climatecosts2040.org/files/ClimateCosts2040_Report-v4.pdf.

[186] Ruhl, *supra* note 168, at 422-27; Verchick & Scherega, *supra* note 175, at 239 (referring to adjustment).

[187] *See* Sierra C. Woodruff, Sara Meerow, Missy Stults, & Chandler Wilkins, *Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change*, J. PLANNING EDU. & RESEARCH 1, 1-3 (2018), https://doi.org/10.1177/0739456X18801057

[188] *Id*.

[189] *Id*.

[190] Robin Kundis Craig, *Cleaning Up Our Toxic Coasts: A Precautionary and Human Health-Based Approach to Coastal Adaptation*, 36 PACE ENVTL. L. REV. 1, 1-46 (2018); Robin Kundis Craig, *Oceans and Coasts*, *in* CLIMATE CHANGE, PUBLIC HEALTH, AND THE LAW (Michael Burger & Justin Gundlach, eds.) (Cambridge Univ. Press, 2018), 204-240, doi:10.1017/9781108278010.009; Robin Kundis Craig, *Cholera and Climate Change: Pursuing Public Health Adaptation Strategies in the Face of Uncertainty*, 18 HOUSTON J. HEALTH L. & POL'Y 29, 31=75 (2018).

agriculture.[191] Resilience strategies also can play a role for conservation lands, where managers, recognizing that many changes will be unavoidable, turn their attention to maintaining overall resilience in dynamically transforming ecosystems.[192] Nevertheless, resilience strategies are also subject to many of the same criticisms as resistance.[193]

3. Retreat

Retreat policies focus on intentionally abandoning areas subject to harms and relocating the people and structures to less vulnerable locations.[194] In the context of climate change adaptation, retreat comes into play when it is anticipated that resist and resilience policies will not be technologically or economically practicable or sufficiently effective for reducing or avoiding harms.[195] For example, sea walls may protect a coastal community against storm surge, but they will not prevent saltwater intrusion to groundwater as sea level rises, and it may be cost prohibitive to replace the impaired drinking water source with other sources.[196] Inland, areas on the wildland-urban interface may experience more frequent and intense wildfires that cannot be adequately prevented and controlled.[197] At some point resistance and resilience strategies may simply fail to manage risk to acceptable levels at acceptable cost, leaving retreat as the only viable option.[198]

In climate adaptation policy, retreat is usually described as locally "managed," in that there is a deliberate policy regime and administrator designed to carry out an orderly process for moving the built environment and sub-communities out of harm's way,

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[191] *E.g.*, Rebecca Carter, Tyler Ferdinand, & Christina Chan, Transforming Agriculture for Climate Resilience: A Framework for Systemic Change, World Resources Institute Working Paper 1 (2018) (arguing that "[b]eginning now to identify, plan for, and finance transformative approaches over the coming decades offers the best opportunity to maintain and enhance global food security, avoid maladaptation, and reduce escalating risks of conflict and crisis as climate impacts intensify."), *available at* https://files.wri.org/s3fs-public/transforming-agriculture-climate-resilience-framework-systemic-change_0.pdf.

[192] Clifford et al., *supra* note 180, at 116.

[193] Scott et al., *supra* note 175, at 130. *See also generally* Shalanda H. Baker, *Anti-Resilience: A Roadmap for Transformational Justice within the Energy System*, 54 HARV. CIVIL RIGHTS-CIVIL LIBERTIES L. REV. 1 (2019) (challenging how resilience has been pursued as a goal in energy policy).

[194] Ruhl, *supra* note 168, at 387; Verchick & Scherega, *supra* note 175, at 239. For a comprehensive overview of coastal retreat law and policy in the United States, see J. Peter Byrne & Jessica Grannis, *Coastal Retreat Measures*, in LAW OF ADAPTATION, *supra* note 21, at 267267-306.

[195] John Carey, *Core Concept: Managed Retreat Increasingly Seen as Necessary in Response to Climate Change*, 117 PNAS 13182, 13182-85 (2020), https://doi.org/10.1073/pnas.2008198117; Brent Doberstein, Anne Tadgell, & Alexandra Rutledge, *Managed Retreat for Climate Change Adaptation in Coastal Megacities: A Comparison of Policy and Practice in Manila and Vancouver*, 253 J. ENVT'L MGMT. 109753 (2020), https://doi.org/10.1016/j.jenvman.2019.109753; Miyuki Hino, Christopher B. Field, & Katharine J. Mach, *Managed Retreat as a Response to Natural Hazard Risk*, 7 NATURE CLIMATE CHANGE 364, 364-70 (2017), https://doi.org/10.1038/nclimate3252; Andrea McArdle, *Managing "Retreat": The Challenges of Adapting Land Use to Climate Change*, 40 U. A. LITTLE ROCK L. REV. 605, 618-24 (2018); A.R. Siders, *Managed Retreat in the United States*, 1 ONE EARTH 216, 216-27 (2019), https://doi.org/10.1016/j.oneear.2019.09.008.

[196] Scott et al., *supra* note 175, at 131.

[197] Carey, *supra* note 195, at 13182-85.

[198] *Id*.

ideally well before the harms become significant.[199] Although voluntary post-disaster retreat programs have been implemented in various locations in the United States,[200] this form of "preemptive" retreat—retreat forced and managed in anticipation of conditions exceeding the capacity of resistance and resilience strategies—has not yet been implemented anywhere in the United States and surely would face stiff pushback from many interests, not just the people being relocated.[201] There is a long history of forced relocations in the United States and elsewhere, and they have almost always been controversial.[202] Even when relocation is the only alternative and relocations are provided within the same general area, it disrupts community and culture.[203] Nevertheless, retreat is increasingly being included in policy discussions as either a potentially necessary or more cost-effective adaptation strategy for human communities, particularly among Pacific Island nations already at existential risk from climate change and sea level rise.[204] Retreat is more difficult to implement for conservation lands, which have fixed boundaries. Proposals for migratory conservation spaces do exist,[205] and assisted migration—the translocation of species from degrading habitats to existing or emerging suitable habitats—can be thought of as a form of retreat.[206] However, it is important to remember throughout this discussion of human adaptation responses that *ecosystems* are already both changing compositionally and shifting geographically—i.e., transforming and retreating. As such, ecological change all by itself is increasingly likely to perturb long-established social-ecological relationships, whether those be ranching communities in Montana, sportfishing-dependent communities in Florida, or salmon-focused Tribes in the Pacific Northwest.

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[199] *Id.*; *see also* Byrne & Grannis, *supra* note 194, at 268 ("Local governments will be the primary actors in implementing retreat policies").

[200] *See generally* GEORGETOWN CLIMATE CENTER, MANAGING THE RETREAT FROM RISING SEAS (2020) (providing a series of 17 examples), *available at* https://www.georgetownclimate.org/files/MRT/GCC_20_Taholah-3web.pdf.

[201] Gibbs, *supra* note 36, at 107; Siders, *supra* note 195, at 218. This is not by any means limited to the United States. *See* Christina Hanna, Iain White, & Bruce Glavovic, *The Uncertainty Contagion: Revealing the Interrelated, Cascading Uncertainties of Managed Retreat*, 12 SUSTAINABILITY paper 736 [online] (2020), https://doi.org/10.3390/su12020736 (case study of New Zealand); Judy Lawrence, Jonathan Boston, Robert Bell, Sam Olufson, Rick Kool, Matthew Hardcastle & Adolf Stroombergen, *Implementing Pre-Emptive Managed Retreat: Constraints and Novel Insights*, 6 CURRENT CLIMATE CHANGE REPORTS 66, 66-80 (2020) (New Zealand).

[202] Carey, *supra* note 195, at 13182-85; Hino et al., *supra* note 195, at 364-70.

[203] Carey, *supra* note 195, at 13182-85; Hino, *supra* note 195, at 364-70; Hanna et al., *supra* note 201.

[204] Carey, *supra* note 195, at 13182-85.

[205] Notably, however, most of the proposals focus on the ocean, where private property is far less of a barrier. ROBIN KUNDIS CRAIG, COMPARATIVE OCEAN GOVERNANCE: PLACE-BASED PROTECTIONS IN AN ERA OF CLIMATE CHANGE 155-69 (Edward Elgar 2012); Josh Eagle, James N. Sanchirico, & Barton H. Thompson, *Ocean Zoning and Spatial Access Privileges*, 17 N.Y.U. ENVTL. L. REV. 646, 646-65 (2008).

[206] Alejandro E. Camacho, *Assisted Migration: Redefining Nature and Natural Resource Law Under Climate Change*, 17 YALE J. REG. 171, 202-10 (2010).

B. The Three Rs Versus 4°C

Current adaptation policy proposes deploying the Three Rs to manage the key drivers of adaptation need.[207] The emphasis in the United States (and elsewhere) has been on using incremental adaptation to keep human communities mostly intact, in situ, and close to normal.[208] Of course, it makes sense that a city's or region's adaptation plan would focus on managing adaptation needs of the city or region. But even our national adaptation strategy, when there has been one, has been focused primarily on how to support those local and regional strategies, and adaptation is almost always presented as an adjunct to mitigation.[209] President Biden had the United States rejoin the Paris Climate Accord on his first day in office and issued his Climate Change Executive Order on the eighth.[210] While these are excellent signals of the Administration's prioritization of climate change, the focus remains primarily on mitigation, with adaptation provisions focusing on building in situ resilience.[211]

This focus on incremental, in situ adaptation carried out largely at state and local scales has led to a heavy emphasis on resistance and resilience strategies,[212] even to the point of envisioning "future proofing" or "climate proofing" cities and regions.[213] Managed retreat has been added as a last resort in most instances and is portrayed as part of a local strategy that retains the relocated population and businesses within the general locale.[214] To be sure, it is generally recognized that adaptation will transform how many communities look and operate, but the overwhelming policy goal in most adaptation plans is to stay put.[215] For conservation resources, moving is generally not an option, so staying put means dealing with transformation through resist strategies (e.g., removing invasive

[207] 2014 U.S. CLIMATE IMPACT REPORT, *supra* note 153, at 170; ADAPT NOW, *supra* note 172.

[208] Robert W. Cates et al., *Transformational Adaptation When Incremental Adaptations to Climate Change are Insufficient*, 109 PNAS 7156 (2012).

[209] EXECUTIVE OFFICE OF THE PRESIDENT, THE PRESIDENT'S CLIMATE ACTION PLAN 12 (June 2013), available at https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf. President Trump rescinded the plan and provided no replacement. PRESIDENT DONALD TRUMP, EXECUTIVE ORDER 13783: PROMOTING ENERGY INDEPENDENCE AND ECONOMIC GROWTH (March 28, 2017).

[210] PRESIDENT JOSEPH BIDEN, EXECUTIVE ORDER ON TACKLING THE CLIMATE CRISIS AT HOME AND ABROAD (Jan. 27, 2021), https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/ [hereinafter BIDEN CLIMATE CHANGE E.O.].

[211] The Executive Order, for example, mentions adaptation only in section 211. *Id*.

[212] Cates et al., *supra* note 208, at 7156; Scott et al., *supra* note 175, at 142. This is by no means limited to the United States. *See* Justine Bell & M. Baker Jones, *Retreat from Retreat—The Backward Evolution of Sea-level Rise Policy in Australia, and the Implications for Local Government*, 19 LOCAL GOV'T L.J. 23, 24-30 (2014) (describing a shift in policy from retreat to resist and resilience).

