Article

4°C

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INTRODUCTION

In March 2020, while the world's attention was focused on the coronavirus pandemic, an international team of eighty-nine polar scientists from fifty 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

1. *See Greenland, Antarctica Melting Six Times Faster Than in the 1990s*, NASA GLOB. CLIMATE CHANGE (Mar. 16, 2020), https://climate.nasa.gov/news/2958/greenland-antarctica-melting-six-times-faster-than-in-the-1990s [https://perma.cc/2D2A-CHPG]. In April 2021, scientists reported that an unmanned submarine had similarly revealed that Thwaites Glacier in Antarctica—known as the "Doomsday Glacier" because its disintegration could initiate the loss of the entire West Antarctic ice sheet—has "warm water impinging from all sides on pinning points critical to ice-shelf stability, a scenario that may lead to unpinning and retreat." A. K. Wåhlin, A. G. C. Graham, K. A. Hogan, B. Y. Queste, L. Boehme, R. D Larter, E. C. Pettit, J. Wellner & K. J. Heywood, *Pathways and Modification of Warm Water Flowing Beneath Thwaites Ice Shelf, West Antarctica*, 7 SCI. ADVANCES, Apr. 9, 2021, at 1.

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, glaciers, tropical coral reefs, the Amazon rain forest, and the Arctic boreal forest.[7] To

2. *Greenland, Antarctica Melting Six Times Faster Than in the 1990s*, *supra* note 1.

3. Jeff Berardelli, *Arctic Records Its Hottest Temperature Ever*, CBS NEWS (June 23, 2020), https://www.cbsnews.com/news/arctic-hottest-temperature-ever [https://perma.cc/F6C3-3MKL].

4. *Id.*

5. *See Scotland, Norway and Sweden Already Severely Effected by Forest Fires Due to the Dry Weather in the North*, CTIF: INT'L ASS'N OF FIRE & RESCUE SERVS. (Apr. 24, 2019), https://www.ctif.org/news/scotland-norway-and-sweden-already-severely-effected-forest-fires-due-dry-weather-north [https://perma.cc/F6C3-3MKL].

6. *See* Marten Scheffer, Jordi Bascompte, William A. Brock, Victor Brovkin, Stephen R. Carpenter, Vasilis Dakos, Hermann Held, Egbert H. van Nes, Max Rietkerk & George Sugihara, *Early-Warning Signals for Critical Transitions*, 461 NATURE 53, 53 (2009).

7. *See* 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). 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 COMMC'NS EARTH & ENV'T 1, 1 (2020) (corrected Sept. 4, 2020). Glaciers distinct from Greenland and the Antarctic ice sheet also are experiencing accelerating mass loss. Romain Hugonnet, Robert McNabb,

add an additional chaotic possibility, once these and other systems tip, they might set off cascades of transformations in other natural systems.[8] 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.[9]

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, 414 ppm in 2020,[10] and 419 ppm in 2021.[11] 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.[12] In addition, knowledge and technologies also

Etienne Berthier, Brian Menounos, Christopher Nuth, Luc Girod, Daniel Farinotti, Matthias Huss, Ines Dussaillant, Fanny Brun & Andreas Kääb, *Accelerated Global Glacier Mass Loss in the Early Twenty-First Century*, 592 NATURE 726, 726 (2021).

8. *See* 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 Winkelmann & Hans Joachim Schellnhuber, *Trajectories of the Earth System in the Anthropocene*, 115 PROC. NAT. ACAD. SCI. 8252, 8253–54 (2018).

9. *See* Eystein Jansen, Jens Hesselbjerg Christensen, Trond Dokken, Kerim H. Nisancioglu, Bo M. Vinther, Emilie Capron, Chuncheng Guo, Mari F. Jensen, Peter L. Langen, Rasmus A. Pedersen, Shuting Yang, Mats Bentsen, Helle A. Kjær, Henrik Sadatzki, Evangeline Sessford & Martin Stendel, *Past Perspectives on the Present Era of Abrupt Arctic Climate Change*, 10 NATURE CLIMATE CHANGE 714, 716–18 (2020) (discussing how the Arctic is currently experiencing an abrupt climate change event that climate models underestimated); Aslak Grinsted & Jens Hesselbjerg Christensen, *The Transient Sensitivity of Sea Level Rise*, 17 OCEAN SCI. 181, 181 (2021) (finding that future projections estimated on climate model responses fall below extrapolation based on recent observational records).

10. *Monthly Average Mauna Loa CO_2*, NOAA GLOB. MONITORING LAB'Y, https://www.esrl.noaa.gov/gmd/ccgg/trends (Aug. 5, 2021) [https://perma.cc/2HZ4-SA7M].

11. *Carbon Dioxide Peaks Near 420 Parts Per Million at Mauna Loa Observatory*, NOAA RSCH. NEWS (June 7, 2021), https://research.noaa.gov/article/ArtMID/587/ArticleID/2764/Coronavirus-response-barely-slows-rising-carbon-dioxide [https://perma.cc/GE2J-WWGA].

12. 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 [https://perma.cc/2G3K-LT7Z]; M. Willeit, A. Ganopolski, R. Calov & V. Brovkin, *Mid-Pleistocene Transition in Glacial Cycles Explained by Declining CO_2 and Regolith Removal*, SCI. ADVANCES, Apr. 3, 2019, at 1; *see also Climate Change 2021: The Physical Science Basis*,

are improving as researchers observe climate change, in many cases revealing that projections were underestimating the pace of change.[13] 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.[14]

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.[15] 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. We lean heavily on scientific findings reported in leading peer-reviewed journals,[16] 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 century, and the severity of climate

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INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 9 (2021) https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf [https://perma.cc/AJJ2-MLAK] [hereinafter *2021 IPCC Physical Science Report*] ("[I]n 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years (*high confidence*), and concentrations of CH_4 and N_2O were higher than at any time in at least 800,000 years (*very high confidence*).").

13. *See generally* Michael Oppenheimer & Richard B. Alley, *How High Will the Seas Rise?*, 354 SCIENCE 1375, 1375–76 (2016) (noting that projections of sea level rise keep getting higher based on improved knowledge of dynamical processes).

14. *See generally The Ocean and Cryosphere in a Changing Climate: A Special Report of the Intergovernmental Panel on Climate Change*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 85 (2019), https://www.ipcc.ch/site/assets/uploads/sites/3/2019/12/SROCC_FullReport_FINAL.pdf [https://perma.cc/C6XJ-KNAJ] [hereinafter *2019 IPCC Ocean & Ice Report*] ("[E]ach of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.").

15. *Id.*

16. Although neither of us is a climate scientist, one of us holds a doctoral degree in human geography, and the other is a trained science writer with a doctoral 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.

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[17]—and adaptation—which encompasses efforts to adjust human behavior to climate change's unavoidable alterations[18]—must be *concurrent* governance efforts.[19] Moreover, those efforts must be cognizant of each other, because mitigation and adaptation strategies interact, sometimes working in tandem to produce co-benefits (for example, water conservation generally reduces energy consumption) but sometimes involving trade-off conflicts (for example, subsidizing biofuels at the expense of food security).[20] 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.[21]

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

17. *See Climate Change 2014: Synthesis Report*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 17 (2014), https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf [https://perma.cc/XFT5-EKAN].

18. *Id.* at 19.

19. *Id.* at 17.

20. *See generally* Mia Landauer, Sirkku Juhola & Maria Söderholm, *Inter-Relationship Between Adaptation and Mitigation: A Systematic Literature Review*, 131 CLIMATIC CHANGE 505, 505–17 (2015) (summarizing research on mitigation and adaptation inter-relationships); James E. Parker-Flynn, *The Intersection of Mitigation and Adaptation in Climate Law and Policy*, 38 ENVIRONS ENVT'L L. & POL'Y J. 1 (2014) (discussing synergies and trade-offs); Ayyoob Sharifi, *Co-Benefits and Synergies Between Urban Climate Change Mitigation and Adaptation Measures: A Literature Review*, SCI. TOTAL ENV'T, Jan. 1, 2021, at 9–15 (focusing on the synergies); Ayyoob Sharifi, *Trade-Offs and Conflicts Between Urban Climate Change Mitigation and Adaptation Measures: A Literature Review*, J. CLEANER PROD., Dec. 10, 2020, at 7–12 (focusing on the trade-offs).

21. *See, e.g.*, Elizabeth Burleson, *A Climate of Extremes: Transboundary Conflict Resolution*, 32 VT. 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). *See generally* Katherine Trisolini, *Holistic Climate Change Governance: Towards Mitigation and Adaptation Synthesis*, 85 U. COLO. L. REV. 615 (2014).

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 in the present that are built around a range of dynamic possible future scenarios and require constant monitoring and policy adjustment.[22] The crucial first step in anticipatory governance for climate change adaptation, therefore, is deciding what range of scenarios to use.

Until recently, the answer was straightforward, driven by a unified vision of the future based on a hardline goal for climate mitigation policy. The standard policy goal for the mitigation modality has been to work 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).[23] 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 to 1.5°C."[24]

22. *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, Oct. 9, 2020, at 2; Ray Quay, *Anticipatory Governance: A Tool for Climate Change Adaptation*, 76 J. AM. PLANNING ASS'N 496, 498–99 (2010); Joost Vervoort & Arti Gupta, *Anticipating Climate Futures in a 1.5°C Era: The Link Between Foresight and Governance*, 31 CURRENT OP. IN ENVT'L SUSTAINABILITY 104, 105 (2018). Anticipatory governance theory originated in and has been influential in the nanotechnology realm. *See, e.g.*, David H. Guston, *Understanding "Anticipatory Governance"*, 44 SOC. STUD. SCI. 218, 219 (2014). For more detail on anticipatory governance theory, see *infra* Part IV.C–D.

23. The IPCC 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"). *Global Warming of 1.5 °C*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 56 (2018), https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf [https://perma.cc/5L7C-M4WK] [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 a given 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.*

24. *The Paris Agreement*, U.N. CLIMATE CHANGE (as viewed Jan. 9, 2021), https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement [https://perma.cc/6DX7-JSJC]. *See generally* Yun Gao, Xiang Gao & Xiaohua Zhang, *The*

Adaptation policy has mostly followed mitigation policy's lead, focusing on the measures needed to adjust to a world that is 1.5° to 2°C warmer than pre-industrial times.[25] 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.[26] Framed this way, adaptation policy has supported mitigation policy through their unified view of the future.

However, the 2°C assumption of maximum warming 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 exceed 3°C this century,[27] with increases continuing beyond 2100.[28] 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[29] *and* either (1) technology developed in the next fifty years makes substantial net-negative emissions possible on a global scale, or (2) global emissions peak rapidly and then fall for the next several decades at rates never before voluntarily achieved by any single nation.[30] As we explain in Part I, these are unrealistic assumptions at best.[31]

2°C 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 ENG'G 272, 272 (2017) (providing a history of the 2°C goal); 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. TRANSACTIONS ROYAL SOC'Y A 6, 7–8 (2011).

25. *See generally* THE LAW OF ADAPTATION TO CLIMATE CHANGE: U.S. AND INTERNATIONAL ASPECTS (Michael B. Gerrard & Katrina Fischer Kuh eds., 2012) [hereinafter LAW OF ADAPTATION] (providing a comprehensive survey of United States adaption law and policy). We review adaptation policy design in Part III, *infra*.

26. *2018 IPCC 1.5°C Report*, *supra* note 23, at 5.

27. Céline Guivarch & Stéphane Hallegatte, *2C or Not 2C?*, 23 GLOB. ENVT'L CHANGE 179, 180–86 (2013) (summarizing the growing perspective that 2°C is not attainable).

28. For a discussion of evidence supporting this assessment, see *infra* Part I.

29. For details on climate sensitivity, see *infra* Part I.C.

30. Guivarch & Hallegatte, *supra* note 27, at 186.

31. Importantly, however, while we find the 2°C mitigation goal unlikely to be met, 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

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 at least as high as 4°C.[32]

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.[33] 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

system at as small a global average temperature increase as possible.

In addition, we acknowledge but do not engage here the emerging debate over whether mitigation policy should continue to frame itself around the 1.5°–2°C goal. 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. *Id.* at 179. 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.

Finally, we leave to the side the debate over geoengineering, which we consider to be a mitigation strategy rather than an adaptation strategy. *See, e.g.*, NAT'L ACAD. OF SCI., ENG'G, & MED., REFLECTING SUNLIGHT: RECOMMENDATIONS FOR SOLAR GEOENGINEERING RESEARCH AND RESEARCH GOVERNANCE (2021); Paul Voosen, *U.S. Needs Solar Geoengineering Research Program, Report Says*, 372 SCIENCE 19 (2021) (summarizing the NAS report). *See generally* Albert Lin, *Does Geoengineering Present a Moral Hazard?*, 40 ECOLOGY L.Q. 673 (2013) (providing a thoughtful overview of geoengineering and its implications for climate policy). We do note, however, that the geoengineering techniques that do not directly reduce atmospheric CO_2 concentrations, such as solar radiation management and some forms of aerosol cooling, fail to address some important impacts, especially ocean acidification, and hence merely shift the adaptation problem rather than eliminate it. *See generally, e.g.*, Phillip Williamson & Carol Turley, *Ocean Acidification in a Geoengineering Context*, 370 PHIL. TRANSACTIONS ROYAL SOC'Y A 4317 (2012).

32. *See* J.B. Ruhl, *Schrödinger's Climate*, JDSUPRA (May 19, 2020), https://www.jdsupra.com/legalnews/schrodinger-s-climate-32775 [https://perma.cc/4QCJ-FGC6].

33. Steffen et al., *supra* note 8.

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 they remained where they currently are.[34] It is, however, 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.[35]

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.[36] The first is, where practicable, to *resist* the impacts of climate change, such as by constructing hard sea walls to fend off rising sea levels.[37] 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.[38] The third mode is to *retreat* from unavoidable impacts, such as in areas where coastal resistance using sea walls is not practical.[39] Using these "Three Rs," conventional adaptation policy envisions the end product as something close to life before warming and, importantly, in the same place.

34. Chi Xu, Timothy A. Kohler, Timothy M. Lenton, Jens-Christian Svenning & Marten Scheffer, *Future of the Human Climate Niche*, 117 PROC. NAT. ACAD. SCI. 11350, 11350 (2020).

35. Mark Stafford Smith, Lisa Horrocks, Alex Harvey & Clive Hamilton, *Rethinking Adaptation for a 4°C World*, 369 PHIL. TRANSACTIONS ROYAL SOC'Y A 196, 196 (2011), ("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.").

36. For descriptions of each, see *infra* Part II.A.

37. *See infra* Part III.A.1.

38. *See infra* Part III.A.2.

39. *See infra* Part III.A.3. We acknowledge that there are other ways to name these modalities. *See, e.g.*, Katharine J. Mach & A.J. Siders, *Reforming Strategic, Managed Retreat for Transformative Climate Adaptation*, 372 SCIENCE 1294, 1294 (2021) ("Numerous adaptation actions—often categorized as resistance, accommodation, avoidance, retreat, and advance—can address climate risks."). Our "Three Rs" encompass all of these modalities, but in fewer categories.

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.[40] 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.[41] Many humans facing such conditions will respond by adapting with their feet.[42] Although legal scholars have recognized that potential as largely an international human rights and immigration problem,[43] few have explored the implications of substantial climate-induced domestic migration within the United States.[44]

In short, moving past 2°C will require adding a fourth climate change adaptation mode to U.S. policy—*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.[45] The redesign adaptation mode anticipates, responds to, designs, and facilitates this relocation and reconception of population, infrastructure, agriculture, and other social-ecological system components.

As much as the resist, resilience, and retreat adaptation modes have posed difficult governance challenges already,[46] 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, governance systems are of

40. *See infra* Part II (discussing these and other likely impacts).

41. *See infra* Part III (discussing the growing body of research on this theme).

42. *See infra* Part II.B (discussing research focusing on climate-induced migration).

43. *See generally* Eliza Pan, *Reimagining the Climate Migration Paradigm: Bridging Conceptual Barriers to Climate Migration Responses*, 50 ENVT'L L. 1173 (2020).

44. For a notable exception, see generally Jessica Owley, *Climate-Induced Human Displacement and Conservation Lands*, 58 HOUS. L. REV. 665 (2021) (exploring the opportunities and constraints for using conservation lands to meet international and domestic climate-migrant needs in the United States).

45. *See infra* Part III.C (discussing the redesign adaptation mode).

46. 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) (describing the controversies surrounding the retreat mode).

foremost concern. Specifically, if governments do not implement redesign adaptation effectively, rioting in the streets—or worse—is an all-too-likely response to many other disruptions that will occur as the world increasingly warms. To avoid or minimize that social upheaval, 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 the United States in 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,"[47] 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.

47. Joseph A. Tainter, *Social Complexity and Sustainability*, 3 ECOLOGICAL COMPLEXITY 91, 100 (2006).

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 the mobilization that occurred at the start of World War II.

Part IV then 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. We propose such an initiative be anchored in a nonregulatory, science-based, interdisciplinary federal bureau charged with producing policy-relevant scenarios of how climate adaptation could unfold in the United States in a "beyond 2°C" world. Modeling of climate change impacts, an extensive undertaking already, does not reveal how humans will respond to those impacts. Given how unprecedented conditions beyond 2°C will become, the human responses are likely to be just as unprecedented. Modeling only climate impacts themselves thus provides only half the picture necessary for our nation's climate adaptation policy.

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,[48] and, as of August 2021, according to the Intergovernmental Panel on Climate Change (IPCC), "[e]ach of the last four decades has been successively warmer than any decade that preceded it since 1850."[49] In 2019, global average temperature was already 1.15°C (2.07°F) above the pre-industrial average.[50] 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."[51] At the current rates of increase, global average temperatures will be 1.5°C warmer than pre-industrial levels by 2040[52] and 2°C warmer by roughly 2067. However, the rates of warming are also still accelerating, and "[e]stimated anthropogenic 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*)."[53]

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."[54] Of particular relevance, temperatures over land surfaces, where most people live,

48. Rebecca Lindsey & LuAnn Dahlman, *Climate Change: Global Temperature*, NOAA CLIMATE.GOV (Mar. 15, 2021), https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature [https://perma.cc/EWV6-CGKP].

49. *2021 IPCC Physical Science Report*, *supra* note 12, at 5.

50. *See* Lindsey & Dahlman, *supra* note 48; *see also*, *2021 IPCC Physical Science Report*, *supra* note 12, at 5 (indicating that temperatures in the decade 2011–2020 were 0.95°C to 1.20°C warmer than in 1850–1900).

51. *See* Lindsey & Dahlman, *supra* note 48.

52. *See, e.g.*, *2018 IPCC 1.5°C Report*, *supra* note 23, at 4 ("Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.").

53. *Id.*

54. *Id.*

are increasing faster than global average temperature, which is moderated by the ocean's capacity to absorb heat.[55]

The IPCC reported in 2021 that mean land surface air temperature has increased an estimated 1.59°C (with the possible range being 1.34–1.83°C), while temperatures over the ocean have increased only about 0.88°C (with a possible range of 0.68–1.01°C).[56] Vividly illustrating this terrestrial differential, in 2019 the *Washington Post* compiled multiple data sources to produce a map showing that over one-tenth of the globe has already experienced a 2°C increase, and *most* of the United States west of the Mississippi River plus a large swath of the Southeast has already experienced a 1.5°C increase.[57] Much of the terrestrial world, in other words, has already exceeded the more ambitious of the international 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? The answer 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.[58]

55. *Id.*

56. *2021 IPCC Physical Science Report*, *supra* note 12, at 5; *see also Climate Change and Land*, Intergovernmental Panel on Climate Change 9 (2019), https://www.ipcc.ch/site/assets/uploads/2019/11/SRCCL-Full-Report-Compiled-191128.pdf [https://perma.cc/5X3X-YHXU] [hereinafter *2019 IPCC Land Report*] (similarly reporting that temperatures over land had increased more than global average temperatures).

57. 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 [https://perma.cc/VR7B-YHW9].

58. *See* Michael P. Vandenbergh & Jonathan M. Gilligan, Beyond Politics: The Private Governance Response to Climate Change 37–63 (2017) (leading to the conclusion that extensive private institution responses will be needed in addition to public governance and that "[w]e 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.

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.[59] Climate change will be an issue as long as atmospheric CO_2 concentrations remain high, trapping more heat close to the 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[60]—an unlikely future recently made more unlikely by the fact that nations will presumably 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% lower than in 2019. At the moments of the most restrictive and extensive lockdowns, emissions in some countries hovered nearly 30% below last year's averages . . . .[61]

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 have been roughly 418.4 parts per million.[62] 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.[63]

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59. *2018 IPCC 1.5°C Report*, *supra* note 23, at 5.

60. *2021 IPCC Physical Science Report*, *supra* note 12, at 17 ("Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.").

61. Alejandra Borunda, *Plunge in Carbon Emissions from Lockdowns Will Not Slow Climate Change*, NAT'L GEOGRAPHIC (May 20, 2020), https://www.nationalgeographic.com/science/2020/05/plunge-in-carbon-emissions-lockdowns-will-not-slow-climate-change [https://perma.cc/3TMW-TKUK].

62. *Id.*

63. Piers M. Forster, Harriet I. Forster, Mat J. Evans, Matthew J. Gidden, Chris D.

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."[64] As one scientist put it, "[t]he buildup of CO_2 is a bit like trash in a landfill . . . . As we keep emitting, it keeps piling up."[65] 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).[66]

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 1.5C cap, unless other means are found to remove carbon from the atmosphere . . . ."[67] 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.[68]

Jones, Christoph A. Keller, Robin D. Lamboll, Corinne Le Quéré, Joeri Rogelj, Deborah Rosen, Carl-Friedrich Schleussner, Thomas B. Richardson, Christopher J. Smith & Steven T. Turnock, *Current and Future Global Climate Impacts Resulting from COVID-19*, 10 NATURE CLIMATE CHANGE 913, 913 (2020).

64. Borunda, *supra* note 61.

65. *CO_2 Levels Reach Record High*, WEEK, June 26, 2020, at 19.

66. *2018 IPCC 1.5°C Report*, *supra* note 23, at 12.

67. *Global CO_2 Emissions Could Fall 7 Percent in 2020 due to COVID-19, Study Shows*, FRANCE24 (May 20, 2020), https://www.france24.com/en/20200520-co2-emissions-could-fall-7-percent-in-2020-due-to-covid-19-study-shows [https://perma.cc/22FV-GH7E] (emphasis added) (citing Corinne Le Quéré, Robert B. Jackson, Matthew W. Jones, Adam J. P. Smith, Sam Abernethy, Robbie M. Andrew, Anthony J. De-Gol, David R. Willis, Yuli Shan, Josep G. Canadell, Pierre Friedlingstein, Felix Creutzig & Glen P. Peters, *Temporary Reduction in Daily Global CO_2 Emissions During the COVID-19 Forced Confinement*, 10 NATURE CLIMATE CHANGE 647 (2020)).

68. New et al., *supra* note 24, 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 1 (Peter Christoff ed., 2014) ("[T]here

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.[69] 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 and 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.[70]

The most critical of these social transitions is weaning energy production and consumption off of fossil fuels.[71] As the Pathways to Deep Decarbonization project outlines,[72] 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."[73] These changes will

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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 . . . ."); Peiran R. Liu & Adrian E. Raftery, *Country-Based Rate of Emissions Reductions Should Increase by 80% Beyond Nationally Determined Contributions to Meet the 2°C Target*, 2 COMMC'NS EARTH & ENV'T 29 (2021).

69. *See* Frank W. Geels, Benjamin K. Sovacool, Tim Schwanen & Steve Sorrell, *Sociotechnical Transitions for Deep Decarbonization*, 357 SCIENCE 1242, 1242–44 (2017) (detailing societal change and policies necessary for deep decarbonization).

70. *2018 IPCC 1.5°C Report*, *supra* note 23, at 15.

71. *See* John C. Dernbach, *Legal Pathways to Deep Decarbonization: Postscript*, 48 ENV'T L. REP. 10875, 10881–84 (2018) (providing extensive discussions and references on this theme); Michael B. Gerrard, *Legal Pathways for a Massive Increase in Utility-Scale Renewable Generation Capacity*, 47 ENV'T L. REP. 10591, 10592 (2017); J.B. Ruhl & James Salzman, *What Happens When the Green New Deal Meets the Old Green Laws*, 44 VAND. L. REV. 693, 701–13 (2020).

72. *See* James H. Williams, Benjamin Haley, Fredrich Kahrl, Jack Moore, Andrew D. Jones, Margaret S. Torn & Haewon McJeon, *Pathways to Deep Decarbonization in the United States*, INST. SUSTAINABLE DEV. & INT'L RELS. (2014), https://usddpp.org/downloads/2014-technical-report.pdf [https://perma.cc/5FCZ-VPM7].

73. *Id.* at xiv; *see also* THE WHITE HOUSE, UNITED STATES MID-CENTURY STRATEGY FOR DEEP DECARBONIZATION 7 (2016) (aiming to "[t]ransition[ ] to a low-carbon energy system, by cutting energy waste, decarbonizing the electricity system and deploying clean electricity and low carbon fuels in the transportation, buildings, and industrial sectors") (emphasis omitted). There is growing concern that even these initiatives, if

require rapid and massive national initiatives. On the energy production side, for example, projections using a "high renewables" reference case estimate that between 1,350 and 2,500 gigawatts of new wind and solar renewable power-generating capacity would need to come online in the United States between today and 2050 to meet Paris Accord goals—an amount roughly fifteen to thirty times the present wind- and solar-generating capacity.[74] However, there is no evidence that global greenhouse gas emission levels have peaked and turned the corner.[75] Report after report issued in 2019 confirmed that there is little to suggest that nations are on track to achieve emission-reduction goals set through various international and domestic institutions.[76] Even the most climate-progressive states and cities in the United States are falling behind.[77]

achieved, will not suffice and that carbon dioxide removal technologies must be developed to facilitate net negative emissions. *See* Wim Carton, Adeniyi Asiyanbi, Silke Beck, Holly J. Buck & Jens F. Lund, *Negative Emissions and the Long History of Carbon Removal*, 11 WIREs CLIMATE CHANGE 671, 671 (2020); *An Equitable Path to Decarbonization*, NATURE, Dec. 5, 2019, at 7; *Negative Emissions: The Chronic Complexity of Carbon Capture*, ECONOMIST, Dec. 7, 2019, at 22.

74. *See* THE WHITE HOUSE, *supra* note 73, 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 72, at vii (estimating an additional 2,500 GW, representing 30 times the current capacity).

75. THE WHITE HOUSE, *supra* note 73, at 19.

76. *See, e.g.*, U.N. ENV'T PROGRAMME, EMISSIONS GAP REPORT 2019, at xiv-xv (2019) (noting that global greenhouse gas emissions rose on average 1.5 percent annually over the past decade and "[t]here is no sign of GHG emissions peaking in the next few years"); ROBERT WATSON, JAMES J. MCCARTHY, PABLO CANZIANI, NEBOJSA NAKICENOVIC & LILIANA HISAS, FEU-US, THE TRUTH BEHIND THE CLIMATE PLEDGES, at i (2019) ("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.").