[213] GOVERNOR'S COMMISSION TO REBUILD TEXAS, EYE OF THE STORM 7 (2018) (adopting the "future proofing" theme); EUROPEAN COMMISSION, THE EU STRATEGY ON ADAPTATION TO CLIMATE CHANGE 2 (2013) (adopting the "climate proofing" theme in Action 6).

[214] Gibbs, *supra* note 36, at 107; Siders, *supra* note 195, at 218.

[215] Cates at al., *supra* note 208.

species[216]) and resilience strategies (e.g., managing fire fuel sources[217]), although there has been increasing attention to assisted transformation strategies instead—that is, on guiding the conservation lands into different but still productive ecosystem states.[218]

The emphasis on adapting in place is not surprising, as it would be politically unwise for a local government to declare that its adaptation policy is to dismantle the city and promote out-migration, while conservation resource managers face the reality that moving the protected land boundaries is generally not an option. Nevertheless, climate adaptation policy has generally not peered into the world beyond 2°C. That "high emissions" scenario is described in many adaptation reports and studies, but usually as something to be avoided, not as a world that might actually need to be planned for and governed.[219] We are aware of no national, state, or local adaptation plan that both builds out a 4°C scenario *and* asks: What if staying put for substantial segments of our population is not viable?[220] Nor, it appears, are cities that will be able to stay put asking what happens when they must adapt to substantial in-migration from the other cities.[221] It may very well turn out that many communities and sectors are able to "future proof" against a 2°C world and that conservation managers are able to keep ecological resources functioning, albeit in new forms, at 2°C—particularly in relatively wealthy northern

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[216] *E.g.*, Evelyn M. Beaury, Emily J. Fusco, Michelle R. Jackson, Brittany B. Laginhas, Toni Lyn Morelli, Jenica M. Allen, Valerie J. Pasquarella & Bethany A. Bradley, *Incorporating Climate Change into Invasive Species Management: Insights from Managers*, 22 BIOL. INVASIONS 233, 233-34 (2020), https://doi.org/10.1007/s10530-019-02087-6 (seeking "to facilitate proactive invasive species management that also accounts for climate change"); see also Eric V. Hull, *Climate Change and Aquatic Invasive Species*, 25 GEO. INT. ENVTL. L. REV. 51 (2012).

[217] *E.g.*, Paulo Fernandes, *Forest Fuel Management for Fire Mitigation Under Climate Change*, *in* FOREST MANAGEMENT OF MEDITERRANEAN FOREST UNDER THE NEW CONTEXT OF CLIMATE CHANGE: BUILDING ALTERNATIVES FOR THE COMING FUTURE (M.E. Lucas-Borja, ed.) 31, 31-41 (Nova Science Publishers, 2013).

[218] *E.g.* David G. Angeler, Brian C. Chaffin, Shana M. Sundstrom, Ahjond Garmestani, Kevin L. Pope, Daniel R. Uden, Dirac Twidwell, & Craig R. Allen. *Coerced Regimes: Management Challenges in the Anthropocene*, 25 ECOL. & SOC. art. 4 (2020), https://doi.org/10.5751/ES-11286-250104; David G. Angeler & Craig R. Allen, 53 *Quantifying Resilience*, 54 J. APPLIED ECOLOGY 617 (2017) (eroding an ecosystem's resilience causes it change more easily with the changing climate).

[219] *See e.g.*, *See* 2018 IPCC 1.5ºC REPORT, *supra* note 19, at 5 (providing an overview of the potential impacts and risks associated with climate change); 2014 U.S. CLIMATE IMPACT REPORT, *supra* note 153, at 25.

[220] Notably, however, in 2014 a group of interdisciplinary researchers from Australia did take the idea of a 4ºC future seriously enough to examine what it would mean for Australia. FOUR DEGREES OF GLOBAL WARMING: AUSTRALIA IN A HOT WORLD (Peter Christoff, ed. 2014). From the opposite perspective, some Pacific island nations at significant risk of inundation are already negotiating with countries such as Fiji, Australia and New Zealand for new homelands. *E.g.*, Laurence Caramel, *Besieged by the Rising Tides of Climate Change, Kiribati Buys Land in Fiji*, THE GUARDIAN (June 30, 2014 20.00 EDT), https://www.theguardian.com/environment/2014/jul/01/kiribati-climate-change-fiji-vanua-levu; Helen Dempster & Kayley Ober, *New Zealand's "Climate Refugee"* Visas, DEV. POL'Y CTR.: DevPolicyBlog (Jan. 31, 2020), https://devpolicy.org/new-zealands-climate-refugee-visas-lessons-for-the-rest-of-the-world-20200131/. Thus, neither piece of our quest is completely unthinkable on its own; the trick, rather, is to get places like the United States that are not currently facing an existential climate change threat to seriously anticipate the forced retreat of a 4°C future.

[221] Hauer, *supra* note 162, at 321-25.

hemisphere nations like the United States.[222] It is tempting to believe, therefore, that if the planet warms beyond 2°C the Three Rs will nevertheless continue to support incremental, in situ adaptation and keep existing human communities and conservation resources functioning.

If you buy into that, read Part II carefully again. How do we "future proof" against the 4°C scenario?

The problem is that, as described in Part II, the 2°C mark, as nasty as it is, is likely the threshold at which, if crossed, climate change takes on new and highly unmanageable properties. The Three Rs as currently modeled and integrated into "future proofing" polices do not consider runaway interacting positive feedback loops, cascade effects in the climate system, and the impacts they will have on social-ecological systems. As a result, there is growing concern that climate change beyond 2°C will swamp the capacities of the Three Rs and that transformational adaptation policies will need to operate at much larger scales, introduce novel strategies, and contemplate major changes and relocations.[223]

While it is true that individual humans in small groups can survive a wide range of climatological conditions, humans in larger groups—cities and counties—face real limits on their adaptability. Consider a coastal city in Florida: It may be facing relentless storm surges and hurricanes, a drinking water aquifer contaminated with saltwater, the return of diseases like malaria and dengue fever, and frequent dangerous heat waves. Resistance and resilience strategies would have to be herculean to manage risks of that level (and even at that might fail), and locally-managed retreat is pointless—there is no place locally that is out of harm's way.

In short, adaptation in essence is a form of risk management. A world at 4°C presents not only radically more intense versions of the risks of a 2°C world, but also different *kinds* of risks. It follows that a new kind of risk management mode—one that is both anticipatory and transformative—will be needed.

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[222] Given our focus on governance in the United States. we have largely set to one side for this Article the enormous adaptation inequities at the global scale, in favor of attempting first to address the far smaller—but nevertheless still challenging—issue of adaptation inequity within our own country. Our perhaps presumptuous hope is that if we can begin to successfully address 4°C governance within a nation that should already have the capacity to take the measures that need to be taken, transferable lessons will emerge—perhaps especially from the planning roundtable that we propose in Part IV.D—that can significantly aid equitable adaptation governance capacity building in other places.

[223] Cates, *supra* note 208; *see also* Kirstin Dow. Frans Berkhout, & Benjamin L Preston, *Limits to Adaptation to Climate Change: A Risk Approach*, 5 CURR. OPINION ENVTL. SUSTAINABILITY 384, 384-91 (2013), https://doi.org/10.1016/j.cosust.2013.07.005; Alark Saxen, Kristin Qui, & Stacy-Ann Robinson, *Knowledge, Attitudes and Practices of Climate Adaptation Actors Towards Resilience and Transformation in a 1.5C World*, 80 ENVTL. SCI. & POL'Y 152, 152-59 (2018), https://doi.org/10.1016/j.envsci.2017.11.001; Giacomo Fedele et al., *Transformative Adaptation to Climate Change for Sustainable Social-Ecological Systems*, 101 ENVTL. SCI. & POL'Y 116, 116-25 (2019), https://doi.org/10.1016/j.envsci.2019.07.001; Tyler Felgenhauer, *Addressing the Limits to Adaptation Across Four Damage-Response Systems*, 50 ENVTL. SCI. & POL'Y 214, 214-24 (2015), https://doi.org/10.1016/j.envsci.2015.03.003.

C. Reframing Adaptation for Redesign

The Three Rs will always be necessary, but they are not aimed at managing the fundamental redesign of biophysical systems that 4°C will impose. For that kind of risk, an anticipatory adaptation policy must move from incremental to transformative and be prepared in advance to redesign *social* systems. To put it another way, if the ecological system components of a complex social-ecological system are undergoing deep and unpreventable redesign, so must the social system components and so must the way we approach management of the ecological resources. No amount of locally-governed resistance, resilience, or managed retreat can avoid that fundamental property of the coevolving social and ecological components of large-scale systems in a 4°C world.

So, what does redesign mean? First and foremost, it means letting go of intact, in situ, and close-to-normal as the unyielding goal of adaptation. As discussed in Part II.C, even within the United States we can expect massive human migrations and massive species migrations.[224] We can expect relocation of agricultural crop and livestock lands.[225] We can expect extensive, expensive infrastructure projects to supply housing, water, transportation, and other needs for new and expanding human communities.[226] We can expect deep disruptions to insurance, finance, welfare, and other social and economic systems.[227] Redesign is about designing and facilitating—perhaps even requiring—the relocations and reconfigurations necessary for these adaptations to succeed.

Most importantly, however, we can expect the scale of adaptation to shift its primary locus from local and state to regional and national.[228] It is plausible, when planning for a 2°C world, for a city or state to look *inward*, asking how it can promote its continued functionalities, including growth and development, through the Three Rs. A 4°C world vastly complicates that inward-looking approach by introducing the prospect of substantial inter-regional population migration and all that comes along, or leaves, with it. Similarly, rural areas may face the complete loss, or widespread introduction, of agricultural land uses, and conservation resource managers may find a complete abandonment by, or substantial increase in, recreational users. In short, local adaptation planning, whether for urban or rural communities or conservation resource managers, will need also to look *outward* to plan coherently for the inward perspective.

This outward-looking dimension of adaptation planning necessarily raises the question of how to plan for the *between*. The fate of any city or region will, more than ever before, depend on what is happening in other cities and regions, as people, agriculture, infrastructure, water, energy, and other social-ecological system components shift around the nation, in many cases over relatively short time frames. The between-

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[224] *See supra* notes 160-166.

[225] 2014 U.S. CLIMATE IMPACT REPORT, *supra* note 153, at 150-75.

[226] *Id*.

[227] MARKET RISK ADVISORY COMMITTEE, U.S. COMMODITY FUTURES TRADING COMMISSION, CLIMATE-RELATED MARKET RISK SUBCOMMITTEE, MANAGING CLIMATE RISK IN THE U.S. FINANCIAL SYSTEM 25-27 (Washington, D.C.: 2020).

[228] Cates, *supra* note 208

looking dimension captures the interconnectedness of climate change adaptation at national scale and its influence on local, state, and regional planning.[229]

Of course, there already is a network that connects cities and regions with each other—the highways and other transportation infrastructure, pipelines and transmission lines, product supply chains, banking and finance systems, and other systems that operate at national scale to support local and regional scales. However, if some regions of the nation are literally shutting down and the people leaving, destined either for other cities or for newly developing areas, and yet more people are pressing to enter the nation, the existing interconnection networks will not in the right configurations or scaled to the right local capacities. They will need to be redesigned, as well as technologically improved and innovated, to deal with 4°C conditions. We are going to need to build new and better between infrastructure and capacity, and we will need it to enable massive movement of humans, other species, and what comes along with that.

To be sure, shocks of this magnitude have befallen cities in the past, and there have been pulses of substantial human migration in our nation, such as in response to the Dust Bowl.[230] There is one important distinction, however, between those experiences and the redesign mode of climate change adaptation—we know climate change is coming, that it may drag us near or up to a 4°C world, and that if it does, the kind and scale of disruptions we have outlined in Part II will be inevitable and long-lasting. Redesign will not be optional, nor should it be a surprise that it is necessary. Importantly, however, we also have the ability to plan ahead, a luxury that should not be squandered.

This brings us to the question to which the remainder of this Article is devoted: What to do about it? More to the point, why do anything about it now? After all, it is not as if a 4°C world is just around the corner. If we cross the 2°C threshold as a global average, it will likely be several decades from now at the soonest.[231] Why not just wait and see, letting people decide with their feet and depending on nimble markets and astute policy-makers to take care of the redesign then? And what can be done about it all now, anyway, even if we wanted to? It would be impractical to start building the redesign infrastructure before people need it.

These are legitimate questions. Perhaps this Article should end here, acting as testimony to future generations that we knew what was coming but decided it best to leave it to them to figure out what to do about it.

The two of us choose instead to forge ahead. Specifically, we proceed from here to argue that future generations deserve better than that, and that the present generation can in fact deliver better.

IV. GOVERNING AT 4°C: CONCEPTUALIZING, PLANNING, AND IMPLEMENTING REDESIGN ADAPTATION

As Part II laid out in detail, Planet Earth is well on its way to being 4ºC; indeed, despite the global pandemic, 2020 tied for the hottest year on record (with 2016), with

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[229] *See* Warren, *supra* note 157, at 218-19.
[230] *See infra* Part IV.A.
[231] 2018 IPCC 1.5°C REPORT, *supra* note 19, at 6.

global average temperatures reaching 1.25ºC higher than in preindustrial times.[232] Australian researchers have already concluded, "there is widespread agreement that current mitigation efforts … will lead to global average warming of 4ºC or more from pre-industrial levels by the end of this century … to a Four Degree World."[233] The two of us are not willing to risk the future of democratic governance to unwarranted optimism that the global community will successfully solve the climate change mitigation problem in time to keep the global average increase in temperature below 2ºC. The issue then becomes: What can the United States do *now* to facilitate the survival of democratic governance in a 4ºC world?

The United States (like the rest of the world's governments) will increasingly be dealing with transformational change. This governance challenge will likely last until sometime long after atmospheric concentrations of greenhouse gases finally stabilize.[234] As such, U.S. governance needs to move into—or at least be prepared to move into—the redesign mode of climate change adaptation.

Clearly, we shouldn't be seeking to iron out *all* the nitty-gritty details of a redesigned United States right now. Even setting issues of individual liberty to one side for the moment (something we prefer future governance *not* to do in reality), climate change impacts remain too probabilistic and too long-term for excessively detailed plans.

Nevertheless, probabilities are informative. As the discussions above emphasize, the most important consequence of transformational 4ºC warming for conceptualizing the governance of redesign adaptation is massive human migration within the United States. This focus includes both the attendant needs of that migration (e.g., infrastructure, social reorganization, economic stabilization, food and water security, health care adjustments) and its attendant impacts (e.g., competition with species and ecosystems that are also moving and transforming, competition with agricultural land, abandoned infrastructure and toxic contamination, energy consumption, social and economic disruption). Moreover, while the exact details of future migration patterns cannot yet be pinpointed with any precision, there *is* general consensus that the coasts and the southern parts of the United States are most at risk of becoming unlivable and hence that the country's more northern and interior areas are likely migration destinations. Finally, even acknowledging that surprises like pandemics will occur, climate change experts in the United States already have a working grasp of key systemic vulnerabilities that will warrant governance attention—water supply, food security, energy reliability, economic perturbations, environmental degradation and transformation, and inequitable distribution of and access to all of the above.

Thus, in conceptualizing a redesign mode of adaptation in the United States, we already understand, at least in broad strokes, what goals law and governance need to facilitate—a significant shift of human populations and their housing and other support

[232] Paul Voosen, *Global Temperatures in 2020 Tied Record Highs*, 371 SCI. 334 (2021), https://www.sciencemag.org/news/2021/01/global-temperatures-2020-tied-record-highs.

[233] Christoff, *supra* note 56, at 1.

[234] We acknowledge that eventual climate stabilization is itself an optimistic assumption on our part. Without that assumption, however, this Article's entire exercise is pointless, because the planet will transform radically, and perhaps unstoppably, as global warming exceeds 4ºC, rendering the concept of nation states potentially unworkable.

systems northward and inward, while simultaneously preserving (or opening up) lands for agriculture, species habitat, and migration corridors. Preservation of a functional democracy at the same time imposes two requirements on how the U.S governs toward this goal. First, governance of these changes must be legitimate, so that citizens accept and comply with the changes and their accompanying social and economic dislocations. Second, governance of these changes must be equitable, ensuring the health, safety, and, ideally, prospering of the United States' most vulnerable communities rather than simply exacerbating existing inequalities.[235]

That leaves two last questions: First, How should the United States finance this massive scale of social and economic transformation?; and, second: Who's in charge? Given the scale, both financial and geographic, of redesign adaptation, we posit that the answer to both questions will lie primarily in the federal government—although, as is always true in adaptation governance, governance at all levels will remain necessary, at least through the first few decades. Adapting to 4ºC is beyond the capacity of any single state or local government. Human migration within the United States, and the accompanying reconfigurations of the nation's economic, political, social, energy, food, and transportation systems will require a national perspective, national coordination, and a national budget.[236] For these and other reasons, the two of us find the governance challenges and solutions that emerged through the complex of the Great Depression, Dust Bowl, and World War II ramp-up highly instructive historical precedents for redesign adaptation, as discussed in more detail below.

Which takes us to our second point about governance for 4ºC. Just as probabilistic scenarios are helpful even though they cannot precisely inform us of the future, so, too, do past governance challenges and experiments in the United States—successful or otherwise—provide helpful tools that can increase the odds of the United States' redesign adaptation succeeding, in all the senses of "success" identified above. In part because of its size, in part because of its federalist structure, and in part because of its general willingness to embrace "progress" and technological innovation despite their unintended consequences, the United States has a governance toolbox that is both wide and deep, developed from an ongoing willingness to experiment with governance institutions and

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[235] Redesign adaptation is nothing if not disruptive, but disruptiveness can be harnessed toward positive ends, leveling the playing field among citizens. As one example, food rationing during World War II—a government-induced disruption of the free market—actually *benefitted* poorer residents of both England and the United States by guaranteeing them access to meat and other foods they previously could not afford. Iselin Theien, *Food Rationing During World War Two: A Special Case of Sustainable Consumption?,* S5 ANTHROPOLOGY OF FOOD ¶ 31 (2009). https://doi.org/10.4000/aof.6383; Wendy Moore, *Oh! What a Lovely Diet*, THE GUARDIAN (Jan. 13, 2001, 19:08 EST), https://www.theguardian.com/theobserver/2001/jan/14/life1.lifemagazine5 ("Dieticians have long argued that wartime rationing provided the healthiest diet the British population has ever eaten, leading to dramatic post-war improvements in the nation's health.").

[236] Notably, President Biden's climate change executive order creates the White House Office of Domestic Climate Policy and National Climate Task Force to serve this leadership and coordination roles and, although the focus is international relations and national security, orders the development of a climate finance plan "to assist developing countries in implementing ambitious emissions reduction measures, protecting critical ecosystems, building resilience against the impacts of climate change, and promoting the flow of capital toward climate-aligned investments and away from high-carbon investments." Biden Climate Change E.O., *supra* note 210, at §§ 102(f), 202, 203.

mechanisms while both preserving and evolving core societal values. One contemporary non-climate change example is how to preserve and effectuate Fourth Amendment privacy in a world of "smart" personal electronic devices that are more than capable of spying on, and ratting out, their owners.[237] Administrative law is a largely 20th-century invention that (mostly successfully) allows a federal administrative state to be shoehorned into a Constitution that never imagined a need for daily regulatory interactions between the federal government and the inhabitants of the United States, and this new subset of law eventually provided those residents with multiple ways to keep tabs on their government.[238] It is neither a distortion nor an insult to view the history of U.S. law and governance as 250 years of making it up as we go.

In short, the United States is not stepping into a 4ºC governance future blind and unarmed. Nor are its governance systems so welded to set traditions and unchanging requirements that adaptation governance in a redesign mode requires fundamental revolution. These are bedrock governance advantages that the United States can capitalize upon.

None of which is to say, however, that transitioning to governance for a 4ºC nation will be easy. The remainder of this part explores what the two of us consider the four most critical starting points. Our public and private governance institutions and polity must recognize: (1) that transformative change will occur in diverse modalities simultaneously, complicating the governance of redesign adaptation; (2) that the various governance tools available require careful deployment toward coordinated goals; (3) that such deployment will require a coherent, anticipatory model for designing policy strategies around the intersections of change modes with governance modes; and (4) that there is a need *now* to actively plan for redesign adaptation and its governance, including identifying and then carrying out the multidisciplinary research still needed to guide the planning effort as it unfurls.

A. Different Modes of Change: A Planning Typology for Redesign

Part II presented a blizzard of predictions about what can be expected in a 4ºC world. At a macro scale—albeit a grossly simplified one—the change forces driving those specific conditions can be sorted into three modes: baseline linear, nonlinear, and cascades. These modes of change reflect not only the direct effects of climate change (hotter days) but also the effects of adaptation to them (building sea walls). We use human

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[237] *E.g.*, Carpenter v. United States, --- U.S. ---, 138 S. Ct. 2206, 2217-18 (2018) (holding that the Fourth Amendment expectation of privacy applies to cell site location information); Riley v. California, 573 U.S. 373 (2014) (holding that police officers needed a warrant to search through defendant's cell phone data); Katz v. United States, 389 U.S. 347, 354 (1967) (holding that the police violated the Fourth Amendment expectation of privacy when they used an electronic listening device to listen to a phone both conversation).

[238] *E.g.*, Administrative Procedure Act, 5 U.S.C. §§ 551-559 701-706.

migration to illustrate the three different change modes. Migration, after all, is a form of adaptation,[239] and environmental change has long been a driver of human migration.[240]

In his perceptive assessment of climate change-driven human migration, geographer Robert McLeman outlines a progression of thresholds:

> Six types of thresholds in response to climate hazards are identified: (1) Adaptation becomes necessary; (2) Adaptation becomes ineffective; (3) Substantive changes in land use/livelihoods become necessary; (4) In situ adaptation fails, migration ensues; (5) Migration rates become non-linear; and (6) Migration rates cease to be non-linear.[241]

Migration in stages 1-3 of his model might look little different from current baseline population movement patterns in the United States, perhaps with origins and destinations shifted. Of particular concern to us is McLeman's stage 4, when in situ adaptation fails, and what migration looks like after that. His description of "nonlinear rates" in stage 5 captures the other two of our change modes—nonlinear and cascades. This section examines each of these three change modes.