77. *See Getting Greener: Cost-Effective Options for Achieving New York State's Greenhouse Gas Goals*, CITIZENS BUDGET COMM'N 1–2 (2019), https://cbcny.org/sites/default/files/media/files/REPORT_GettingGreener_120602019.pdf [https://perma.cc/KBT8-TWNP] (identifying obstacles to achieving emission reduction goals); *California Green Innovation Index*, NEXT 10, at 4 (2019), https://www.next10.org/sites/default/files/2019-10/2019-california-green-innovation-index-final.pdf [https://perma.cc/URM7-VAZB]("California will reach its 2030 and 2050 goals in 2061 and 2157, respectively – representing a 31-year and a 107-year delay."); *see also* Samuel A. 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 INST. 3 (2020), https://www.brookings.edu/wp-content/uploads/2020/10/FP_20201022_ghg_pledges_v4.pdf

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, organizations, markets, regulations, and user practices that together deliver societal functions."[78] 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 after shown to fall significantly short of what will be needed[79] and the "stickiness" of energy path dependencies becomes more obvious.[80] 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.[81] The world's continuing inability to tackle these transformations on the mitigation side gives credence to our concerns for 4°C adaptation governance.[82]

[https://perma.cc/QRT2-AXCU] (noting that two-thirds of U.S. 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 SCIENCE 508, 509 (2020).

78. Geels et al., *supra* note 69, at 1242.

79. Steven J. Davis, Long Cao, Ken Caldeira & Martin I. Hoffert, *Rethinking Wedges*, ENV'T RSCH. LETTERS, Jan. 9, 2013, at 1–2. *See generally* Eli Kintisch, *Climate Study Highlights Wedge Issue*, 339 SCIENCE 128, 128–29 (2013) (summarizing the study).

80. *See, e.g.*, Melissa Powers, *Natural Gas Lock-In*, 69 KAN. L. REV. 889, 941 (2021).

81. *See, e.g.*, Johan Rockström, Owen Gaffney, Joeri Rogelj, Malte Meinshausen, Nebojsa Nakicenovic & Hans Joachim Schellnhuber, *A Roadmap for Rapid Decarbonization*, 355 SCIENCE 1269, 1270–71 (2017) (outlining successively aggressive stages needed for decarbonization); Lila Warszawski, Elmar Kriegler, Timothy M. Lenton, Owen Gaffney, Daniela Jacob, Daniel Klingenfeld, Ryu Koide, María Máñez Costa, Dirk Messner, Nebojsa Nakicenovic, Hans Joachim Schellnhuber, Peter Schlosser, Kazuhiko Takeuchi, Sander Van Der Leeuw, Gail Whiteman & Johan Rockström, *All Options, Not Silver Bullets, Needed to Limit Global Warming to 1.5°C: A Scenario Appraisal*, ENV'T RSCH. LETTERS, May 26, 2021, at 6 (ruling out meeting the 1.5°C without using multiple mitigation levers at technologically "challenging" levels).

82. *See* Martin Parry, Jason Lowe & Clair Hanson, *Overshoot, Adapt, and Recover*, 458 NATURE 1102, 1102–03 (2009) (outlining likely scenarios as mitigation fails to gain traction); *2021 IPCC Physical Science Report*, *supra* note 12, at 13, SPM-17 to SPM-18 (accepting 3°C as the amount of warming most likely to occur by 2100, with a continuing "business as usual" scenario projecting even higher global average increases of 3.3°C to 5.7°C by the end of the century; and projecting that the world will exceed 1.5°C for at least some decades this century; moreover, only the lowest emissions scenario has no chance of exceeding 2°C, while the three highest emissions scenarios have no chance of *not* exceeding 2°C).

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°C or 2°C above pre-industrial levels? The IPCC, for example, stated in 2018 that accumulated anthropogenic carbon emissions at that point were unlikely sufficient to push global average warming past 1.5°C within this century.[83] However, those emissions did not stop, or reach "net zero,"[84] 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,[85] but the total global emissions still increased, reaching 36.81 Gt.[86] 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 (39–45 Gt per year).[87]

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.

83. *2018 IPCC 1.5°C Report*, *supra* note 23, at 5.

84. *2021 IPCC Physical Science Report*, *supra* note 12, at SPM-36 ("Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to likely cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C.").

85. *Global CO_2 Emissions in 2019*, INT'L. ENERGY AGENCY (Feb. 11, 2020), https://www.iea.org/articles/global-co2-emissions-in-2019 [https://perma.cc/JE9F-KZPA].

86. 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 [https://perma.cc/M9HS-RC5G].

87. *2018 IPCC 1.5°C Report*, *supra* note 23, at 12.

According to the IPCC in 2021, humanity had emitted 2,390 $GtCO_2$ between 1850 and 2019, give or take 240 Gt.[88] It estimated that, to have a two-thirds chance (meaning odds that are twice as bad as in Russian Roulette) of staying within 1.5°C or 2.0°C of global average warming, humanity had 400 or 1,150 Gt, respectively, of CO_2 emissions left—*ever*.[89] To increase the chances to 83 percent, the remaining carbon budgets drop to 300 or 900 Gt, respectively.[90] If humanity continues to emit around 40 Gt per year, it will use up the higher-odds budget for 1.5°C sometime in 2027 and the higher-odds budget for 2°C sometime in 2043.

Nevertheless, individual carbon-budget studies exhibit considerable 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."[91] 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.[92] Worse still, another study

88. *2021 IPCC Physical Science Report*, *supra* note 12, at SPM-38.

89. *Id.* at SPM-38, tbl.SPM.2.

90. *Id.*

91. 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 [https://perma.cc/VR6G-YJQZ].

92. 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). 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 SCIENCE 17, 17–18 (2020) (reporting that 432 mines worldwide, mostly in Asia and many of which are publicly financed, are planned to open or expand to produce 2.5 billion tons of new mining capacity by 2030). Over 70% of the new capacity would produce thermal coal used for fueling power plants. *See* RYAN DRISKELL TATE, CHRISTINE SHEARER & ANDISWA MATIKINCA, DEEP TROUBLE: TRACKING GLOBAL COAL MINE PROPOSALS 4 (2021).

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."[93] 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 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.[94]

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."[95] 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.[96] 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.[97] 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

93. Michael A. Clark, Nina G. G. Domingo, Kimerly Colgan, Sumil K. Thakrar, David Tilman, John Lynch, Inês L. Azevedo & Jason D. Hill, *Global Food System Emissions Could Preclude Achieving the 1.5°C and 2°C Climate Change Targets*, 370 SCIENCE 705, 705–08 (2020).

94. Lenton et al., *supra* note 7, at 594 (citations omitted).

95. Elizabeth Pennisi, *Tropical Forests Store Carbon Despite Warming*, 368 SCIENCE. 813, 813 (2020).

96. 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 [https://perma.cc/D8JY-E8YY].

97. *Id.*

the Arctic is currently emitting.[98] 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 (that is, 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 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 4°C increase in global average temperature, which could occur as soon as fifty years from now.

The IPCC, for example, most consistently compares four scenarios.[99] Its business-as-usual scenarios tend to suggest that the world could reach 4°C by the end of this century.[100] In 2017, researchers using a different methodology published their projections in *Nature*,

98. Nabil Sultan, Andreia Plaza-Faverola, Sunil Vadakkepuliyambatta, Stefan Buenz & Jochen Knies, *Impact of Tides and Sea-Level on Deep-Sea Arctic Methane Emissions*, NATURE COMMC'NS, Oct. 9, 2020, at 1–2.

99. *2019 IPCC Synthesis Report*, *supra* note 17, at 8.

100. *Id*. at 9 fig.SPM 5(a), 12 fig.SPM 7; *see also* New et al., *supra* note 24, at 9–10 ("All but two of the models [in a series of model runs] 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 68 ("[T]here 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."); *2021 IPCC Physical Science Report*, *supra* note 12, at SPM-17 to SPM-18, tbl.SPM.1 (indicating that under a business-as-usual scenario, global average temperature could increase as much as 5.7°C by the end of the century).

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 . . . ."[101]

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.[102] 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.[103] One of the first assessments, a 1979 study by the National Research Council, produced a broad range of 1.5°C to 4.5°C.[104] 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.[105] The study concludes that at 560 ppm the likely (66% chance) warming range is between 2.6°C and 3.9°C.[106] 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.[107] 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 increase to 2.6°C, just as likely to reach 3.9°C, and the possibility of reaching 4.0°C or higher cannot be ignored.

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 the

101. Adrian E. Raftery, Alec Zimmer, Dargan M. W. Frierson, Richard Startz & Peiran Liu, *Less than 2°C Warming by 2100 Unlikely*, 7 NATURE CLIMATE CHANGE 637, 639 (2017).

102. S. C. Sherwood, M. J. Webb, J. D. Annan, K. C. Armour, P. M. Forster, J. C. Hargreaves, G. Hegerl, S. A. Klein, K. D. Marvel, E. J. Rohling, M. Watanabe, T. Andrews, P. Braconnot, C. S. Bretherton, G. L. Foster, Z. Hausfather, A. S. von der Heydt, R. Knutti, T. Mauritsen, J. R. Norris, C. Proistosescu, M. Rugenstein, G. A. Schmidt, K. B. Tokarska & M. D. Zelinka, *An Assessment of Earth's Climate Sensitivity Using Multiple Lines of Evidence*, REVS. GEOPHYSICS, July 22, 2020, at 2.

103. *Id.*

104. *Id.*

105. *Id.* at 1; *see also* Paul Voosen, *Earth's Climate Destiny Finally Seen More Clearly*, 369 SCIENCE 354, 354–55 (2020) (summarizing the study).

106. Sherwood et al., *supra* note 102, at 1.

107. *Id.* (debating over the upper bounds of climate sensitivity); *see also* Paul Voosen, *New Climate Models Forecast a Warming Surge*, 364 SCIENCE 222 (2019) (discussing debate over recent models showing warming rising to 5°C).

last three million years."[108] True to the "trash pile" metaphor,[109] even after another year of pandemic conditions the May 2021 measurement broke that record, coming in at just over 419 ppm.[110] 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."[111] 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.

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 a massive scale). Moreover, for more than a decade now, the CO_2 concentration in the atmosphere has been increasing roughly 2.3 ppm per year.[112] 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°C mitigation target will be a historical footnote. Importantly for adaptation governance, however, warming doesn't stop in 2100, nor is 560 ppm a naturally imposed ceiling on greenhouse gas concentrations; as a result, adaptation governance must itself be continually adaptable, at least until both atmospheric greenhouse gas concentrations and the resulting changes to Earth's systems stabilize.

108. Borunda, *supra* note 61.

109. *See CO_2 Levels Reach Record High*, *supra* note 65.

110. *Carbon Dioxide Peaks Near 420 Parts Per Million at Mauna Loa Observatory*, NOAA RSCH NEWS (June 7, 2021), https://research.noaa.gov/article/ArtMID/587/ArticleID/2764/Coronavirus-response-barely-slows-rising-carbon-dioxide [https://perma.cc/B3NF-WXCZ].

111. Lindsey, *supra* note 12.

112. *Id.*

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 4°C requires policy-makers 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.[113] 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 worldwide, among other disruptions to natural systems upon which humans depend.[114]

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

113. *See* Bill McKibben, *How Fast Is the Climate Changing?: It's a New World, Each and Every Day*, 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 [https://perma.cc/JJ8M-LHJX] (describing the wildfire and hurricane combinations in late August and early September 2020); Kelly Levin, *Climate Change, Frigid Temperatures and the Polar Vortex: 3 Things to Know,* WORLD RES. INST. (Jan. 30, 2019), wri.org/insights/climate-change-frigid-temperatures-and-polar-vortex-3-things-know [https://perma.cc/G8LY-V393] (describing the relationship between climate change and Polar Vortex).

114. *See* Steven L. Chown, *Marine Food Webs Destabilized*, 369 SCIENCE 770, 770–71 (2020) (discussing a collection of research studies on this theme); 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); Christy M. McCain, Sarah R. B. King & Tim M. Szewczyk, *Unusually Large Upward Shifts in Cold-Adapted, Montane Mammals as Temperature Warms*, ECOLOGY, Apr. 2021, at 1; Marten Scheffer, Steve Carpenter, Jonathan A. Foley, Carl Folke & Brian Walker, *Catastrophic Shifts in Ecosystems*, 413 NATURE 591, 591–96 (2001); Brett R. Scheffers, Luc De Meester, Tom C. L. Bridge, Ary A. Hoffmann, John M. Pandolfi, Richard T. Corlett, Stuart H. M. Butchart, Paul Pearce-Kelly, Kit M. Kovacs, David Dudgeon, Michela Pacifici, Carlo Rondinini, Wendy B. Foden, Tara G. Martin, Camilo Mora, David Bickford & James E. M. Watson, *The Broad Footprint of Climate Change from Genes to Biomes to People*, 354 SCIENCE 719, 719–20 (2016).

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.[115] To make matters even more chaotic, different systems transform at different temperatures. Some, like Arctic and coral reef social-ecological systems, are already transforming.[116] Others, like mangrove social-ecological systems, currently face far less risk.[117] Nevertheless, 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.[118]

Thus, as the IPCC has emphasized, even the difference between 1.5°C and 2°C is important when thinking about future adaptation

115. *See* Smith et al., *supra* note 35 (discussing adapting to 4 °C will be a more substantial, continuous, and transformative process).

116. *See 2018 IPCC 1.5°C Report*, *supra* note 23, at 11 fig. SPM.2; *see also* Robin E. Bell & Helene Seroussi, *History, Mass Loss, Structure, and Dynamic Behavior of the Antarctic Ice Sheet*, 367 SCIENCE 1321, 1321–25 (2020) (discussing the average air temperature on the Antarctic Peninsula between 1950 and 2000, and Antarctic contribution to SLR since 1992, which will accelerate if temperatures keep rising); Lenton et al., *supra* note 7, at 593 (discussing the evidence that the Greenland ice sheet is experiencing mass loss at accelerating rates and has switched to a new dynamic state of sustained mass loss).

117. *2018 IPCC 1.5°C Report*, *supra* note 23, at 11 fig. SPM.2.

118. *See* Elizabeth Pennisi, *An Ecosystem Goes Topsy-Turvey as a Tiny Fish Takes Over*, 369 SCIENCE 1154, 1154–55 (2020); Douglas B. Rasher, Robert S. Steneck, Jochen Halfar, Kristy J. Kroeker, Justin B. Ries, M. Tim Tinker, Phoebe T. W. Chan, Jan Fietzke, Nicholas A. Kamenos, Brenda H. Konar, Jonathan S. Lefcheck, Christopher J. D. Norley, Benjamin P. Weitzman, Isaac T. Westfield & James A. Estes, *Keystone Predators Govern the Pathway and Pace of Impacts in a Subarctic Marine Ecosystem*, 369 SCIENCE 1351, 1351–54 (2020).

governance.[119] For example, in some locations, 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[120]—an example of geometric impacts.[121] Half a degree Celsius also 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."[122] Here, a 0.5°C difference in the increase in global average temperature leads to a tenfold 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*)."[123]

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 thirty 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

119. *2018 IPCC 1.5°C Report*, *supra* note 23, at 7; *see also 2021 IPCC Physical Science Report*, *supra* note 12, at SPM-19 ("With every additional increment of global warming, changes in extremes continue to become larger."), SPM-32 ("With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.").

120. *See 2018 IPCC 1.5°C Report*, *supra* note 23, at 7 ("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.").

121. *See also* New et al., *supra* note 24, at 10 ("The broadly constant ratio of local climate change to global temperature change implies that these local changes are amplified in a 4°C world; for example, a local change of 3°C in a +2°C world (1°C greater than the global average) becomes 7.5°C in a +4°C world (3.5°C above the global average).").

122. *2018 IPCC 1.5°C Report*, *supra* note 23, at 8.

123. *Id.*

> damaging hot spell for maize increases from 5 to 50% at 4°C, whilst the chance for rice rises from 27 to 46%.[124]

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.[125] For all practical purposes, when making plans and policy in such an environment, one will need to assume that debilitating heatwaves, drought, crop failure, floods, and other harms are the new normal.[126]

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.[127] Many ecosystems are already crossing transformational tipping point thresholds at 1.0°C of warming,[128] 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

124. 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).

125. *See* Solomon Hsiang, Robert Kopp, Amir Jina, James Rising, Michael Delgado, Shashank Mohan, D. J. Rasmussen, Robert Muir-Wood, Paul Wilson, Michael Oppenheimer, Kate Larsen & Trevor Houser, *Estimating Economic Damage from Climate Change in the United States*, 356 SCIENCE 1362, 1364–65 (2017) (suggesting that above 1°C, there will be losses of 1.2 percent US GDP per 1°C of warming, and mortality is the largest incremental factor above 2.5°C); *see also* William A. Pizer, *What's the Damage from Climate Change?*, 356 SCIENCE 1330, 1330–31 (2017) (estimating that 3°C leads to a loss of 2% of U.S. GDP, and 6°C is 6% loss).

126. *See* Toby R. Ault, *On the Essentials of Drought in a Changing Climate*, 368 SCIENCE 256, 256–60 (2020) (introducing an in-depth, accessible explanation of how rising temperatures lead inevitably to more intense, frequent, and long-lasting droughts).

127. *See* New et al., *supra* note 24, at 10–11 ("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.").

128. *See* Lenton et al., *supra* note 7, at 592.

projected to be approximately 50% lower at 1.5°C compared to 2°C (medium confidence).[129]

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*.[130]

We are well on the way there. Pervasive shifts in forest vegetation are already occurring and are likely to accelerate under future global changes.[131] Most at risk are tropical forests, which are already exhibiting nonlinear, unpredictable trajectories of change in structure and diversity.[132] Diverse terrestrial and marine species are exhibiting poleward range extensions and changes in abundance and distribution.[133] Rising carbon reduces the nutrients in plants, which is already dwindling terrestrial insect populations.[134] All herbivores are at risk if this trend continues.[135] In many systems, nonlinear effects accelerate the pace of transformation.[136] Projections suggest that shifts in

129. *2018 IPCC 1.5°C Report*, *supra* note 23, at 8.

130. *See* Helmut Hillebrand, Ian Donohue, W. Stanley Harpole, Dorothee Hodapp, Michal Kucera, Aleksandra M. Lewandowska, Julian Merder, Jose M. Montoya & Jan A. Freund, *Thresholds for Ecological Responses to Global Change Do Not Emerge from Empirical Data*, 4 NATURE ECOLOGY & EVOLUTION 1502, 1502–09 (2020) (discussing that precise projections of which systems cross thresholds at which temperature regimes have proven elusive, therefore suggesting that policy should not assume there are "safe operating spaces" below specified levels of temperature rise).

131. *See* Nate G. McDowell, Craig D. Allen, Kristina Anderson-Teixeira, Brian H. Aukema, Ben Bond-Lamberty, Louise Chini, James S. Clark, Michael Dietze, Charlotte Grossiord, Adam Hanbury-Brown, George C. Hurtt, Robert B. Jackson, Daniel J. Johnson, Lara Kueppers, Jeremy W. Lichstein, Kiona Ogle, Benjamin Poulter, Thomas A. M. Pugh, Rupert Seidl, Monica G. Turner, Maria Uriarte, Anthony P. Walker & Chonggang Xu, *Pervasive Shifts in Forest Dynamics in a Changing World*, SCIENCE, May 29, 2020, at 1–3.

132. *See* Harald Bugmann, *Tree Diversity Reduced to the Bare Essentials: Tropical Forest Dynamics Can Be Explained by Merely Two Functional Trait Axes*, 368 SCIENCE 128, 128–29 (2020).

133. *See*, *e.g.*, Camille Parmesan, Nils Ryrholm, Constantí Stefanescu, Jane K. Hill, Chris D. Thomas, Henri Descimon, Brian Huntley, Lauri Kaila, Jaakko Kullberg, Toomas Tammaru, W. John Tennent, Jeremy A. Thomas & Martin Warren, *Poleward Shifts in Geographical Ranges of Butterfly Species Associated with Regional Warming*, 399 NATURE 579, 579–83 (1999) (suggesting that this effect has been documented since the late 1990s).

134. *See* Elizabeth Pennisi, *Carbon Dioxide Increase May Promote 'Insect Apocalypse': Study Links Low-Nutrient Plants to Fewer Grasshoppers*, 368 SCIENCE 459, 459 (2020).

135. *See id.*

136. *See* Eric Sanford, Jacqueline L. Sones, Marisol García-Reyes, Jeffrey H. R. Goddard & John L. Largier, *Widespread Shifts in the Coastal Biota of Northern California During the 2014–2016 Marine Heatwaves*, SCI. REPS., Mar. 12, 2019, at 6–12.

Earth ecosystems are likely to occur over "human" timescales of years and decades, meaning that the collapse of large vulnerable ecosystems, such as the Amazon rainforest and Caribbean coral reefs, may take only a few decades once triggered.[137]

Although other systems will take longer to transform, once they cross thresholds of nonlinear change, the transformation will for all practical purposes be irreversible.[138] 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.[139] 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.[140] Similar concerns are coming from research on Arctic ice[141] and on ocean circulation systems.[142] Recent research shows that the Atlantic Meridional Overturning Circulation, one of Earth's major ocean circulation systems responsible for planetary heat redistribution and known to be subject to historical nonlinear shifts, is at its weakest in the last millennium.[143] Crossing any of these and similar

137. *See* Gregory S. Cooper, Simon Willcock & John A. Dearing, *Regime Shifts Occur Disproportionately Faster in Larger Ecosystems*, 11 NATURE COMMC'NS, Mar. 10, 2020, at 7.

138. *See* Lenton et al., *supra* note 7, at 592 (discussing that passing tipping points would potentially commit the world to long-term irreversible changes).

139. *See* Frank Pattyn & Mathieu Morlighem, *The Uncertain Future of the Antarctic Ice-Sheet*, 367 SCIENCE 1331, 1331–35 (2020).

140. *See id.*; *see also* Jason P. Briner, Joshua K. Cuzzone, Jessica A. Badgeley, Nicolás E. Young, Eric J. Steig, Mathieu Morlighem, Nicole-Jeanne Schlegel, Gregory J. Hakim, Joerg M. Schaefer, Jesse V. Johnson, Alia J. Lesnek, Elizabeth K. Thomas, Estelle Allan, Ole Bennike, Allison A. Cluett, Beata Csatho, Anne de Vernal, Jacob Downs, Eric Larour & Sophie Nowicki, *Rate of Mass Loss from the Greenland Ice-Sheet Will Exceed Holocene Values this Century*, 586 NATURE 70, 70–74 (2020); Ian Joughin, Richard B. Alley & David M. Holland, *Ice-Sheet Response to Oceanic Forcing*, 338 SCIENCE 1172, 1172–76 (2012); Dirk Notz, *The Future of Ice Sheets and Sea Ice: Between Reversible Retreat and Unstoppable Loss*, 106 PROC. NAT. ACAD. SCI. 20590, 20590–95 (2009).

141. *See* I. Eisenman & J.S. Wettlaufer, *Nonlinear Threshold Behavior During the Loss of Artic Sea Ice*, 106 PROC. NAT. ACAD. SCI. 28, 28–32 (2009) (describing a threshold of Arctic ice loss that leads to permanent year-round ice-free conditions).

142. *See* Thomas F. Stocker, *Surprises for Climate Stability*, 367 SCIENCE 1425, 1425–26 (2020).

143. *See* Niklas Boers, *Observational-based Early-warning Signals for a Collapse of the Atlantic Meridional Overturning Circulation*, 11 NATURE CLIMATE CHANGE 680, 680 (2021); L. Caesar, G. D. McCarthy, D. J. R. Thornalley, N. Cahill & S. Rahmstorf, *Current Atlantic Meridional Overturning Circulation Weakest in Last Millennium*, 14 NATURE GEOSCIENCE 118, 118–20 (2021).

planetary mega-thresholds amplifies the potential for crossing others, and vice versa.[144]

In short, almost everywhere researchers explore, they are finding evidence of a changing world increasingly dominated by accelerating nonlinear effects, tipping-point thresholds, multiple interrelated positive-feedback effects, 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,[145] 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.[146] For instance, *drops* in global average temperature of 4°C from pre-industrial levels have led to ice ages.[147] 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 Circle."[148] In one of the most comprehensive paleoclimate analyses, Nolan et al. concluded that without

144. *See* Frederick van der Ploeg, *Reacting to Multiple Tipping Points*, 6 NATURE CLIMATE CHANGE 442, 442–43 (2016) (introducing the study of the likelihood of each of five tipping points and how each depends on the state of others).

145. *See* New et al., *supra* note 24, 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.").

146. *See* Jessica E. Tierney, Christopher J. Poulsen, Isabel P. Montañez, Tripti Bhattacharya, Ran Feng, Heather L. Ford, Bärbel Hönisch, Gordon N. Inglis, Sierra V. Petersen, Navjit Sagoo, Clay R. Tabor, Kaustubh Thirumalai, Jiang Zhu, Natalie J. Burls, Gavin L. Foster, Yves Goddéris, Brian T. Huber, Linda C. Ivany, Sandra Kirtland Turner, Daniel J. Lunt, Jennifer C. McElwain, Benjamin J. W. Mills, Bette L. Otto-Bliesner, Andy Ridgwell & Yi Ge Zhang, *Past Climates Inform Our Future*, SCIENCE, Nov. 6, 2020, at 7 (noting that improved geochemical and statistical techniques are providing more reliable projections from paleoclimate models); Thomas Westerhold, Norbert Marwan, Anna Joy Drury, Diederik Liebrand, Claudia Agnini, Eleni Anagnostou, James S. K. Barnet, Steven M. Bohaty, David De Vleeschouwer, Fabio Florindo, Thomas Frederichs, David A. Hodell, Ann E. Holbourn, Dick Kroonvittoria Lauretano, Kate Littler, Lucas J. Lourens, Mitchell Lyle, Heiko Pälike, Ursula Röhl, Jun Tian, Roy H. Wilkens, Paul A. Wilson & James C. Zachos, *An Astronomically Dated Record of Earth's Climate and its Predictability Over the Last 66 Million Years*, 369 SCIENCE 1383, 1383–87 (2020) (describing new techniques and results).

147. *How Is Today's Warming Different from the Past?*, NASA EARTH OBSERVATORY (June 3, 2010), https://earthobservatory.nasa.gov/features/GlobalWarming/page3.php [https://perma.cc/TP2N-GX9B].

148. 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 [https://perma.cc/H2GD-FBEB].

substantial mitigation efforts, all global terrestrial ecosystems are at risk of major transformation in composition and structure.[149] In particular, during the Paleocene-Eocene Thermal Maximum (PETM) of roughly 55.9 million years ago, a rapid and sustained increase in atmospheric CO_2 over the course of a few millennia led to a sustained warming that fossil and other records show "caused amplifying feedbacks, dwarfing of large animals, ecosystem disruptions, soil degradation, water-cycle shifts, and other major changes."[150] "PETM CO_2 remained elevated for over 150,000 years," suggesting that current anthropogenic emissions could have similar long-lasting effects.[151]

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 at 2°C.[152] 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.[153] For wildfire damage, our current 1°C increase in global average temperature means a longer fire season; at 2.5°C, 50 percent 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.[154] With respect to food security, the planet moves from infrequent, locally important spikes in food prices at 1°C to "periodic food shocks across

149. Connor Nolan, Jonathan T. Overpeck, Judy R. M. Allen, Patricia M. Anderson, Julio L. Betancourt, Heather A. Binney, Simon Brewer, Mark B. Bush, Brian M. Chase, Rachid Cheddadi, Morteza Djamali, John Dodson, Mary E. Edwards, William D. Gosling, Simon Haberle, Sara C. Hotchkiss, Brian Huntley, Sarah J. Ivory, A. Peter Kershaw, Soo-Hyun Kim, Claudio Latorre, Michelle Leydet, Anne-Marie Lézine, Kam-Biu Liu, Yao Liu, A. V. Lozhkin, Matt S. McGlone, Robert A. Marchant, Arata Momohara, Patricio I. Moreno, Stefanie Müller, Bette L. Otto-Bliesner, Caiming Shen, Janelle Stevenson, Hikaru Takahara, Pavel E. Tarasov, John Tipton, Annie Vincens, Chengyu Weng, Qinghai Xu, Zhuo Zheng & Stephen T. Jackson, *Past and Future Global Transformation of Terrestrial Ecosystems Under Climate Change,* 361 SCIENCe 920, 920 (2018).