1. Baseline Linear Change

Many of the direct effects of climate change, such as sea level rise, warming, and the shifting of species ranges, will transpire in incremental, linear trends over relatively long timeframes. Against this slow-moving background, some measure of human migration will also take place at a baseline historical level. People have always moved around in the United States—baseline migration is nothing new. Nevertheless, over long time frames, baseline population migration and other incremental, linear changes can produce significant macro-level change; for example, the ranking of US cities by population since the 1700s exhibits a massive reshuffling.[242] Long-term effects of baseline linear migration, such as movement from rural to urban areas, thus eventually can present policy challenges from accumulating effects, such as increased competition for employment and housing.[243] In the short term, however, the changes may seem imperceptible and not warranting any particular policy concern. As people and employers begin to factor climate change into their location decisions, it is entirely possible that climate change has already become a factor influencing this kind of domestic U.S.

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[239] For an overview of law and policy of human migration induced by climate change, focusing on international migration, see Michelle Leighton, *Population Displacement, Relocation, and Migration*, in LAW OF ADAPTATION, *supra* note 21, at 693-729.

[240] *E.g.*, Myron P. Gutman & Vincenzo Field, *Katrina in Historical Context: Environment and Migration in the US*, 31 POPULATION & ENVT. 3, 5-6 (2010), DOI: 10.1007/s11111-009-0088-y (looking at demographic changes as a result of hurricanes in the U.S.).

[241] Robert McLeman, *Thresholds in Climate Migration*, 39 POPULATION & ENVT. 319, 319 (2018).

[242] *Historical Metropolitan Populations of the United States: Graph of Metro Area Population Rank Over Time*, PEAKBAGGER.COM (as viewed Jan. 29, 2021), https://www.peakbagger.com/pbgeog/histmetropop.aspx.

[243] Leighton, *supra* note 239, at 693.

baseline migration pattern, but in ways that have not yet surfaced at the macro-scale into policy concerns.[244]

2. Nonlinear Change

Climate change already is having effects that depart from baseline linear change and which over time will shift the entire envelope of variability for phenomena such as storm intensity.[245] Similarly, population migration in the U.S. has never been purely a baseline linear phenomenon; instead, episodes of amplified, purposeful migration occurred throughout the nation's history. The settlement of the American West through the 1800s, for example, was a long process with many complex causes and effects, laying the foundation for later national-scale baseline migration.[246] In the 1900s, the migration of blacks from the South to the North, Midwest, and West shifted over six million people between 1915 and 1970.[247] In contrast to baseline moves for a new job or to retire to a warmer climate, broad social and economic forces induced these building waves of migration, creating uneven effects across the national landscape. These migrations also raised policy issues; as one example, the West adopted prior appropriation for its water law, participated in massive irrigation projects with the new U.S. Bureau of Reclamation and through the many reclamation laws Congress enacted, and continues to move massive amounts of water to service farms and cities.[248]

Sea level rise is expected to produce this kind of nonlinear migration wave, as a large swath of the population—coastal residents and employers—faces a common motivation for moving.[249] The impacts of sea level rise migration also will likely be uneven, with some models suggesting that most relocations will be to nearby inland counties, but also into the interior of the nation.[250] As these pulses of migration build, policy issues are sure to arise as out-migration threatens economic and social prosperity in some areas and influxes of population stress housing supply and infrastructure capacity in other areas.[251]

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[244] *See* McLeman, *supra* note 241, at 326.

[245] Robin Kundis Craig. *"Stationarity Is Dead"—Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 HARV. ENVTL. L. REV. 9, 23-27 (2010); P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCI. 573, 573-74 (2008), DOI: 10.1126/science.1151915.

[246] For a literature survey, see Kim M Gruenwald, *Migration and Settlement from the Atlantic to the Pacific, 1750-1890: A Survey of the Literature*, NAT'L PARK SERVICE RESEARCH (2007), https://www.nps.gov/parkhistory/resedu/settlement.htm.

[247] ISABEL WILKERSON, THE WARMTH OF OTHER SUNS: THE EPIC STORY OF AMERICA'S GREAT MIGRATION 8-16 (2010).

[248] For the classic account of water development and policies in response to settlement of the American West, see generally MARC REISNER, CADILLAC DESERT: THE ANERICAN WEST AND ITS DISAPPEARING WATER (1986).

[249] *See* Hauer, *supra* note 162, at 321-25.

[250] Caleb Robinson, Bistra Dilkina, & Juan Moreno-Cruz, *Modeling Migration Patterns of the USA Under Sea Level Rise*, 15 PLoS ONE e0227436, at 10 (2020), https://doi.org/10.1371/journal.pone.0227436.

[251] Fan et al., *supra* note 164.

3. Cascades Change

As explained in Part II, rising temperatures will cause ecological systems to cross tipping points and experience systemic cascades of rapid change. So, too, with social systems. Such tipping point "sudden onset" events have triggered migration cascades in the past, classic cases being the Dust Bowl migration of the 1930s and the post-Katrina relocation out of the New Orleans area.[252] Both of these migratory cascades occurred over short time frames and had national policy consequences. The Dust Bowl, for example, was triggered when farmers in the Great Plains "pushed beyond the 'unstable equilibrium' of cropland-to-grassland" and led afterwards to "a greatly expanded participation of government in land management and soil conservation."[253] It would be naïve to fail to anticipate similar sudden onset migration cascades on the way to a 4ºC future.

B. The Toolbox: An Implementation Typology for Redesign

Having simplified adaptation into three modes of change, we continue with our gross simplification of anticipatory adaptation in this section by reducing adaptation governance to three top-level modes: laissez faire, planning and prompting, and preemption and mandates. We suggest how specific examples of each mode could guide policy design in the 4ºC adaptation context.

1. Laissez Faire

Faith in the invisible hand of the market is never far from the surface of American politics and policies, and, especially in the early stages, the normal forces of supply and demand may in fact work surprisingly well to push and pull adaptation to a 4ºC United States in the right directions. For example, water-rich areas in cooler climates may start tempting water-dependent industries, like many of those in Silicon Valley, to move, facilitating migration away from water-constrained locations.[254] Such municipal and state business plans might simultaneously encourage voluntary migrants to re-occupy cities that have significantly declined in population, such as Detroit, potentially reducing the eventual infrastructure costs of redesign adaptation. Evidence that water may become a driving force of new markets as well as relocation comes from California, where a water

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[252] McLeman, *supra* note 241, at 325-27; Robert A. McLeman, Juliette Dupre, Lea Berrang Ford, James Ford, Konrad Gajewski, & Gregory Marchildon *What We Learned from the Dust Bowl: Lessons in Science, Policy, and Adaptation*, 35 POPULATION & ENVT. 417, 429 (2014).

[253] McLeman et al., *supra* note 252, at 429.

[254] Steven R. Strahler, *How Chicago's Enviable Water Supply Could Lure Future Business*, CHICAGO BUSINESS, Sept. 26, 2019, https://www.chicagobusiness.com/crains-forum-water/how-chicagos-enviable-water-supply-could-lure-future-business; Rachael Gleason & Laura Fosmire, *How Should the Great Lakes Cities Tap their Water Wealth?*, GREAT LAKES ECHO, Aug. 8, 2011, https://greatlakesecho.org/2011/08/08/how-should-great-lakes-cities-tap-their-water-wealth/.

futures market to reduce local risks of drought began trading in December 2020,[255] and from increasing investor interest in marketing Colorado River water.[256]

Existing markets will also respond to climate change, sending signals that larger change is near. For example, John Nolon assembled several case studies of real estate markets across the United States where "land use climate bubbles" have burst or are at significant risk of bursting—that is, places "where land and building values are declining due to consequences associated with climate change."[257] The climate risks inherent in real estate markets are also an equity issue; for example, it is lower-income families that tend to end up owning properties at significant risk of flooding.[258]

One important player in climate-affected markets is likely to be the private insurance industry. Insurance companies already have considerable expertise at factoring climate change risk into their premiums, and they have already sued governments that have made their losses worse by failing to build climate change resilience into local infrastructure.[259] Perhaps the more important adaptation role for private insurance companies, however, is as market signalers of when in situ adaptation is becoming too expensive to be profitable, as has occurred both in response to increasing wildfire damage in California[260] and hurricane damage along the Gulf. After the disastrous hurricane season of 2004-2005, companies providing homeowners insurance left the Florida market in droves.[261] Insurance companies are similarly poised to stop issuing wildfire insurance in California, discontinuing hundreds of thousands of policies in 2019 and 2020.[262] Clearer pre-collapse warnings that in situ adaptation may be becoming impossible in these locations are difficult to conceive.

Private insurance market signals will be most effective, however, if federal and state governments do not intervene. Evidence to date, however, indicates that politics will produce exactly the opposite result. Private insurance companies long ago gave up on

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[255] Kim Chipman, *California Water Futures Begin Trading Among Fear of Scarcity*, BLOOMBERG GREEN, Dec. 6, 2020, https://www.bloomberg.com/news/articles/2020-12-06/water-futures-to-start-trading-amid-growing-fears-of-scarcity.

[256] Ben Rider Howe, *Wall Street Eyes Billions in the Colorado's Water*, THE NEW YORK TIMES, Jan. 3, 2021, https://www.nytimes.com/2021/01/03/business/colorado-river-water-rights.html?action=click&module=Top%20Stories&pgtype=Homepage.

[257] John R. Nolon, *Land Use and Climate Change Bubbles: Resilience, Retreat, and Due Diligence*, 39 WM. & MARY ENVTL. L. & POL'Y REV. 321, 323-24, 325-27 (2015), https://scholarship.law.wm.edu/wmelpr/vol39/iss2/2.

[258] *Id*.

[259] Ari Phillips, *In Landmark Class Action, Farmers Insurance Sues Local Governments for Ignoring Climate Change*, THINKPROGRESS (May 19, 2014, 4:51 PM), https://thinkprogress.org/in-landmark-class-action-farmers-insurance-sues-local-governments-for-ignoring-climate-change-19c31eef042e#.q33quzenc.

[260] Christopher Flavelle, *California Bars Insurers From Dropping Policies in Wildfire Areas*, THE N.Y. TIMES (Nov. 5, 2020), https://www.nytimes.com/2020/11/05/climate/california-wildfire-insurance.html.

[261] Ed Leefeldt, *Why IS Homeowners In Florida Such a Disaster?*, FORBES ADVISOR (Oct. 21, 2020, 6:21 AM), https://www.forbes.com/advisor/homeowners-insurance/why-is-homeowners-insurance-in-florida-such-a-disaster/.