150. Richard B. Alley, *A Heated Mirror for Future Climate: Climatic Changes 55.9 Million Years Ago Resemble Those Expected in the Future*, 352 SCIENCE 151, 151 (2016).

151. *Id.*

152. *See 2019 IPCC Land Report*, *supra* note 56, at 16–17 fig. SPM.2 ("[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 exists at 2 °C.").

153. *Id.*

154. *Id.*

regions" at 3.2°C to "sustained food supply disruptions globally" at about 4.3°C.[155] 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 1°C to 6°C.[156] At 4°C, 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 gradually become fortified islands, largely below sea level and under siege from all sides by the advancing waters."[157] At the same time, food security becomes an international crisis as the world's "breadbaskets" fail in rapid succession, often replaced by deserts,[158] while lands recently freed of ice and snow, like Canada and Russia, prove unequal to the task of replacing them.[159] Lynas concludes that "all of these regions will be haemorrhaging people in the biggest human migration ever seen, with hundreds of millions on the move in search of food and water,"[160] and "that mass starvation will be a permanent danger for much of the human race in the four-degree world . . . ."[161]

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.[162] 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."[163]

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155. *Id.*

156. *See generally* MARK LYNAS, SIX DEGREES: OUR FUTURE ON A HOTTER PLANET (Nat'l Geographic ed. 2008) (describing how the world will look as global temperatures continue to rise).

157. *Id.* at 187.

158. *Id.* at 195.

159. *Id.*

160. *Id.*

161. *Id.* at 196.

162. 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 [https://perma.cc/4X2B-PZ2K].

163. Gaia Vince, *The Heat Is on Over the Climate Crisis. Only Radical Measures Will*

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.[164] Second, food insecurity escalating to mass starvation will become a real problem for almost everyone as both terrestrial and marine food systems fail.[165] 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.[166] 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.[167] 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 (such as food) and capacity for relief efforts.[168] Governments and governance systems need to be prepared, or we can certainly add war, famine, disease, and increased inequalities into the narrative.

Work, GUARDIAN (U.K.) (May 18, 2019), https://www.theguardian.com/environment/2019/may/18/climate-crisis-heat-is-on-global-heating-four-degrees-2100-change-way-we-live [https://perma.cc/R9AK-ZZQY]. Interested readers might also explore Kim Stanley Robinson's novel *Ministry of the Future* for an immersive imagining of a much warmer future.

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

165. Vince, *supra* note 163; *see also* Éva Plagányi, *Climate Change Impacts on Fisheries*, 363 SCIENCE 930, 930–31 (2019) (concluding that there has already been a 4% decline in global productivity of marine fisheries between 1930 and 2010).

166. Vince*, supra* note 163.

167. *Id.*

168. In 2021, for example, the National Academies of Science, Engineering, and Medicine (NASEM) identified risks to Americans from climate change to include "health, food, water, energy, and transportation systems, and risks that affect the economy and national security. New research is needed to understand and communicate complex interactions among climate change (including uncertainties), other global changes such as disruption of the global nitrogen cycle, and societal development." *See Global Change Research Needs and Opportunities for 2022–2031*, NAT'L ACADS. OF SCI., ENG'G, & MED. 2 (2021) [hereinafter 2021 NASEM *Global Change Research Report*].

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 today, humans, *as a species*, have never experienced those temperatures.[169] 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."[170] They further conclude that temperature is the main determinant of where people live[171] and that humanity's temperature preferences have not changed for at least 8,000 years.[172] These researchers suggest that "[t]his distribution likely reflects a human temperature niche related to fundamental constraints."[173]

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,[174] giving both humans and ecosystems far less time to move to the temperature zones that will allow them to continue to survive.[175]

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

169. Vince, *supra* note 163.
170. Xu et al., *supra* note 34, at 11350.
171. *Id.*
172. *Id.* at 11350–51.
173. *Id.* at 11350.
174. Scott & Lindsey, *supra* note 148.
175. 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 PROC. NAT. ACAD. SCI. 21108, 21108–10 (2020); Kangning Huang, Xia Li, Xiaoping Liu & Karen C. Seto, *Projecting Global Urban Land Expansion and Heat Island Intensification Through 2050*, 14 ENV'T RSCH. LETTERS, Nov. 14, 2019, at 1–3.

very question.[176] The project vividly illustrated that the United States in a 4°C world looks quite different from the United States at 2°C.[177] Defining a "suitable zone" as the area of the nation in the sweet spot of Xu et al.'s "human climate niche,"[178] the project reveals that this 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.[179] Putting these maps into descriptive words, Abrahm Lustgarten of the *New York Times* observes that

> 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.[180]

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.[181] Increased competition for water—both among humans and between humans and ecosystems—is likely in the Southeast, Caribbean, Great Plains, Hawai'i, the Pacific Island Territories, and especially the Southwest, which also faces

176. *See* Abrahm Lustgarten, *How Climate Migration Will Reshape America*, N.Y. TIMES MAG. (Sept. 15, 2020), https://www.nytimes.com/interactive/2020/09/15/magazine/climate-crisis-migration-america.html [https://perma.cc/FA58-3976]; 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 [https://perma.cc/DJ7B-7HTT].

177. Shaw et al., *supra* note 176.

178. *See* Xu et al., *supra* note 34.

179. *See* Shaw et al., *supra* note 176.

180. Lustgarten, *supra* note 176.

181. *See Climate Change Impacts in the United States: The Third National Climate Assessment*, U.S. GLOB. CHANGE RSCH. PROGRAM 9 (2014), https://nca2014.globalchange.gov/downloads/high/NCA3_Climate_Change_Impacts_in_the_United%20States_HighRes.pdf [https://perma.cc/DV6W-6CF3] [hereinafter 2014 U.S. Climate Impact Report].

increasing risks of catastrophic wildfires.[182] The nation's coasts are increasingly at risk from sea-level rise and worsening storm surge, especially in the Gulf of Mexico and Southeast.[183] 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 that every region of the nation is affected.[184] 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.[185] Likewise, the United States will feel effects from around the globe as well, where in all cases social-ecological system conditions worsen as temperatures increase.[186]

One need not fully accept all the projections that the ProPublica/*New York Times* project produced to appreciate that the United States in a 4°C world would join the ranks of nations perceived today as most at risk in a 2°C world.[187] At 4°C, the United States' comparable wealth will not be enough to stop the "suitable zone" from exiting northward.[188] Welcome, United States, to a club no nation wishes to join.

As the ProPublica/*New York Times* project emphasizes, the most significant consequence of the high emissions scenario for the United States is *internal* domestic human migration.[189] 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

182. *Id.* at 11.

183. *Id.*

184. *See* Lustgarten, *supra* note 176. Domestic internal migration is likely to be prevalent in many nations. *See* François Gemenne, *Climate-Induced Population Displacements in a 4°C+ World*, 369 PHIL. TRANSACTIONS ROYAL SOC'Y A 182, 182–83 (2011).

185. *See* Rachel Warren, *The Role of Interactions in a World Implementing Adaptation and Mitigation Solutions to Climate Change*, 369 PHIL. TRANSACTIONS ROYAL SOC'Y A 217, 219–33 (2011).

186. *See 2019 IPCC Land Report*, *supra* note 56, at 8–9.

187. Lustgarten, *supra* note 176.

188. Shaw et al., *supra* note 176.

189. Lustgarten, *supra* note 176; Shaw et al., *supra* note 176.

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.[190] 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."[191] 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 in the United States to be as high as 13 million people.[192] His main point, however, is that they are moving somewhere inland, meaning inland communities will have to adapt as well.[193] 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.[194] Other studies make predictions about domestic migration responses to heat and natural disasters, often finding nonlinear effects.[195]

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.[196] New modalities of adaptation governance will be necessary to cope with the impacts of mass domestic migration and the many other transformations occurring in a 4°C world.[197] We turn to that theme in the next Part.

190. Shaw et al., *supra* note 176.

191. Lustgarten, *supra* note 176.

192. Mathew E. Hauer, *Migration Induced by Sea-Level Rise Could Reshape the US Population Landscape*, 7 NATURE CLIMATE CHANGE 321, 321–25 (2017).

193. *Id.*

194. Qin Fan, Karen Fisher-Vanden & H. Allen Klaiber, *Climate Change, Migration, and Regional Economic Impacts in the United States*, 5 J. ASS'N ENV'T & RES. ECONOMIST 643, 644–45 (2017).

195. *Id.* at 643–44.

196. *See* Gemenne, *supra* note 184, at 187–88.

197. W. Neil Adger, Anne-Sophie Crépin, Carl Folke, Daniel Ospina, F. Stuart Chapin III, Kathleen Segerson, Karen C. Seto, John M. Anderies, Scott Barrett, Elena M. Bennett, Gretchen Daily, Thomas Elmqvist, Joern Fischer, Nils Kautsky, Simon A. Levin, Jason F. Shogren, Jeroen van den Bergh, Brian Walker & James Wilen, *Urbanization, Migration, and Adaptation to Climate Change*, 3 ONE EARTH 396, 396 (2020).

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 the (at that time) 1.5°C goal could be achieved.[198] Indeed, in some policy circles, speaking of adaptation was forbidden, lest its potential for alleviating harm suppresses support for aggressive, costly mitigation policy.[199] 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.[200] Adaptation policy[201] 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.[202]

Nevertheless, adaptation policy has largely centered around the 1.5°–2°C scenario,[203] although more recently cities in the United States have begun to include a high emissions scenario in their adaptation plans.[204] 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,

198. 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 ENV'T L. 363, 365–75 (2010). *See also* Xueqing Shan, *Coordinating Local Adaptive Strategies Through a Network-Based Approach*, 29 DUKE ENV'T L. & POL'Y F. 183, 187 (2018).

199. Ruhl, *supra* note 198, at 366–70.

200. *Id.*

201. Jacobs, *supra* note 162.

202. Eli Kintisch, *In New Report, IPCC Gets More Specific About Warming Risks*, 344 SCIENCE 21, 21 (2014); *see also Adapt Now: A Global Call for Leadership on Climate Resilience*, GLOB. COMM'N ON ADAPTATION 3 (2019) https://gca.org/wp-content/uploads/2019/09/GlobalCommission_Report_FINAL.pdf [https://perma.cc/9GYN-969W] [hereinafter *Adapt Now*] (identifying human, environmental, and economic imperatives to adapt quickly).

203. *See* Warren, *supra* note 185, at 218–19.

204. *See* Missy Stults & Larissa Larsen, *Tackling Uncertainty in US Local Climate Adaptation Planning*, 40 J. PLAN. EDUC. & RSCH. 416, 420, 425 (2020).

increase the disruptions to social-ecological systems from climate change.[205] In particular, domestic inter-regional migration in the United States will disrupt the population landscape, with cascading consequent impacts.[206] 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).[207]

These modalities are not necessarily mutually exclusive and in many contexts may need to be deployed simultaneously—for example, 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.[208] Nevertheless, the "Three Rs" are distinct in terms of their core orientations to an adaptation response.[209]

1. Resistance

Resistance policies focus on building infrastructure and other mostly technological defenses to climate change impacts in order to

205. *See infra* Part II.A.

206. *See infra* Part II.A.

207. *See* Ruhl, *supra* note 198, 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 25, at 239 (using the terms resistance, adjustment, and retreat); Trip Pollard, *Damage Control: Adapting Transportation to a Changing Climate*, 39 WM. & MARY ENV'T L. & POL'Y REV. 365, 378 (2015) (listing the various terms); Mark Scott & Mick Lennon, *Climate Disruption and Planning: Resistance or Retreat?*, 21 PLAN. THEORY & PRAC. 125, 130 (2020) (using a variety of these terms); A.R. Siders & Jesse M. Keenan, *Variables Shaping Coastal Adaptation Decisions to Armor, Nourish, and Retreat in North Carolina*, 183 OCEAN & COASTAL MGMT., Jan. 1, 2020, at 2.

208. *See* Jeroen C. J. H. Aerts, W. J. Wouter Botzen, Kerry Emanuel, Ning Lin, Hans de Moel & Erwann O. Michel-Kerjan, *Evaluating Flood Resilience Strategies for Coastal Megacities*, 344 SCIENCE 473, 473–75 (2014) (evaluating different mixes of strategies based on evidence from New York approaches to flood resilience); Audrey Baills, Manuel Garcin & Thomas Bulteau, *Assessment of Selected Climate Change Adaptation Measures for Coastal Areas*, 185 OCEAN & COASTAL MGMT. 105059, at 4–5, 7 (2020) (outlining a broad array of strategies and criteria for evaluating selection).

209. *See* Ruhl, *supra* note 198, at 383 (distinguishing between proactive and reactive adaptation strategies to climate change).

protect human communities.[210] Resistance has long been a core policy approach to natural hazards in the United States.[211] Classic examples include seawalls along coastal areas and dams and levees along flood-prone rivers.[212] It is no surprise, therefore, that resistance strategies are prominent in many local and regional climate change adaptation plans.[213] 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.[214]

Resistance policies have been criticized from a number of perspectives, even in the purely disaster-prevention context.[215] One is that they encourage development in the protected area, exposing more people and capital to risk if the infrastructure fails.[216] Another is that they are expensive and thus most likely to be used to protect affluent and politically powerful populations.[217] Resistance strategies often take the form of "hard" infrastructure, which almost inevitably comes with significant environmental impacts, from interruption of sand and sediment flows to blocked animal migration pathways to

210. *See* Ruhl, *supra* note 198, at 385–86; *see also* Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, *in* LAW OF ADAPTATION, *supra* note 25, at 235–37; Mach & Siders, *supra* note 39.

211. *Cf.* Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, *in* LAW OF ADAPTATION, *supra* note 25, at 240–50 (discussing the federal framework and implications of American fortification projects).

212. *See* Scott & Lennon, *supra* note 207, at 130–31, 142; *see also* Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, *in* LAW OF ADAPTATION, *supra* note 25, at 240.

213. *See* Aerts et al., *supra* note 208, at 474 (discussing New York City resistance strategies and costs); Baills et al., *supra* note 208, at 2 (evaluating coastal adaptation measures in the Aquitaine region of southwestern France).

214. *See* Katherine R. Clifford, Laurie Yung, William R. Travis, Renee Rondeau, Betsy Neely, Imtiaz Rangwala, Nina Burkardt & Carina Wyborn, *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) ("[R]esistance strategies become more labor-intensive and less effective over time.").

215. *See* Scott & Lennon, *supra* note 207, at 142 (criticizing "protection and accommodation" because they are "expensive and allow continued investment in vulnerable areas").

216. *See* Scott & Lennon, *supra* note 207, at 126–27 ("[T]hese houses [are] being accommodated in areas vulnerable to wildfires."); Robin Kundis Craig, *Coastal Adaptation, Government-Subsidized Insurance, and Perverse Incentives to Stay*, 152 CLIMATIC CHANGE 215, 220–24 (2019)(emphasizing that the National Flood Insurance Program facilitates "rebuilding in risky areas, rather than encouraging property owners to migrate inland").

217. Scott et al., *supra* note 207, at 130–31.

altered habitat.[218] This conventional approach conflicts with the growing advocacy for natural or "green" approaches, such as enhancing coastal wetlands.[219]

For 4°C climate adaptation, all of these objections to resistance strategies remain, with the added disincentive that the scale of necessary deployment presents staggering economic costs.[220] Resistance strategies, while likely necessary for many communities (at least in the short term), thus must be carefully planned to avoid spending excessive amounts of money[221] on infrastructure that exacerbates social inequity,[222] environmental degradation,[223] and disaster risk[224] and increases conflict among community adaptation strategies in order to provide local protection that lasts only a scant few years.[225]

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.[226] For example, there is no conceivable way a city could prevent ambient air temperatures from increasing or halt sea-level rise, but it could subsidize air conditioning to make

218. *See* Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, *in* LAW OF ADAPTATION, *supra* note 25, at 240–41.

219. *Id.* at 250–51. *See generally* Siddharth Narayan, Michael W. Beck, Borja G. Reguero, Iñigo J. Losada, Bregje van Wesenbeeck, Nigel Pontee, James N. Sanchirico, Jane Carter Ingram, Glenn-Marie Lange & Kelly A. Burks-Copes, *The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences*, PLOS ONE, May 2, 2016, at 5–6 (assessing the benefits of coastal restoration); Niki L. Pace, *Wetlands or Seawalls?—Adapting Shoreline Regulation to Address Sea Level Rise and Wetland Preservation in the Gulf of Mexico*, 26 J. LAND USE & ENV'T. L. 327, 340–41 (2011) (discussing the environmental benefits of using "living shorelines" to preserve wetlands).

220. 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. *See* Sverre LeRoy & Richard Wiles, *High Tide Tax: The Price to Protect Coastal Communities from Rising Seas*, CTR. FOR CLIMATE INTEGRITY 1 (2019) https://www.climatecosts2040.org/files/ClimateCosts2040_Report-v4.pdf [https://perma.cc/8NXV-7NLE].

221. *See id.*

222. *See* Scott & Lennon, *supra* note 207, at 126–27, 130–31.

223. *See* Pace, *supra* note 219, at 338–39.

224. *See* Scott & Lennon, *supra* note 207, at 142.

225. *See id.* at 142–44 (discussing the difficulties of planners and officials in implementing accommodation and retreat strategies in Florida communities).

226. *See* Ruhl, *supra* note 198, at 385–86; Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, *in* LAW OF ADAPTATION, *supra* note 25, at 239 (referring to adjustment); *see also* Mach & Siders, *supra* note 39, at 1294 (discussing accommodation measures to "reduce sensitivity to hazards").

indoor conditions more hospitable and adopt building and planning codes that integrate heat-conscious and flood-conscious design.[227] 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.[228] Such strategies can range from new forms of training to the conscious diversification of industry and other forms of income.[229]

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.[230] Technology-based resilience generally allows infrastructure to "bend rather than break" during natural disasters and includes homes elevated on stilts in coastal areas and architectural innovations that allow skyscrapers in earthquake-prone areas to sway.[231] Management strategies, in turn, change normal social and commercial functions in response to specific events or triggers,[232] such as when the Federal Emergency Management Agency (FEMA) activates new emergency supply chains and provides temporary housing in response to hurricanes.[233]

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.[234] Moreover, some new forms of resilience strategies are likely to be necessary for a 4°C future, from adaptive

227. *See generally* Sierra C. Woodruff, Sara Meerow, Missy Stults & Chandler Wilkins, *Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change*, J. PLAN. EDUC. & RSCH. 1, 2 (2018) ("Resilience plans generally take a more 'systems' or integrated approach to managing risk and are more participatory, which is consistent with theories of urban resilience.").

228. *See id.* at 1–3.

229. *See id.* at 8 (quoting city officials on how resilience "means tackling systemic, interdependent challenges, such as equitable access to quality education and jobs, housing security, community safety and vibrant infrastructure to better prepare us for shocks like earthquakes and stresses like climate change.").

230. *See id.* at 1–3.

231. *Cf.* Aerts et al., *supra* note 208, at 474 ("Implementing improved cost-effective building codes . . . such as elevating new buildings and protecting critical infrastructure by including adaptation measures into maintenance works—is the most cost-effective strategy.").

232. *See* Woodruff et al., *supra* note 227, at 1–3.

233. *Cf.* Craig, *supra* note 216, at 217 (discussing congressional passage of the National Flood Insurance Act as a supplement to federal disaster relief provided by FEMA.).

234. *See* Woodruff et al., *supra* note 227, at 1–3.

training in the health care sector in response to emerging health threats[235] to crop diversification in agriculture.[236] 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.[237] Nevertheless, resilience strategies are also subject to many of the same criticisms as resistance.[238]

3. Retreat

Retreat policies focus on intentionally abandoning areas subject to harms and relocating the people and structures to less vulnerable locations.[239] 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.[240] For example, sea

235. *See* Robin Kundis Craig, *Cleaning Up Our Toxic Coasts: A Precautionary and Human Health-Based Approach to Coastal Adaptation*, 36 PACE ENV'T L. REV. 1, 40–47 (2018); Robin Kundis Craig, *Oceans and Coasts*, *in* CLIMATE CHANGE, PUBLIC HEALTH, AND THE LAW 204, 220–22 (Michael Burger & Justin Gundlach eds., 2018); Robin Kundis Craig, *Cholera and Climate Change: Pursuing Public Health Adaptation Strategies in the Face of Scientific Debate*, 18 HOUS. J. HEALTH L. & POL'Y 29, 56–67 (2018).

236. *See* Rebecca Carter, Tyler Ferdinand & Christina Chan, *Transforming Agriculture for Climate Resilience: A Framework for Systemic Change* 1 (World Res. Inst., Working Paper No. 1, 2018) ("Beginning 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.").

237. Clifford et al., *supra* note 214, at 616.

238. *See* Scott & Lennon, *supra* note 207, at 130–31. *See generally* Shalanda H. Baker, *Anti-Resilience: A Roadmap for Transformational Justice Within the Energy System*, 54 HARV. C.R.-C.L. L. REV. 1, 25–37 (2019) (challenging how resilience has been pursued as a goal in energy policy).

239. *See* Ruhl, *supra* note 198, at 388–89; Robert R.M. Verchick & Joel D. Scheraga, *Protecting the Coast*, *in* LAW OF ADAPTATION, *supra* note 25, at 239; Mach & Siders, *supra* note 39. 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 25, at 267–306.

240. *See* John Carey, *Managed Retreat Increasingly Seen as Necessary in Response to Climate Change's Fury*, 117 PROC. NAT. ACAD. SCI. 13182, 13183–85 (2020); 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. ENV'T MGMT. 109753, 109753–54 (2020); Miyuki Hino, Christopher B. Field & Katharine J. Mach, *Managed Retreat as a Response to Natural Hazard Risk*, 7 NATURE CLIMATE CHANGE 364, 364–65 (2017); Andrea McArdle, *Managing "Retreat": The Challenges of Adapting Land Use to Climate Change*, 40 U. ARK. LITTLE ROCK L. REV.

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.[241] Inland, areas on the wildland-urban interface may experience more frequent and intense wildfires that cannot be adequately prevented and controlled.[242] 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.[243] As a result, "[r]etreat has often been viewed as a failure to adapt or considered only when all other options are exhausted."[244]

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, ideally well before the harms become significant.[245] Moreover, as Mach and Siders point out, careful deliberation about and planning of retreat can transform this putative failure into "an adaptive option that can proactively support social values through a plurality of specific measures," not only reducing risk but simultaneously increasing social equity and increasing economic efficiency.[246] Nevertheless, although voluntary post-disaster retreat programs have been implemented in various locations in the United States,[247] Mach and Siders' vision of "pre-emptive" retreat—retreat forced and managed in *anticipation* of conditions that will eventually exceed the capacity of resistance and resilience strategies[248]—has not yet been widely implemented anywhere in the United States and surely would face stiff pushback from

605, 618–24 (2018); A.R. Siders, *Managed Retreat in the United States*, 1 ONE EARTH 216, 216–19 (2019).

241. Scott & Lennon, *supra* note 207, at 131.

242. Carey, *supra* note 240, at 13183.

243. *See id.* at 13182–85.

244. Mach & Siders, *supra* note 39 (citations omitted).

245. *See* Carey, *supra* note 240, at 13182–85; *see also* Byrne & Grannis, *supra* note 239, at 268 ("Local governments will be the primary actors in implementing retreat policies.").

246. Mach & Siders, *supra* note 39.

247. *See generally* Katie Spidalieri & Jessica Grannis, *Managing the Retreat from Rising Seas*, GEO. CLIMATE CTR. (2020), https://www.georgetownclimate.org/files/MRT/GCC_20_Taholah-3web.pdf [https://perma.cc/88F5-KSVQ] (providing a series of 17 examples).

248. *See* Gibbs, *supra* note 46, at 108.

many interests, not just the people being relocated.[249] There is a long history of forced relocations in the United States and elsewhere, and they have almost always been controversial.[250] Even when relocation is the only alternative and relocations are provided within the same general area, it disrupts community and culture.[251]

Despite these realities and political resistance, 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.[252] Moreover, retreat is increasingly recognized as a potentially creative mode of adaptation that can not only respond to a variety of climate change-induced risks but also accommodate a variety of social values, including increased equity.[253] While retreat is more difficult to implement for conservation lands, which have fixed boundaries,[254] proposals for migratory conservation spaces do exist,[255] and assisted migration—the

249. *See id.* at 107–08, 111 ("Political hazard and risk can emerge . . . with the preemptive retreat option for owners of high-value foreshore properties, who may feel like they are being forcibly relocated to avoid some ambiguous future risk."); Siders, *supra* note 240, at 218 ("Managed retreat has been limited in the US by numerous barriers."). 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 736, 737 (2020) (presenting a case study of New Zealand and indicating that "attempts to implement managed retreat invoke public dispute and litigation"); 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 REPS. 66, 68–70 (2020) (discussing barriers to pre-emptive retreat implementation); Mach & Siders, *supra* note 39, at 1294, 1295–96 (presenting a general survey of frequency and types of retreat globally and discussing challenges to implementation).

250. Carey, *supra* note 240, at 13182–83; Hino et al., *supra* note 240 (indicating that "[o]ver the past three decades, approximately 1.3 million people have relocated through managed retreat" (citation omitted)).

251. Carey, *supra* note 240, at 13184–85; Hino et al., *supra* note 240, at 364–65; Hanna et al., *supra* note 249.

252. Carey, *supra* note 240, at 13183.

253. Mach & Siders, *supra* note 39, at 1296–99.

254. *See generally* Clifford et al., *supra* note 214, at 614–17 (discussing approaches to climate adaptation on public land).

255. Notably, however, most of the proposals focus on the ocean, where private property is far less of a barrier. *See* ROBIN KUNDIS CRAIG, COMPARATIVE OCEAN GOVERNANCE: PLACE-BASED PROTECTIONS IN AN ERA OF CLIMATE CHANGE 155–69 (2012) (discussing anticipatory and dynamic zoning); Josh Eagle, James N. Sanchirico & Barton H. Thompson, Jr., *Ocean Zoning and Spatial Access Privileges: Rewriting the Tragedy of the*

translocation of species from degrading habitats to existing or emerging suitable habitats—can be thought of as a form of managed retreat.[256]

However, it is important to remember throughout this discussion of human adaptation responses that *ecosystems* are already both changing compositionally and shifting geographically—that is, transforming and retreating.[257] As such, ecological change all by itself is increasingly likely to perturb long-established social-ecological relationships, whether those be ranching communities in Montana,[258] sportfishing-dependent communities in Wisconsin,[259] or salmon-focused Tribes in the Pacific Northwest.[260]

B. THE THREE RS VERSUS 4°C

Current adaptation policy proposes deploying the Three Rs to manage the key drivers of adaptation need.[261] 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, with place-based security for people and property the overarching goal.[262] Of course, it makes sense that a city's or region's

Regulated Ocean, 17 N.Y.U. ENV'T L.J. 646, 651–65 (2008) (discussing "the application of comprehensive zoning to U.S. ocean space").

256. *See* Jedediah F. Brodie, Susan Lieberman, Axel Moehrenschlager, Kent H. Redford, Jon Paul Rodríguez, Mark Schwartz, Philip J. Seddon & James E. M. Watson, *Global Policy for Assisted Colonization of Species*, 372 SCIENCE 456 (2021); Alejandro E. Camacho, *Assisted Migration: Redefining Nature and Natural Resource Law Under Climate Change*, 17 YALE J. ON REGUL. 171, 202–10 (2010).

257. *See* Camacho, *supra* note 256, at 228 (emphasizing that ecological management should account for that character of "perpetually changing ecological communities").