[262] Khristopher J. Brooks, *California Insurers are Dropping Homeowners Threatened by Wildfires*, CBS NEWS (Oct. 21, 2020, 1:43 PM), https://www.cbsnews.com/news/california-wildfires-home-insurers-dropping-homeowners/.

insuring areas of high flood risk, which is why the federal government stepped in with the National Flood Insurance Program, which is now significantly in debt.[263] Similarly, instead of listening to the market, the State of Florida stepped in to fill the 2005 insurance void, and homeowners' insurance in Florida remains a "disaster" 15 years later.[264] Most recently, the California Legislature instituted a one-year freeze in November 2020, prohibiting insurance companies from discontinuing wildfire policies.[265]

Thus, insurance markets also reveal the public's and politicians' limited appetites for truly *laissez-faire* economics when migration has become a financially rational adaptation response. Acknowledging that political reality, state and federal governments can begin to act now to legally change their responses to bursting real estate climate bubbles and insurance company withdrawals. Given public demands for government action when the market signals become focused enough, governments should direct those emerging social licenses to act toward the ends of equitable redesign adaptation. For example, if governments want to help owners of properties at risk from climate change, they should do so on the understanding that the "insurance" payout is really the government's purchase of the at-risk property (probably at a higher-than-market rate) that enables the former property owner to move somewhere safer rather than to rebuild in place.[266] Such creative approaches to disaster insurance would both facilitate migration as it becomes necessary and ensure that the nation's most vulnerable citizens aren't left holding title to worthless real estate with no means to move.

2. Planning and Prodding

Few policy realms in the United States are left solely or even largely to markets. A soft mode of government intervention involves planning to guide public policy and prodding to guide private actors into stepping in line with those policies. Planning and prodding will play important roles in shaping anticipatory adaptation for a 4ºC nation.

a. Planning

If the discussions in Parts III and IV suggest anything, it is that redesign adaptation for a 4ºC United States will require massive exercises in planning. First, redesign adaptation requires a spatial rearrangement of both people and land uses on a national scale. Decisions regarding where people can live and where various kinds of human uses of space can occur has long been considered both a proper governmental function, from

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[263] Robin Kundis Craig, *Harvey, Irma, and the NFIP: Did the 2017 Hurricane Season Matter to Flood Insurance Reauthorization?*," 40 U. ARK. LITTLE ROCK L. REV. 481, 484-92 (2018).
[264] Leefeldt, *supra* note 261.
[265] Flavelle, *supra* note 260.
[266] Craig, *supra* note 181, at 220-24.

land use planning and zoning on land[267] to marine spatial planning in the ocean.[268] Marine spatial planning provides an improved model for redesign adaptation over land use planning because it also takes into account the needs of the natural environment and ecosystems[269]—needs that should be very much part of redesign adaptation.

Second, redesign adaptation will require infrastructure upgrades, construction, and dismantling, with sequencing considerations and impacts—both environmental and societal—that warrant significant planning. Notably, there is considerable agreement that the United States' basic infrastructure already warrants increased investment. For example, the American Society of Civil Engineers last Report Card on America's Infrastructure, in 2017, gave the nation's infrastructure an overall grade of D+.[270] In 2016, then Candidate Trump promised $1 trillion toward infrastructure development, giving some indication of the needed investment just to deal with current infrastructure issues.[271] President Biden's January 2021 Climate Change Executive Order also includes a substantial commitment to infrastructure development.[272] The bipartisan appeal of infrastructure investment and its bridging of white collar and blue collar, local and national, urban and rural, and economic and security interests make infrastructure a leading candidate both to heal social and political rifts and to kickstart adaptation to a 4ºC United States.

Third, redesign adaptation will require increased and directed research in the "hard," "applied," and social sciences and in engineering to better project climate change impacts across the United States, human responses to those impacts, and ecosystem responses and needs; to identify important tipping points and thresholds; and to both identify and develop tools for the multiple transitions—everything from drought-resistant crops and revised agricultural business strategies (e.g., a transition away from monocropping) to climate-adjusted healthcare training and treatments to various forms of prediction software to colocation strategies for species to psychological support systems to equity-enhancing policies. These research programs warrant planning to avoid ad hoc

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[267] Village of Euclid, Ohio, v. Ambler Realty, Co., 272 U.S. 365, 386-90, 395 (1926) (upholding the validity of local government zoning); *see also generally* Fukuo Akimoto, *The Birth of 'Land Use Planning' in American Urban Planning*, 24 PLANNING PERSPECTIVES 457, 457-83 (2009), https://doi.org/10.1080/02665430903145705 (tracing the development of urban land use planning in the United States into its broad acceptance in the 1950s and 1960s).

[268] CRAIG, *supra* note 205, at 105-06; Charles N. Ehler, *Marine Spatial Planning, in* OFFSHORE ENERGY AND MARINE SPACIAL PLANNING 6–15 (Katherine L. Yates & Corey J.A. Bradshaw eds., 2018).

[269] CRAIG, *supra* note 205, at 106 & sources cited therein.

[270] *2017 Infrastructure Report Card: America's Infrastructure Scores a D+*, AMER. SOC. CIV. ENGRS. (2017), https://www.infrastructurereportcard.org. A "D" grade means that "[t]he infrastructure is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of serious concern with strong risk of failure." *2017 Infrastructure Report Card: What Makes a Grade?*, AMER. SOC. CIV. ENGRS. (2017), https://www.infrastructurereportcard.org/making-the-grade/what-makes-a-grade/.

[271] Jeff Stein, *Trump's 2016 campaign pledges on infrastructure have fallen short, creating opening for Biden*, THE WASH. POST (Oct. 18, 2020, 9:32 AM MDT), https://www.washingtonpost.com/us-policy/2020/10/18/trump-biden-infrastructure-2020/.

[272] BIDEN CLIMATE E.O., *supra* note 210, at §§ 212, 213.

studies, to coordinate research across disciplines, and to improve information dissemination.

Finally, as current infrastructure needs amply demonstrate, redesign adaptation requires significant amounts of money—including money for the planning process itself. Thus, financial planning must also be part of the adaptation toolbox.

b. Prodding

Government can also prod private institutions into planning and action. As noted, left to its own devices, the insurance industry is likely to provide fairly strong signals of when the time has come for humans to abandon certain areas of the country. Governments could then reinforce these market signals with additional inducements. The conversion of government insurance subsidies to buyout programs already discussed is one such strategy, combining the incentive of government support with an eventual mandate to leave.

The closely related government provision of disaster relief is another area of aid that governments could adjust to better serve the 4ºC adaptation enterprise. In terms of politics, governments are unlikely to resist calls for disaster relief when the next hurricane, flood, or wildfire wipes out a community of uninsured residents and businesses. Nor, given our goal of using redesign adaptation as a means of increasing social equity, do the two of us advocate that governments simply ignore these disasters. Rather, disaster relief, like all redesign adaptation, needs to shift its focus away from in situ remedies—food, water, shelter, rebuilding—to redesign goals operating at a higher scale. Thus, disaster relief should increasingly take the form of relocating destroyed communities and should include retraining and education so that victims can thrive in the evolving 4ºC economy. This reformulated relief could simultaneously promote social equity by providing more benefits to migrants who were already disadvantaged. Fortunately, acceptance of differential access to government relief is deeply embedded in U.S. law and society; the trick will be to prevent the attachment of stigma (e.g., "welfare moms") to qualification for and/or acceptance of this relief. In this respect, the coronavirus pandemic may provide a helpful example. Whatever legitimate criticisms might be leveled at Congress's provision of coronavirus relief in 2020, that relief when it arrived *both* included differential access *and* remained relatively untainted by social stigma. Governance for 4ºC redesign adaptation thus might strive to figure climate change as a common enemy that nevertheless hurts some people more than others through no real fault of theirs.

Of course, other climate-relevant government subsidies and payment programs already exist.[273] These programs can change individual and business behavior[274]—

[273] *See, e.g.*, BIDEN CLIMATE E.O., *supra* note 210, at § 209 (seeking to end federal fossil fuel subsidies).

[274] *E.g.*, Richard W. Willson & Donald C. Shoup, *Parking Subsidies and Travel Choices: Assessing the Evidence*, 17 TRANSPORTATION 141, 141, 152-57 (1990), https://doi.org/10.1007/BF02125333 (demonstrating that more employers drive to work solo when emplorers subsidize their parking); John S. Moot, *Subsidies, Climate Change, Electric Markets, and the*

although, admittedly, many operate as perverse incentives.[275] Crop subsidies are one obvious example existing subsidies that government could retool to far better incentivize redesign adaptation. These subsidies already create perverse incentives;[276] the worsening of water pollution as a result of incentivizing crops for ethanol fuels is particularly well studied.[277] In redesign adaptation, agricultural subsidies could serve much more useful—if completely different—goals than they currently do, such as reducing the economic risks to farmers agreeing to farm new lands as agriculture shifts geographically, to experiment with new crops and seed stocks that are better suited to the changing climate, to diversify their crops to reduce the risks of catastrophic failure of monocrops, and to experiment with new forms of integrated pest management (to reduce pesticide use) and crop combinations (to take advantage of functional interactivity). Future Farm Bills might also incentivize farmers to invest in water conservation technologies for irrigated agriculture in the "right" locations while simultaneously engaging in best management practices to improve water quality, or simply fund that technological and management evolution outright.

Tax incentives, similarly, can help incentivize voluntary contributions to redesign adaptation. Conservation easements provide one model of land use incentive with an important tax component—although, as several scholars have pointed out, the model could be improved to allow for gradual evolution and better monitoring.[278] Nevertheless, conservation easements might be rethought to incentivize the creation of migration corridors for other species or the translocation of species that need human assistance to find new habitats. Municipalities have long used tax breaks and other financial incentives to induce businesses to choose to move there,[279] and state and federal governments could conceivably add their own tax inducements to encourage businesses and their ancillary support systems to begin the migration to redesign-desirable new locations. For example, at the beginning of 2020, the state of Vermont implemented a New Worker Incentive Program to encourage young families to move to Vermont and work for Vermont employers, building on a Remote Worker Grant Program that pre-dated the pandemic and

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FERC, 35 ENERGY L.J. 345, 346–47 (2014 (arguing that price suppression caused by subsidies leads to more generator retirements, which in turn leads to more subsidies to "maintain resource adequacy").

[275] Craig, *supra* note 181, at 216-20; Anthony Kammer, *Cornography: Perverse Incentives and the United States Corn Industry*. 8 J. FOOD L. & POL'Y 1, 2-4 (2012).

[276] Kammer, *supra* note 275, at 14-41.

[277] NATIONAL RESEARCH COUNCIL, WATER IMPLICATIONS OF BIOFUELS PRODUCTION IN THE UNITED STATES 27-35, 57-60 Washington D.C.: National Academies Press, 2008); David Pimental, *Ethanol Fuels*, 12 NAT. RES. RSCH. 127 (2003); Renee Cho, *Ethanol's Impact on Our Water Resources*, EARTH INST.: STATE OF THE PLANET (March 21, 2011), https://blogs.ei.columbia.edu/2011/03/21/ethanol's-impacts-on-our-water-resources/.

[278] Adena R. Rissman, Jessica Owley, M. Rebecca Shaw, & Barton (Buzz) Thompson, *Adapting Conservation Easements to Climate Change*, 8 CONSERVATION LETTERS 68, 68, 70-74 (2015), https://doi.org/10.1111/conl.12099; Jessica Owley, *Conservation Easements at the Climate Change Crossroads*, 74 L. & CONTEMPORARY PROBS. 199, 200, 218-23 (2011).