258. *See* Anne Cantrell, *MSU Study: Climate Change Generating Anxiety and Distress for Montana Farmers, Ranchers*, MONT. STATE U. (Apr. 23, 2020), https://www.montana.edu/news/19885/msu-study-climate-change-generating-anxiety-and-distress-for-montana-farmers-ranchers [https://perma.cc/7UT4-HAKB].

259. *See* Elizabeth Weise, *Global Warming Could Mean Fewer Fish for Sport Fishing, More Die-Offs Across US*, USA TODAY (July 9, 2019), https://www.usatoday.com/story/news/nation/2019/07/09/global-warming-killing-fish-hurting-sportfishing-industry/1675771001 [https://perma.cc/VX63-9RMT].

260. *See Salmon and Climate Change*, TULALIP TRIBES NAT. RES. DEP'T (2017), https://nr.tulaliptribes.com/Topics/ClimateChange/SalmonAndClimateChange [https://perma.cc/Q2DQ-DA3C].

261. *See* 2014 U.S. Climate Impact Report, *supra* note 181, at 201–02, 671–706 (discussing "[a]daptation in the context of biodiversity and natural resource management"); *Adapt Now*, *supra* note 202, at 9–11, 19–21, 31–34.

262. *See* Mach & Siders, *supra* note 39 ("To date, managed retreat projects have

adaptation plan would focus on managing adaptation needs of the city or region.[263] 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.[264] 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.[265] 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.[266]

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,[267] even to the point of envisioning "future-proofing" or "climate-proofing" cities and regions.[268] Managed retreat has

been largely incremental, minor adjustments implemented using a handful of policy tools, guided by a limited set of social values, and small scale in their contributions to climate change adaptation."); Sara Hughes, *A Meta-Analysis of Urban Climate Change Adaptation Planning in the U.S.*, 14 URB. CLIMATE 17, 23 (2015) ("[U]rban adaptation planning is primarily framed as, and motivated by, the need to protect valuable assets and reduce the city's vulnerability."); Robert W. Kates, William R. Travis & Thomas J. Wilbanks, *Transformational Adaptation When Incremental Adaptations to Climate Change are Insufficient*, 109 PROC. NAT. ACAD. SCI. 7156, 7156 (2012).

263. *See generally Adapt Now*, *supra* note 202, at 27 ("[A] climate-smart approach requires packages of measures tailored to local conditions").

264. *See* THE PRESIDENT'S CLIMATE ACTION PLAN, EXEC. OFF. PRESIDENT 12 (June 2013), https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf [https://perma.cc/3HCJ-NR7Z]. President Trump rescinded the plan and provided no replacement. Exec. Order No. 13,783, 82 Fed. Reg. 16,093, 16,094 (Mar. 28, 2017).

265. Exec. Order No. 14,008, 86 Fed. Reg. 7,619 (Jan. 27, 2021) [hereinafter BIDEN CLIMATE CHANGE E.O.].

266. The Executive Order, for example, mentions adaptation only in section 211. *Id.* at 7619–22, 7625–26.

267. *See generally* Kates et al., *supra* note 262 ("We think of incremental adaptations to change in climate as extensions of actions and behaviors that already reduce the losses or enhance the benefits of natural variations in climate and extreme events."); Scott & Lennon, *supra* note 207, at 142 ("Florida officials . . . have most often taken the short-term view of 'engineering' resilience . . . or sometimes to accommodate development to the hazard." (citations omitted)). This is by no means limited to the United States. *See* Justine Bell & Mark Baker-Jones, *Retreat from Retreat—The Backward Evolution of Sea-Level Rise Policy in Australia, and the Implications for Local Government*, 19 LOC. GOV'T L.J. 23, 24–30 (2014) (describing a shift in policy "towards greater regulation and control of development in coastal areas").

268. *See Eye of the Storm*, REBUILD TEX. 154–57 (2018), https://www.rebuildtexas.today/wp-content/uploads/sites/52/2018/12/12-11-18-EYE-OF-THE-

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.[269] 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.[270] For conservation resources, moving is generally not an option, so staying put means dealing with transformation through resist strategies (such as removing invasive species[271]) and resilience strategies (such as managing fire fuel sources[272]), 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.[273]

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.[274] Nevertheless,

STORM-digital.pdf [https://perma.cc/3GN2-TL3R] (adopting the "future-proofing" theme); *The EU Strategy on Adaptation to Climate Change*, EUR. COMM'N 2 (2013), https://ec.europa.eu/clima/system/files/2016-11/eu_strategy_en.pdf [https://perma.cc/MMV5-JJW4] (adopting the "climate-proofing" theme in Action 6).

269. *See generally* Gibbs, *supra* note 46, at 107–08 (discussing the characteristics and implementation of pre-emptive, just-in-time, and reactive retreat); Siders, *supra* note 240, at 217–18 (citing the benefits and obstacles of managed retreat).

270. *See generally* Kates et al., *supra* note 262, at 7156–59 ("Conceptions of self-identity and sense of place and preferences for stability over disruption make relocation very difficult.").

271. *See* 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 BIOLOGICAL INVASIONS 233, 233–34 (2020) (seeking "to facilitate proactive invasive species management that also accounts for climate change"); *see also* Eric V. Hull, *Climate Change and Aquatic Invasive Species: Building Coastal Resilience Through Integrated Ecosystem Management*, 25 GEO. INT'L ENV'T L. REV. 51, 82–93 (2012).

272. *See* P.M. Fernandes, *Forest Fuel Management for Fire Mitigation Under Climate Change*, *in* FOREST MANAGEMENT OF MEDITERRANEAN FORESTS UNDER THE NEW CONTEXT OF CLIMATE CHANGE: BUILDING ALTERNATIVES FOR THE COMING FUTURE 31, 33–37 (Manuel Esteban Lucas-Borja ed., 2013).

273. *See* 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 ECOLOGY & SOC'Y, 2020, at 2–5; David G. Angeler & Craig R. Allen, *Quantifying Resilience*, 53 J. APPLIED ECOLOGY 617, 618 (2017) (eroding an ecosystem's resilience causes it to change more easily with the changing climate).

274. *See generally* Clifford et al., *supra* note 214, at 616 (discussing barriers to transformation adaptation strategies among public land managers).

climate adaptation policy has generally not peered into the world beyond 2°C.[275] 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.[276] 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?[277] 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.[278]

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 Hemisphere nations like the United States.[279] It is tempting to believe, therefore, that if the planet warms beyond 2°C the Three Rs will

275. *See generally 2018 IPCC 1.5°C Report*, *supra* note 23, at 5 (focusing on a 1.5°C future but mentioning 2°C implications).

276. *See id.* (providing an overview of the potential impacts and risks associated with climate change); 2014 U.S. Climate Impact Report, *supra* note 181, at 25 (discussing a "wider range of potential changes in global average temperature in the latest generation of climate model simulations").

277. Notably, however, in 2014 a group of interdisciplinary researchers from Australia did take the idea of a 4°C future seriously enough to examine what it would mean for Australia. *See* FOUR DEGREES OF GLOBAL WARMING: AUSTRALIA IN A HOT WORLD, *supra* note 68. 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. *See, e.g.*, Laurence Caramel, *Besieged by the Rising Tides of Climate Change, Kiribati Buys Land in Fiji*, GUARDIAN (U.K.) (June 30, 2014), https://www.theguardian.com/environment/2014/jul/01/kiribati-climate-change-fiji-vanua-levu [https://perma.cc/4UM6-GCG5]; Helen Dempster & Kayly Ober, *New Zealand's "Climate Refugee" Visas*, DEV. POL'Y CTR.: DEVPOLICY BLOG (Jan. 31, 2020), https://devpolicy.org/new-zealands-climate-refugee-visas-lessons-for-the-rest-of-the-world-20200131 [https://perma.cc/NTB6-WLR5]. 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.

278. Hauer, *supra* note 192 (emphasizing the absence of scholarship modeling how sea level rise "is expected to reshape the US population distribution").

279. 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.

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.[280] The Three Rs as currently modeled and integrated into "future-proofing" policies do not consider runaway interacting positive feedback loops, cascade effects in the climate system, and the impacts they will have on social-ecological systems.[281] 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.[282]

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 those herculean efforts might fail), and locally managed retreat is pointless when there is no place locally that is out of harm's way.

280. *See* Steffen et al., *supra* note 8, at 8254–56.

281. *See generally* GOVERNOR'S COMM'N TO REBUILD TEX., *supra* note 268 (discussing the implementation of "future-proofing" in Texas).

282. Kates et al., *supra* note 262, at 7158 ("Transformational adaptation could . . . be driven by severe climate change [including] changes beyond the likely range of current assessments, local 'hot spots' where global change is amplified, or tipping points that cause rapid climate change impacts in certain regions or globally"); *see also* Kirstin Dow, Frans Berkhout & Benjamin L. Preston, *Limits to Adaptation to Climate Change: A Risk Approach*, 5 CURRENT OP. ENV'T SUSTAINABILITY 384, 385–86 (2013) ("[Concepts] such as tipping points and key vulnerabilities imply that climate change impacts may overwhelm society's capacity to respond to avoid significant harm."); Alark Saxena, Kristin Qui & Stacy-Ann Robinson, *Knowledge, Attitudes and Practices of Climate Adaptation Actors Towards Resilience and Transformation in a 1.5°C World*, 80 ENV'T SCI. & POL'Y 152, 157–58 (2018); Giacomo Fedele, Camila I. Donatti, Celia A. Harvey, Lee Hanna & David G. Hole, *Transformative Adaptation to Climate Change for Sustainable Social-Ecological Systems*, 101 ENV'T SCI. & POL'Y 116, 116–20 (2019); Tyler Felgenhauer, *Addressing the Limits to Adaptation Across Four Damage-Response Systems*, 50 ENV'T SCI. & POL'Y 214, 214–15 (2015).

In short, adaptation in essence is a form of risk management.[283] 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.[284] It follows that a new kind of risk-management mode—one that is both anticipatory and transformative—will be needed.

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.[285] 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.[286] 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 goals of adaptation. As discussed in Part II.C, even within the United States we can expect massive human migrations and massive species migrations.[287] We can expect relocation of agricultural crop and livestock lands.[288] We can expect extensive, expensive infrastructure projects to supply housing, water, transportation, and other needs for new and expanding human communities.[289] We can expect deep disruptions to

283. Felgenhauer, *supra* note 282, at 220 ("[O]ver long timeframes mitigation and adaptation are complementary tools of climate change risk management.").

284. *See* Felgenhauer, *supra* note 282, at 215 ("[A] 4°C change[] will bring increasingly severe impacts that may surpass society's ability to adapt.").

285. *See* Kates et al., *supra* note 262, at 7159 ("In sustaining transformational adaptation, it seems likely that supportive social contexts, especially if they are combined with incentives, and the availability of acceptable options and resources for actions are key enabling factors.").

286. *See id.*

287. *See* Hauer, *supra* note 192, at 321 ("[U]nmitigated [sea level rise] is expected to reshape the US population distribution.").

288. *See* 2014 U.S. Climate Impact Report, *supra* note 181, at 150–74.

289. *Id.* at 89–90, 114, 131.

insurance, finance, welfare, and other social and economic systems.[290] 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.[291] 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.[292] 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-looking dimension captures the interconnectedness of climate change adaptation at the national scale and its influence on local, state, and regional planning.[293]

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 a national scale to support local and regional scales. However, if some regions of the nation are literally shutting down and the people leaving,

290. *See* CLIMATE-RELATED MKT. RISK SUBCOMM., MANAGING CLIMATE RISK IN THE U.S. FINANCIAL SYSTEM 25–27 (2020); Beatrice Crona, Carl Folke & Victor Galaz, *The Anthropocene Reality of Financial Risk*, 4 ONE EARTH 618, 618–20 (2021).

291. *See generally* Kates, *supra* note 262 ("In some places . . . vulnerabilities and risks may be so sizeable that they can be reduced only by novel or dramatically enlarged adaptation.").

292. *See generally* Hauer, *supra* note 192, at 321 ("[U]nmitigated [sea level rise] is expected to reshape the US population distribution.").

293. *See* Warren, *supra* note 185, at 218–19.

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 be 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 everything that goes with them.

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.[294] 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.[295] 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.[296] 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 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.

294. *See infra* Part IV.A.

295. *See generally* Warren, *supra* note 185, at 227 (addressing climate change affects "[c]onsidering the large impacts in the agricultural, hydrological and ecosystem sectors expected in a 4°C world").

296. *See 2018 IPCC 1.5°C Report*, *supra* note 23, at 4–6 ("Estimated anthropogenic 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.").

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 4°C; indeed, despite the global pandemic, 2020 tied for the hottest year on record (with 2016), with global average temperatures reaching 1.25°C higher than in pre-industrial times.[297] Australian researchers have already concluded 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 . . . to a Four Degree World."[298] 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 2°C. The issue then becomes: what can the United States do *now* to facilitate the survival of democratic governance in a 4°C world?

The United States (like the rest of the world's governments) will increasingly be dealing with transformational change.[299] This governance challenge will likely last until sometime long after atmospheric concentrations of greenhouse gases finally stabilize.[300] 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 4°C warming for conceptualizing the governance of redesign

297. Paul Voosen, *Global Temperatures in 2020 Tied Record Highs*, 371 SCIENCE 334, 334 (2021).

298. Christoff, *supra* note 68.

299. *See generally* Kates et al., *supra* note 262 (discussing transformational adaptation needs).

300. 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 4°C, rendering the concept of nation states potentially unworkable.

adaptation is massive human migration within the United States.[301] This focus includes both the attendant needs of that migration (for example, infrastructure, social reorganization, economic stabilization, food and water security, health care adjustments) and its attendant impacts (for example, competition with species and ecosystems that are also moving and transforming, competition with agricultural land, abandoned infrastructure and toxic contamination, energy consumption, and social and economic disruption).[302] 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.[303] 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 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.[304]

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 systems northward and inward,[305] while simultaneously preserving (or opening up) lands for agriculture, species habitat, and migration corridors.[306] Preservation of a functional democracy at the same time imposes two additional requirements on how the United States 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

301. *See generally* Warren, *supra* note 185, at 228 (discussing cross-regional migration resulting from 4°C warming consequences).