[279] Andrew Hanson & Shawn Rohlin, *Do Location-Based Tax Incentives Attract New Business Establishments?*, 51 J. REGIONAL SCI. 427, 427-28 (2011) (noting the ubiquity of these incentives); Timothy A. Dunn, Note, *Business Tax Incentives*, 40 TEX. J. BUS. L. 235, 237–240 (2004).

encouraged people to live in Vermont while working for an employer elsewhere.[280] The individual efforts of Vermont and other destination states could result in competition for migrants—a competition that could become exceedingly helpful to redesign adaptation with a bit of coordination and considerable funding from the federal government. This incentive structure, too, already exists in federal law, most notably in the multiple environmental law grant programs and Revolving State Loan funds that helped the nation initially invest in sewage treatment infrastructure,[281] improve its municipal drinking water treatment capacity,[282] and clean up open dumps,[283] among other noteworthy goals.[284]

A final incentive that might well be worth reviving is land giveaways, perhaps reconceived in conjunction with insurance buyouts as land swaps. Throughout the United States' history, the federal government has gifted land to various groups of people in pursuit of national goals, such as the (largely failed) goal of providing newly freed slaves with the means to support themselves[285] and the far more successful goal of settling the West through Homestead Acts.[286] The two of us are *not* in any way suggesting that all federal public lands be converted to private ownership.[287] Nevertheless, some of these lands currently serve specific purposes that might become impossible as climate change worsens, even as other public lands are becoming critical havens and corridors for shifting species and ecosystems. Humans are far less fussy about their habitats than many protected species, and evolving ecosystems in National Forests or National Grasslands may lose their current non-human inhabitants and not, for whatever reason, acquire others.

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[280] State of Vermont, *Relocate, Recalibrate, Succeed*, https://thinkvermont.com/relocate-2/ (as viewed Jan. 10, 2021).

[281] Clean Water Act, 33 U.S.C. §§ 1255, 1256, 1263a, 1281-1301, 1329, 1381-1388.

[282] Safe Drinking Water Act, 42 U.S.C. §§ 300j to 300j-3d, 300j-12; *see* Arnall Golden & Gregory, *Georgia Receives First Grant Under Drinking Water Revolving Loan Fund*, 8 NO. 10 GA. ENVTL. L. LETTER 5 (1997).

[283] Resource Conservation & Recovery Act, 42 U.S.C. §§ 6931, 6947-6949.

[284] These include air quality monitoring and improvement grants. Clean Air Act, 42 U.S.C. §§7405, 7616.

[285] Mark A. Graber, *The Second Freedman's Bureau Bill's Constitution*, 94 TEX. L. REV. 1361, 1362 (2016) (analyzing the Second Freedman's Bureau Bill). The promise of "40 acres and a mule" actually came from General William T. Sherman's Special Field Order 15 (Jan. 16, 1865), which set aside 400,000 acres of confiscated Confederate lands for the purpose. Sarah McCammon, *The Story Behind '40 Acres and a Mule'*, NPR CODE SWITCH (Jan. 12, 20156:02 PM ET), https://www.npr.org/sections/codeswitch/2015/01/12/376781165/the-story-behind-40-acres-and-a-mule. However, after President Lincoln's assassination, President Johnson returned most of the land to white Southerners. Mary Wood, *Why Land Redistribution to Former Slaves Unraveled After the Civil War*, UNIV. VA. SCHOOL OF LAW (Oct. 29, 2019), https://www.law.virginia.edu/news/201910/why-land-redistribution-former-slaves-unraveled-after-civil-war. While the newly freed slaves were eligible for land under both the Homestead Act of 1862 and the Southern Homestead Act of 1866, the former operated in practice to favor while settlers, while the latter involved lands of poor quality and provided little support for the would-be new farmers.

[286] Act of May 20, 1862, 12 Stat. 392; Act of March 3, 1891, 26 Stat. 1097; Act of February 8, 1908, 35 Stat. 6; *see* Hannah L. Anderson, *That Settles It: The Debate and Consequences of the Homestead Act of 1862*, 45 THE HISTORY TEACHER 117, 188–120 (2011).

[287] Notably, however, President Biden in January 2021 did seek to enlist the federal public lands in climate change mitigation efforts, both to increase renewable energy production and to reduce fossil fuel extraction. BIDEN CLIMATE E.O., *supra* note 212, at §§ 207, 208.

Suggesting that the federal government might consider gifting *any* of the remaining public lands is virtually certain to raise objections. If outright gifts of public lands remain politically infeasible in the early stages of redesign adaptation, land swaps may be a more palatable approach. For example, we have suggested that governments acquire coastal properties, and these are likely to retain considerable recreational, coastal habitat and fisheries, aquaculture, transportation, and/or national security value even as they lose their capacities to support human settlement. Instead of purchasing these properties for cash, governments might exchange some of their inland property instead, or purchase land in and around cities abandoned for other reasons (e.g., Detroit) if they turn out to be excellent locations for future human settlement. Regardless of the exact incentive structure, however, government-owned land can once again become a tool to effectuate policy, this time incentivizing settlement into safer areas of the country and new agricultural production areas while (through swaps, at least) simultaneously shifting other kinds of public uses to depopulated regions. Even the expanding deserts of the American Southwest may retain public value as the sites of solar or algae energy farms. The larger point is that, as part of redesign adaptation, Americans need to be willing to reconceive the nation's land use patterns, including in terms of public lands.

3. Preemption and Mandates

The United States is no stranger to more forceful modes of public governance intervention, including mandates and top-down preemption from federal and state authorities. Although almost always controversial, it is difficult to imagine how adaptation policy for a 4ºC nation could succeed without ample use of strong forms of public governance intervention. We outline several examples below.

a. Cooperative Federalism

If uncoordinated federal and state action is one potential redesign problem—as it has been for the nation's COVID-19 response—the cooperative federalism embedded in multiple environmental and natural resources statutes provides one tested mechanism for coordinating those governments toward a common goal. Within these statutes, Congress generally uses its constitutional authority (often the Commerce Clause) to force all 50 states into baseline protections of environmental quality and human health, but leaves each state free to enact more stringent protections.[288]

Cooperative federalism for redesign adaptation might require a little heavier hand on Congress's part, essentially requiring that every state participate in redesign adaptation planning and management. For example, with regard to outmigration states, Congress might create (or delegate authority to create) a "climate livability index" that incorporates objective standards for assessing when migration out of certain areas is, progressively, rational, warranted, recommended, or required. The federal government could then phase out key federal support mechanisms and/or phase in federal migration programs (like land swap offers or insurance buyout structures) at each stage, while leaving each state free to

[288] *E.g.*, Clean Water Act, 33 U.S.C. §1370.

create its own interim adaptation plans and programs. At the same time, Congress could create grants, technology transfers, and planning incentives to assist in-migration states in planning and building for anticipated arrivals of migrants, while still leaving each state considerable freedom to plan its own settlement patterns.

b. Public Works Programs

If the federal government is going to end up paying for a lot of the redesign adaptation infrastructure anyway, it might consider doing so through a public works program that both creates paying jobs and provides "future-proof" training to employees. The most obvious model for this massive federal public works program is President Franklin Delano Roosevelt's "alphabet soup" of programs during the Great Depression,[289] albeit with significantly more focused final aims. Notably, President Biden has already incorporated a Civilian Climate Corps and other employment measures in his Climate Change Executive Order.[290]

In an ideal world, the economic dislocation from COVID-19 would provide the excuse to start this process more or less immediately, in concert with President Biden's Executive Order. In particular, the climate change redesign alphabet soup could start with a focus on infrastructure. First steps would be to thoroughly assess existing infrastructure vulnerabilities to climate change, and then to start upgrading infrastructure capacity in the areas likely to support concentrated human settlement in the future. W ith a bit more planning, the federal government could create programs to start building the infrastructure necessary to decarbonize the energy system, especially in the areas most likely to support future concentrations of human population. In addition, the federal government could build on its existing authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[291] and other federal pollution statutes to anticipatorily clean up toxic hotspots, particularly along the coasts, in places where people are likely to live in the future, in areas where future agriculture is most likely to flourish, and along likely species and ecosystem migration routes. Reducing the nation's toxic burden and exposure is a good idea under any circumstances and could well help to avoid future adaptation delays (e.g., agriculture can't shift locations until the ground is clean enough to grow food) and future environmental justice issues. New programs within the Department of Agriculture could encourage farmers and universities to start diversifying agricultural production and experimenting at commercial scale with climate-resilient crops, while Congress should simultaneously continue and probably intensify its current interest in promoting deepwater marine aquaculture, albeit in more explicitly climate-ready and environmentally friendly directions.

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289 For an overview of these programs, see *The New Deal: FDR's Alphabet Soup*, USHISTORY.ORG (as viewed Jan31, 2021), https://www.ushistory.org/us/49e.asp.

290 BIDEN CLIMATE E.O., *supra* note 210, at §§ 214-219.

291 42 U.S.C. §§ 9601-9675.

c. Social Support Networks

The migration scenario we envision will be disruptive. To avoid worsening rather than improving existing inequities, governments will probably need to expand social support networks, especially during nonlinear and cascade migration events. Fully portable health coverage will be beneficial. Food rationing, like during World War II, may be necessary to ensure distributional equity and at least minimal food security. Personal migration financing may both become a new financial planning specially, akin to retirement planning, and require substantial governmental underwriting, such as through substantially subsidized loans, individual assistance programs, and/or subsidized mass public transportation to new communities. As noted, retraining support and adult education will be helpful supports to transition displaced workers to new employment opportunities.

d. National Economic Policy

The federal government played a key leadership role in preparing the nation for World War II in terms of both preparedness and actual conversion of the country's industry to a wartime economy.[292] "Preparedness" described "the national project to ready for war by enlarging the military, strengthening certain allies such as Great Britain, and *above all converting America's industrial base to produce armaments and other war materiel rather than civilian goods*."[293] As two examples, merchant shipbuilding mobilized to build the wartime fleet, and—albeit with more resistance—automobile companies converted to aircraft manufacturing.[294] The economic conversion was matched, moreover, by a new wartime administrative bureaucracy.[295] A number of financial innovations, including taxes and war bonds, also contributed to the effort.[296]

Redesign adaptation will require a similar scale of economic and societal conversion, both of the World War II type and geographical. There are certainly constitutional issues that would arise if the government starts ordering people to move, just as there were constitutional challenges to the government's actions in World War II.[297] However, there are also synergistic benefits for all involved in coordinating mass relocations of industries that we want to preserve, such as relocating Silicon Valley to Detroit. As in World War II, this scale of redesign is best coordinated from the national government.

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[292] Christopher J. Tassava, *The American Economy During World War II*, EH.NET ENCYCLOPEDIA, (Feb. 10, 2008), http://eh.net/encyclopedia/the-american-economy-during-world-war-ii/

[293] *Id*. (emphasis added).

[294] *Id*.

[295] *Id*.

[296] *Id*.

[297] These challenges took numerous forms, producing a range of Supreme Court decisions. Some of the decisions were regrettable and have since been overturned. Korematsu v. United States, 323 U.S. 214, 217-19 (1944) (upholding the constitutionality of Japanese internment), *abrogated by* Trump v. Hawaii, --- U.S. --, 138 S. Ct. 2392, 2423 (2018). Others remain unremarkable. Lichter v. United States, 334 U.S. 742, 783-84 (1948) (upholding the Renegotiating Act, which allowed the U.S. government to recover excess profits from war contracts, against a nondelegation doctrine challenge).

C. Anticipatory Governance: Building Future Scenarios for Policy Strategy Design

Perhaps the greatest governance challenge of redesign adaptation is that there will be no single mode of change—baseline, nonlinear, and cascade changes will be occurring simultaneously. Nor will a single mode of governance—laissez faire, planning and prodding, or preemption and mandates—be able to effectively engage that multi-modal change dynamic across all the relevant variables. Anticipatory adaptation policy design, therefore, must anticipate both multi-modal change and multi-modal governance. The question is which governance strategy to aim at which mode of change. For that purpose, our vastly simplified models of three modes of change and three modes of governance produce a three-by-three matrix of intersection possibilities, as shown in Table 1. Obviously, the 4ºC governance world will engage more than nine policy strategies, but the exercise of conceptualizing even a simplified matrix of change-governance mode intersections demonstrates the core process of anticipatory governance.

Anticipatory governance refers broadly to policies for "governing in the present to adapt to or shape uncertain futures."[298] It is a relatively new concept, practiced primarily in planning disciplines and in futures studies, such as science and technology and sociology of the future.[299] Anticipatory governance depends heavily on constructing multiple plausible scenarios of the future, embraces rather than denies high levels of uncertainty, and seeks adaptive policy implementation tools to respond to changing conditions and knowledge over time.[300] Although some legal scholars have incorporated anticipatory governance into law and policy for emerging technologies,[301] only a few have connected it to climate change adaptation policy.[302]

We do not here attempt to plumb the depths of adaptive governance theory for each of the nine policy strategy design intersections in Table 1, which the two of us do not have the collective expertise to even attempt. Instead, we present this broad overview to make our central point, developed in the next section, that beginning a data-driven multi-disciplinary research and planning initiative is the critical first step. A model like ours, or something like it, can help focus such an initiative by establishing rudimentary scenarios upon which to guide research and build more detail and refinement towards policy design.

For example, although laissez faire, market-based responses may be capable of managing baseline changes such as gradual incorporation of new building materials for greater insulation, cascade change events such as collapse of regional water supply will

[298] Muiderman et al., *supra* note 18, at 1.

[299] *Id*. at 5-6.

[300] *Id*. at 3-10.

[301] Millie M. Georgiadis & Margaret Ryznar, *Regulating What Has Yet To Be Created: An Introduction*, 98 TEX. L. REV. ONLINE 71 (2019); Albert C. Lin, *Revamping Our Approach To Emerging Technologies*, 76 BROOK. L. REV. 1309 (2011).

[302] Indeed, we could identify only one law journal article mentioning anticipatory governance for climate change adaptation in any substantive manner, doing so in a larger and very comprehensive survey of anticipatory governance in various urban policy settings. *See* Edward W. De Barbieri, *Urban Anticipatory Governance*, 46 FLA. ST. U. L. REV. 75, 102-06 (2018).

likely overwhelm that governance mode. Conversely, while the strong-arm of federal preemption may be required to manage the effects of such a cascade event, ensuring the orderly movement of people and infrastructure to avoid replicating another Dust Bowl, it may be overkill to use it to manage baseline changes.

That, however, is a very high-level overview of a very simple model of the coming national governance challenges. Undoubtedly, more sophisticated and subtle blends of policy instruments are possible allowing for more effective and fine-tuned governance responses to a spectrum of change mode mixes occurring at different places and among different subcultures of the U.S. population. As one example, looking just at human migration, the Gulf Coast (sea level rise and storms), Arizona (heat waves), and Great Lakes states (in-migration) could be dominated by cascade change while the rest of the West is dominated by drought-driven nonlinear change while transitional zones plod along at what still looks mostly like baseline change. That is only one of hundreds of possible national scenarios that anticipatory governance could consider. Far more information and deliberation will be needed before governments at any level can confidently craft governance instruments that assemble the best tools to respond to the particular mix of change modalities they are most likely to face—*as well as the governance mechanisms to evolve those assemblages as the mix of change modes evolves*. We thus offer the contents of the boxes in Table 1 as illustrations of the kinds of high-level change-governance modal assessments that will need to occur—assessments that will require far more detail and refinement before they can be translated into concrete law and policy for anticipatory adaptation governance.

Table 1. Change Mode and Governance Mode Intersections.

	Laissez Faire	**Planning and Prodding**	**Preemption and Mandates**
Baseline linear	Potentially effective in most circumstances but would still benefit from coordination and/or agreed adaptation goals so that ad hoc policies still work toward common ends.	Serves an educational function and allows for the building of legitimacy and public consensus; allows equity measures to be put in place early to incentivize the most vulnerable to improve their positions; allows early adopters to prove the advantages.	Probably overkill until the trickle of changes build up over the longer term, such as the eventual abandonment of southern and coastal cities.
Nonlinear	Inadequate, because ad hoc and market policies are likely to produce uncoordinated and even contradictory local, state, or regional responses.	Necessary to coordinate adaptation responses, promote equity, and minimize conflicts; preserves some voluntariness in individual response; provides mass incentives to induce individuals and sectors to follow preferred adaptation pathways.	Increasingly necessary in regions where nonlinear change occurs on a large scale; precautionary measures provide warning of future adaptation requirements and increase motivation to engage early with the "prods"
Cascades	Potentially disastrous, because changes are occurring too rapidly, too transformatively, and on too large a scale for adaptation to occur equitably without significant government intervention and oversight.	Incentives aligned with the overall adaptation redesign can still help to motivate and incentivize certain groups of individuals and entities to engage in redesign adaptation semi-voluntarily.	Necessary, because at this point transformative change is happening so fast and on such a large scale that far more centralized control is necessary to achieve redesign adaptation equitably and relatively peacefully.

Two important points can be derived from this simplified exercise. First, state and local governments deploying the Three Rs of adaptation policy—resist, resilience, and retreat—are unlikely to achieve sufficiently coordinated or strategic policies to manage even these nine change-governance modal intersections, especially nonlinear and cascade change forces needing large-scale prescriptive governance responses. Redesign policies will be needed, and anticipatory redesign governance needs to occur within a national policy framework.[303] Second, adaptation planning at all government scales must explicitly build nonlinear and cascade change into adaptation plans. Behaving as if in situ climate proofing is plausible for every locality, and that out-migration and in-migration and what follows from them will not eventually take place at large scales, is not only unrealistic but also irresponsible. The next section presents our proposal for how to begin.

D. An Initial Step: Creating a National Foresight System for 4ºC Adaptation Planning

Even if it were certain that average global warming will reach 4°C by the end of this century, high degrees of uncertainty remain regarding what that means for the United States. Part II outlined broad biophysical patterns of change, many of which are expected to lead to (or require) movement of domestic population and infrastructure. But how much movement, when, and to where? What are the impacts on regions experiencing out-migration and in-migration? In short, what future do we anticipate in the planning?

To address questions like these, anticipatory governance begins with a future scenarios analysis designed to inform flexibility in planning and governance to allow adjustment to multiple possible realities.[304] Anticipatory governance accepts that some aspects of the future are not knowable and builds that reality into planning.[305] It is "a mode of decision-making that perpetually scans the horizon" in order to develop a data-driven "foresight system," integrate that foresight into policy-making, and use feedback to assess and adjust policy implementation.[306] That is where adaptation governance for a 4ºC nation must begin, and governance institutions must get used to testing, learning, and adjusting as the warming unfolds.

As discussed in Part III, climate change adaptation planning has not yet anticipated the need for redesign when in situ adaptation becomes untenable, but the forces of change requiring redesign will transpire at all scales of planning, from local to international. To support planning and governance design at all of these scales, we propose that the federal government construct a robust national foresight system as the first step in anticipatory governance for redesign adaptation.

To be effective, such a national foresight system must fully embrace a future 4°C world. It must be broadly multidisciplinary, uniting climate scientists predicting climate impacts with anthropologists predicting human responses with technologists developing the predictive analytics they and the other represented disciplines will use. To give it gravitas and credence, particularly given it would be delivering mostly unpleasant news, it would likely need to be formed as a new science-based research bureau or service

[303] Some US cities have used techniques of anticipatory governance in connection with climate change adaptation infrastructure planning, but, as with all local climate adaptation plans to date, the focus has been on using the Three Rs for in situ adaptation. *See* Quay, *supra* note 19, at 499-505 (presenting case studies of Denver, New York, and Phoenix).

[304] Silva Serrao-Neuman, Ben P. Harman, & Darryl Low Choy, *The Role of Anticipatory Governance in Local Climate Adaptation: Observations from Australia*, 28 J. PLANNING PRACTICE & RESEARCH 440, 440 (2013), https://doi.org/10.1080/02697459.2013.795788.

[305] Quay, *supra* note 18, at 498.

[306] Stefano Maffei, Francesco Leoni & Beatrice Villari, *Data-driven Anticipatory Governance. Emerging Scenarios in Data for Policy Studies*, 3 POLICY DESIGN & PRACTICE 123, 125 (2020), https://doi.org/10.1080/25741292.2020.1763896.

within the federal government, akin to the U.S. Geological Survey, rather than as a task force. The work product cannot be a report, destined to collect headlines followed by dust, but rather continuous development and dissemination of foresight for redesign adaptation.

This foresight system initiative would address a broad array of questions relevant to the next step in anticipatory governance—namely, integrating the foresight into policymaking. Representative examples include:

- Which regions are most likely to experience extreme conditions of heat, saltwater intrusion, storm, drought, flood, and other climate impacts, and which the least?
- What are plausible social-technological-ecological system cascade failure scenarios for areas experiencing the most extreme effects?
  - What do population demographics and other socioeconomic conditions suggest in terms of demand for out-migration opportunities?
  - Where can migrants go? Of areas experiencing the least effects, which are most amendable to in-migration, agricultural development, migration corridors and new habitat, energy production, and other needed land uses?
  - What infrastructure will be required for human and agricultural relocations?
- How do the various scenarios hold up under financial and other social system stress testing?
- What technological developments can influence flows of migration and infrastructure relocation?
- What are potential uses of abandoned areas?
- What are potential uses of federal public lands to accommodate redesign, including the possibility of using them as new population centers?
- What are projected species migrations and how?

This list is far from exhaustive. Indeed, the objective of the initiative would be to construct and continuously refine as close to "whole world" future scenarios as possible.

Although in the previous section we suggested broad governance implications for different change modes, we go no further in this Article than to urge creation of this national foresight system. Based on what experts believe they know now, summarized in Part II, a significantly warming United States will experience multiple disruptions at a variety of scales. Our nation can choose to go into that future blind and unprepared, or can go into it with foresight and adaptive planning, having made many of the difficult governance decisions in advance. Given the high probability that our future is a 4°C world, the two of use choose foresight and adaptive planning.

CONCLUSION

We fully expect critics will cast us as prophets of exaggerated doom and gloom. However, we are simply the bearers of the bad news science is producing, translating it into a governance scenario that seems more than plausible once one considers how different, and how horrible, a 4°C world looks compared to the one we live in today.

Other critics might fully accept our depiction of the 4°C future and the governance challenges it poses, but scoff at the idea that our nation could actually put together a plan and then follow it when conditions begin to unravel. They could point to our nation's handling of the coronavirus pandemic as Exhibit 1. But that misses the point. We are not proposing a plan "for later," when the world moves past 2°C of warming, but rather a starting action to put anticipatory redesign adaptation measures into place. The time to start building national adaptation foresight is *now*.

We now come full circle to what motivated this project—our concern that climate change will lead to a tipping point in our nation's governance. Recent experience justifies our concern.

Americans overestimate the resilience of our democracy to our peril. Notably, martial law—essentially, the conversion of a democratic regime to an authoritarian one—was raised as a possibility during the coronavirus pandemic[307] and could certainly become a governance strategy to cope with a 4°C world. The storming of the U.S. Capitol on January 6, 2021, as Congress tallied Electoral College votes, provides stark evidence that social and governance tipping points ("flash points") exist even in the United States, allowing the previously unthinkable to become reality in a matter of hours.[308] Magnifying this discomforting truth, a 4°C world has the potential to push the United States (and much of the world) all the way back to tribalism as the basic mode of governance,[309] hints

[307] *E.g.*, Sarah Sicard, *Will Coronavirus Lead to Martial Law?*, MILITARY TIMES (Mar. 17, 2020), https://www.militarytimes.com/news/your-military/2020/03/17/will-coronavirus-lead-to-martial-law/; Staff, *False claim: U.S. Coronavirus Response 'Slowly Introducing' Martial Law*, REUTERS (April 14, 2020, 9:17 AM), https://www.reuters.com/article/uk-factcheck-coronavirus-introducing-mar/false-claim-u-s-coronavirus-response-slowly-introducing-martial-law-idUSKCN21W250; Joseph Nunn, *Can the President Declare Martial Law in Response to Coronavirus?*, BRENNAN CENTER FOR JUSTICE (April 16, 2020), https://www.brennancenter.org/our-work/analysis-opinion/can-president-declare-martial-law-response-coronavirus.

[308] Indeed, in media portrayals, the siege on the Capitol evidenced at least two kinds of tipping points. The first was the conversion of a peaceful protest into a violent riot. *E.g.*, Tom Costello, *55 Charges So Far from Capitol Riot, One Suspect had 11 Molotov Cocktails*, NBC NEWS (Jan. 7, 2021, 3:02 PM MST), https://www.nbcnews.com/politics/congress/live-blog/2021-01-06-congress-electoral-vote-count-n1253179/ncrd1253367#blogHeader. The second was the effect the siege had on many Trump supporters, especially Republican lawmakers who had intended to protest the election results in several states. *E.g.*, Amy Kolbuchar, *Siege of Capitol a 'Tipping Point' for Those Who Have Stood by Trump*, CBS NEWS (April 7, 2021, 10:48 AM), https://www.cbsnews.com/news/amy-klobuchar-reacts-to-siege-of-capitol-by-trump-supporters/.

[309] For example, concern is growing that "in the era of social media and partisan news outlets, America's differences have become dangerously tribal, fueled by a culture of outrage and taking offense." Stephen Hawkins, Daniel Yudkin, Míriam Juan-Torres, & Tim Dixon, *Hidden Tribes: A Study of America's Polarized Landscape* 4 (More in Common 2018), *available at* https://hiddentribes.us/pdf/hidden_tribes_report.pdf. *See also* Yale Program on Climate Change Communication, *Global Warming's Six Americas* (as viewed July 6, 2020), https://climatecommunication.yale.edu/about/projects/global-warmings-six-americas/; Amy Chua & Jed Rubenfeld, *The Threat of Tribalism*, THE ATLANTIC (Oct. 2018), https://www.theatlantic.com/magazine/archive/2018/10/the-threat-of-tribalism/568342/; COLIN WOODWARD, AMERICAN NATIONS: A HISTORY OF THE ELEVEN RIVAL REGIONAL CULTURES OF NORTH AMERICA (2012).

of which also surfaced during the pandemic.[310]

Scholars and politicians alike could debate endlessly the amount and variety of cultural, social, political, and economic fracture lines in the United States (and other nations)[311] and the relative importance of each to climate change adaptation. The more important point here, as the coronavirus pandemic deftly demonstrated,[312] is that different regions of the United States "instinctively" react to new crises differently. Climate change will likely complicate these already divisive instincts further by posing different adaptation challenges in different regions, some of which are more familiar to those populations (e.g., drought in the Southwest) than are others (e.g., mass migration, collapse of basic infrastructure like drinking water and sewage systems, water-borne disease).

Even well-functioning democratic governance systems will need to adapt in order to manage a 4°C world effectively, and the United States' current default to an extreme version of individualistic democracy will not serve us well. Our democracy focuses on preserving individual choice, ensuring broad participation in governance at all levels for all decisions, and protection of private property, often at the expense of public values.[313] The cost of such individualism can be and often has been a lack of comprehensive and coordinated economic and social planning at almost any scale, from communities to the nation as a whole.[314] Indeed, responses to the coronavirus epidemic in the United States

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[310] Although, allegiances to tribes may have helped us survive up until this point in human history, it may be having the exact opposite effect today. As one commentator observed, "there seems to be a difference in the way we are responding to the COVID-19 pandemic depending on the tribe (friends, church groups, news feeds and TV networks) we have aligned ourselves with." Thomas Pagano, *Tribalism in a Time of COVID-19*, CITIZEN TIMES (April 16, 2020), https://www.citizen-times.com/story/opinion/2020/04/16/coronavirus-nc-tribalism-time-covid-19-opinion/5135096002/. *See also* Yuval Levine, *Tribalism Comes for Pandemic Science*, THE NEW ATLANTIS (June 5, 2020), https://www.thenewatlantis.com/publications/tribalism-comes-for-pandemic-science; Sarah Lahn, *Midwest Dispatch: Republican Tribalism Won't Protect Us from the Pandemic*, THE PROGRESSIVE (Nov. 17, 2020), https://progressive.org/dispatches/republican-tribalism-wont-protect-pandemic-lahm-201117/.

[311] For a sweeping discussion of the perilous state of democracy in the United States, see SANFORD LEVINSON & JACK M. BALKIN, DEMOCRACY AND DYSFUNCTION (Univ. Chicago Press 2019).

[312] *E.g.*, Tucker Doherty, Victoria Guida, Bianca Quilantan, & Gabrielle Wanneh, *Which States had the Best Pandemic Response?*, POLITICO (as updated Oct. 15, 2020, 04:05 PM EDT), https://www.politico.com/news/2020/10/14/best-state-responses-to-pandemic-429376.

[313] Constitutional takings and standing limitations on environmental protection provide two obvious examples at the federal level. For discussion of takings limitations, see generally, e.g., Beckett G. Cantley, *Environmental Preservation and the Fifth Amendment: The Use and Limits of Conservation Easements by Regulatory Taking and Eminent Domain*, 20 HASTINGS W-N.W. J. ENVTL. L. & POL'Y 215 (Winter 2014); ROBERT MELTZ, DWIGHT H. MARRIEN, & RICHARD M. FRANK, THE TAKINGS ISSUE: CONSTITUTIONAL LIMITS ON LAND USE CONTROL AND ENVIRONMENTAL REGULATION (Washington, D.C.: Island Press 1999). For discussions of standing limitations, see generally, e.g., Jeffrey T. Hammons, Note, *Public Interest Standing and Judicial Review of Environmental Matters: A Comparative Approach*, 41 COLUM. J. ENVTL. L. 515 (2016); Robin Kundis Craig, *Removing "the Cloak of a Standing Inquiry": Pollution Regulation, Public Health, and Private Risk in the Injury-in-Fact Analysis*, 29 CARDOZO L. REV. 149 (Oct. 2007); Jeffrey W. Ring & Andrew F. Behrend, *Using Plaintiff Motivation to Limit Standing: An Inappropriate Attempt to Short-Circuit Environmental Citizen Suits*, 8 J. ENVTL. L. & LITIG. 345 (Spring 1994).

[314] Notably, a nation's commitment to individualism appears to be related to its susceptibility to disease outbreaks. *See* Serge Morand & Bruno A. Walther, *Individualistic values are related to an increase*

exposed many of the weaknesses of this governance orientation at a moment when a strong national response to the crisis was required.[315] Multiple governments and levels of government issued uncoordinated and occasionally contradictory responses,[316] leading to costly "loss from anarchy."[317] Individuals felt free to mistrust, deny, and distort the science and to ignore "shelter in place" orders and health-preserving best practices like wearing a face mask, leading to notable resurgences in infection rates in many states after the Memorial Day, July 4, Labor Day, Thanksgiving, Christmas, and New Year holidays.[318] Nationwide, there was a general disregard for public welfare, ranging from an inability or unwillingness to institute comprehensive COVID testing programs[319] to limited and only short-term social support measures that increased the pressures to go back to work.[320]

Nothing in this experience, fueled by an increasingly politically sectarian nation,[321] bodes well for envisioning how an individualistic democracy would manage life at 4°C. To be sure, it will take a long time to reach 4°C, but the tipping points along the way will lead to cascades of change in social-ecological systems that will rival the pandemic in their flash point disruption effects. If we had developed a robust national foresight system for pandemics and followed through with planning and implementation, the experience might have been much different. Knowing that, we can do better to prepare the nation for the path to 4°C. The first step is gaining foresight.

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in the outbreaks of infectious diseases and zoonotic diseases, 8 SCIENTIFIC REPORTS 3866 (2018), https://doi.org/10.1038/s41598-018-22014-4.

[315] *See* George Packer, *We Are Living in a Failed State*, THE ATLANTIC (June 2020), https://www.theatlantic.com/magazine/archive/2020/06/underlying-conditions/610261/ ("With no national plan—no coherent instructions at all—families, schools, and offices were left to decide on their own whether to shut down and take shelter."); *see also* Rebecca L. Haffajee, *Thinking Globally, Acting Locally—The U.S. Response to Covid-19*, 2020 N. ENG. J. MED. 382:e75 (May 28, 2020), DOI: 10.1056/NEJMp2006740.

[316] James Brown, *America's Coronavirus Response 'Completely Uncoordinated'*, UNITED STATES STUDY CENTRE (April 2, 2020), https://www.ussc.edu.au/analysis/americas-coronavirus-response-completely-uncoordinated.

[317] David Holtz et al., *Interdependence and the Cost of Uncoordinated Responses to COVID-19* (MIT Working Paper May 22, 2020), *available at* http://ide.mit.edu/sites/default/files/publications/Interdependence_COVID_522.pdf. ("These results suggest a substantial cost of uncoordinated government responses to COVID-19 when people, ideas, and media move across borders.")

[318] *E.g.*, Dakin Andone, *Health Officials Brace for a Surge in US Covid-19 Cases after the Holidays*, CNN (as updated Dec. 26, 2020, 8:32 PM ET), https://www.cnn.com/2020/12/26/health/us-coronavirus-saturday/index.html.

[319] *Id*. (describing missteps the CDC took in developing a testing protocol and equipment).

[320] Andrew Stettner, Ellie Kaverman, Amanda Novello, & Moshe Marvit, *Fighting for the Right to a Safe Return to Work during the COVID-19 Pandemic*, FOUNDATION (July 29, 2020), https://tcf.org/content/report/fighting-right-safe-return-work-covid-19-pandemic/ (describing decisions by some states to reopen economic activity).

[321] Eli J. Finkel et al., *Political Sectarianism in America*, 370 SCI. 533, 533-34 (2020), DOI: 10.1126/science.abe1715 (noting that American sectarianism is increasing at the fastest rate among nine western democracies).