302. *Id. See generally* Fan et al., *supra* note 194 (assessing "the regional economic impacts of climate-change-induced migration" in the United States).

303. *See* Hauer, *supra* note 192, at 323 ("[M]any inland communities could see tens of thousands of [sea-level rise] . . . migrants, and many coastal communities could lose tens of thousands of residents.").

304. *See generally 2018 IPCC 1.5°C Report*, *supra* note 23.

305. *See* Hauer, *supra* note 192, at 323 ("[M]any inland communities could see tens of thousands of [sea-level rise] . . . migrants, and many coastal communities could lose tens of thousands of residents.").

306. *See generally* Warren, *supra* note 185, at 228–32 (discussing climate change effects on migration, land-use, and ecosystems).

changes must be equitable, ensuring the health, safety, and, ideally, prospering of the United States' most vulnerable communities rather than simply exacerbating existing inequalities.[307]

That leaves two last questions. First, how should the United States finance this massive scale of social and economic transformation? Second, who's in charge?[308] 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 4°C 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.[309] 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.

307. 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?*, ANTHROPOLOGY FOOD S5, Sept. 2009, at ¶ 31; Wendy Moore, *Oh! What a Lovely Diet*, GUARDIAN (U.K.) (Jan. 13, 2001), https://www.theguardian.com/theobserver/2001/jan/14/life1.lifemagazine5 [https://perma.cc/974K-7E2B] ("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.").

308. For a comprehensive survey of climate change adaptation federalism focused on the three Rs of adaptation, see Robert L. Glicksman, *Climate Change Adaptation: A Collective Action Perspective on Federalism Considerations*, 40 ENV'T L. 1159 (2010), providing a framework for determining how to structure a policy to facilitate adaptation to climate change that assigns appropriate roles to all levels of government. *See also* ALEJANDRO E. CAMACHO & ROBERT L. GLICKSMAN, REORGANIZING GOVERNMENT: A FUNCTIONAL AND DIMENSIONAL FRAMEWORK 197–205 (2019).

309. Notably, President Biden's Climate Change Executive Order creates the White House Office of Domestic Climate Policy and National Climate Task Force to serve these 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 265, at §§ 102(f), 202, 203.

Which takes us to our second point about governance for 4°C. 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 possesses a governance toolbox that is both wide and deep, developed from an ongoing willingness to experiment with governance institutions and 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.[310] Administrative law is a largely twentieth-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.[311] 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 4°C 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 4°C nation will be easy. The remainder of this Part explores

310. *E.g.*, Carpenter v. United States, 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, 386–401 (2014) (holding that police officers needed a warrant to search through defendants' cell-phone data); Katz v. United States, 389 U.S. 347, 353 (1967) (holding that FBI agents violated the Fourth Amendment expectation of privacy when they used an electronic listening device to listen to a phone booth conversation).

311. *E.g.*, Administrative Procedure Act, 5 U.S.C. §§ 551–559, 701–706 (governing the ways in which federal administrative agencies may issue regulations and providing standards for judicial review of agency actions).

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.

Critical to our conception here is that what is possible politically along the path to a 4°C world will change both progressively and in punctuated bursts in response to new realities, as was the case during the Great Depression,[312] World War II,[313] the Civil Rights Movement,[314] and COVID-19.[315] Thus, the fact that a potential redesign adaptation measure would be politically impossible to implement *now* should pose no barrier to its full theoretical development *now*, positioning it to be ready for the moment when it becomes both politically feasible and desperately needed (the former largely because of the latter).

A. DIFFERENT MODES OF CHANGE: A PLANNING TYPOLOGY FOR REDESIGN

Part II presented a blizzard of predictions about what can be expected in a 4°C world. At a macro scale—albeit a grossly simplified

312. *See generally* Myron P. Gutmann, Daniel Brown, Angela R. Cunningham, James Dykes, Susan Hautaniemi Leonard, Jani Little, Jeremy Mikecz, Paul W. Rhode, Seth Spielman & Kenneth M. Sylvester, *Migration in the 1930s: Beyond the Dust Bowl*, 40 SOC. SCI. HIST. 707 (2016) (mapping out different migration patterns).

313. *Social Changes During the War*, DIGIT. HIST., https://www.digitalhistory.uh.edu/disp_textbook.cfm?smtID=2&psid=3493 [https://perma.cc/3QD2-WY5Q] (tracking migration north to cities and west to California, and social changes for women, African Americans, and Mexican Americans).

314. *Civil Rights Movement*, HISTORY (May 17, 2021), https://www.history.com/topics/black-history/civil-rights-movement [https://perma.cc/6BUY-5R8Y] (explaining the changes brought by social movements and Civil Rights Acts of the 1950s and 1960s).

315. Manuel Arias, *Social Changes in a Post-COVID World—Opportunities and Challenges for PAOs*, INT'L FED'N ACCTS. (May 4, 2020), https://www.ifac.org/knowledge-gateway/developing-accountancy-profession/discussion/social-changes-post-covid-world-opportunities-and-challenges-paos [https://perma.cc/35X9-KA5U] (cataloging the daily social changes made in the wake of the COVID-19 crisis).

one—the forces of change 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 migration to illustrate the three different change modes. Migration, after all, is a form of adaptation,[316] and environmental change has long been a driver of human migration.[317]

The decision to migrate or stay in the face of a climate-induced threat such as sea level rise is influenced by a complex interaction of economic, environmental, political, demographic, and social forces.[318] 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.[319]

Collectively, McLeman's six stages embody the three modes of change resulting from climate-change-induced human migration that we want to emphasize here. Baseline linear change remains the dominant mode of migration in stages 1–3 of his model, which might look little different from current baseline population movement patterns in the United States, perhaps with origins and destinations shifted. Nonlinear change begins in McLeman's stage 4 and continues into stage 5, when in situ adaptation fails, which is the stage that represents the start of our real concerns for 4°C adaptation.[320] Finally, in McLeman's stage 6, cascade change becomes the dominant mode, during which human migration sets in motion numerous other system changes.[321] This Section examines each of these three change modes in turn.

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316. 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 25, at 693–729.

317. *E.g.*, Myron P. Gutmann & Vincenzo Field, *Katrina in Historical Context: Environment and Migration in the U.S.*, 31 POPULATION & ENV'T 3, 5–6 (2010) (looking at demographic changes as a result of hurricanes in the U.S.).

318. *See* Mathew E. Hauer, Elizabeth Fussell, Valerie Mueller, Maxine Burkett, Maia Call, Kali Abel, Robert McLeman & David Wrathall, *Sea-Level Rise and Human Migration*, 1 NATURE REVS. EARTH & ENV'T 28, 29 (2020).

319. Robert McLeman, *Thresholds in Climate Migration*, 39 POPULATION & ENV'T 319, 319 (2018).

320. *Id.* at 324.

321. *Id.* at 325–26.

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.[322] 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.[323] Nevertheless, over long time frames, baseline population migration and other incremental, linear changes can produce significant macro-level change; for example, the ranking of U.S. cities by population since the 1700s exhibits a massive reshuffling.[324] 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.[325]

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. baseline migration pattern, but in ways that have not yet surfaced at the macro-scale into policy concerns.[326]

2. Nonlinear Change

Climate change already is having effects that depart from baseline linear change and that, over time, will shift the entire envelope of variability for phenomena such as storm intensity.[327] Similarly,

322. *See* Andrew C. Kemp & Benjamin P. Horton, *Contribution of Relative Sea-Level Rise to Historical Hurricane Flooding in New York City*, 28 J.Q. SCI. 537, 539 (2013) (charting linear sea-level rise since 1775); *see also* Syun-Ichi Akasofu, *On the Present Halting of Global Warming*, 1 CLIMATE 4, 5 (2013) (indicating a near-linear trend in global warming); John P. McCarty, *Ecological Consequences of Recent Climate Change*, 15 CONSERVATION BIOLOGY 320, 323 (2001) (cataloguing effects of climate change on various species).

323. *See* Raven Molloy, Christopher L. Smith & Abigail Wozniak, *Internal Migration in the United States*, 25 J. ECON. PERSPS. 173, 174 (2011) (charting interstate migration rates from 1900 to 2010).

324. *Historical Metropolitan Populations of the United States: Graph of Metro Area Population Rank Over Time*, PEAKBAGGER.COM, https://www.peakbagger.com/pbgeog/histmetropop.aspx [https://perma.cc/CP69-NXPX].

325. Leighton, *supra* note 316, at 693–94.

326. *See* McLeman, *supra* note 319, at 326–27.

327. Robin Kundis Craig, *"Stationarity Is Dead"—Long Live Transformation: Five*

population migration in the United States has never been purely a baseline linear phenomenon; instead, episodes of amplified, purposeful migration have 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.[328] In the 1900s, the migration of Black Americans from the South to the North, Midwest, and West shifted over six million people between 1915 and 1970.[329] 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.[330]

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.[331] 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 well into the interior of the nation.[332] 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

Principles for Climate Change Adaptation Law, 34 HARV. ENV'T L. REV. 9, 23–27 (2010); P.C.D. Milly, Julio Betancourt, Malin Falkenmark, Robert M. Hirsch, Zbigniew W. Kundzewicz, Dennis P. Lettenmaier & Ronald J. Stouffer, *Stationarity Is Dead: Whither Water Management?*, 319 SCIENCE 573, 573–74 (2008).

328. 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 SERV., https://www.nps.gov/parkhistory/resedu/settlement.htm [https://perma.cc/CK8U-XJDX].

329. ISABEL WILKERSON, THE WARMTH OF OTHER SUNS: THE EPIC STORY OF AMERICA'S GREAT MIGRATION 8–16 (2010).

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

331. *See* Hauer, *supra* note 192.

332. Caleb Robinson, Bistra Dilkina & Juan Moreno-Cruz, *Modeling Migration Patterns in the USA Under Sea Level Rise*, 15 PLOS ONE, Jan. 22, 2020 at 8–11; Daniel C. Vock, *Climate Migrants Are on the Move: Which Cities Need to Plan for Population Booms?*, PLANNING (Jan. 1, 2021), https://www.planning.org/planning/2021/winter/climate-migrants-are-on-the-move [https://perma.cc/3QGG-NVL7].

in other regions stress housing supply, employment opportunity, and infrastructure capacity.[333]

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, with classic cases being the Dust Bowl migration of the 1930s and the post-Katrina relocation out of the New Orleans area.[334] Both of these migratory cascades occurred over short timeframes 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 it led afterwards to "a greatly expanded participation of government in land management and soil conservation."[335] It would be naïve to fail to anticipate similar sudden onset migration cascades on the way to a 4°C 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 prodding, and preemption and mandates. We suggest how specific examples of each mode could guide policy design in the 4°C adaptation context.

1. Laissez-Faire

Faith in the invisible hand of the market is never far from the surface of contemporary 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 4°C 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

333. Fan et al., *supra* note 194 (exploring the effects of population redistribution due to climate change on housing, wages, and labor demands in the United States).

334. McLeman, *supra* note 319, at 324–27; 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 & ENV'T 417, 429, 433–34 (2014).

335. McLeman et al., *supra* note 334, at 429.

water-constrained locations.[336] Such municipal and state business plans might simultaneously encourage voluntary migrants to reoccupy 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 futures market to reduce local risks of drought began trading in December 2020,[337] and from increasing investor interest in marketing Colorado River water.[338]

Existing markets will also respond to climate change, sending signals that larger change is near. For example, John R. 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."[339] 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.[340]

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

336. Steven R. Strahler, *How Chicago's Enviable Water Supply Could Lure Future Business*, CHI. BUS. (Sept. 26, 2019), https://www.chicagobusiness.com/crains-forum-water/how-chicagos-enviable-water-supply-could-lure-future-business [https://perma.cc/QS7C-EC9F]; Rachael Gleason & Laura Fosmire, *How Should 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 [https://perma.cc/5SQY-4PCV].

337. Kim Chipman, *California Water Futures Begin Trading Amid Fear of Scarcity*, BLOOMBERG GREEN (Dec. 7, 2020), https://www.bloomberg.com/news/articles/2020-12-06/water-futures-to-start-trading-amid-growing-fears-of-scarcity [https://perma.cc/H8CL-MJ2H].

338. Ben Ryder Howe, *Wall Street Eyes Billions in the Colorado's Water*, N.Y. TIMES (Jan. 3, 2021), https://www.nytimes.com/2021/01/03/business/colorado-river-water-rights.html [https://perma.cc/Q3AL-YWAF].

339. John R. Nolon, *Land Use and Climate Change Bubbles: Resilience, Retreat, and Due Diligence*, 39 WM. & MARY ENV'T L. & POL'Y REV. 321, 323–24, 325–27 (2015).

340. Daniel Cusick, *Flood Risks to Low-Income Homes to Triple by 2050*, SCI. AM. (Dec. 1, 2020), https://www.scientificamerican.com/article/flood-risks-to-low-income-homes-to-triple-by-2050 [https://perma.cc/LS9B-8CGH] (detailing the factors that leave lower-income renters "trapped in properties with rising disaster risk"); *see also* JOHN R. NOLON, CHOOSING TO SUCCEED: LAND USE LAW & CLIMATE CONTROL 1–18 (2021) (expanding the discussion of climate bubbles and describing how low income families struggled to rebuild after storms while wealthier developers bought and flipped damaged homes).

premiums, and they have already sued governments that have made their losses worse by failing to build climate change resilience into local infrastructure.[341] 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[342] and hurricane damage along the Gulf.[343] After the disastrous hurricane season of 2004–2005, companies providing homeowners insurance left the Florida market in droves.[344] Insurance companies are similarly poised to stop issuing wildfire insurance in California, discontinuing hundreds of thousands of policies in 2019 and 2020.[345] Clearer pre-collapse warnings that in situ adaptation may be becoming untenable in these locations are difficult to conceive.

Private insurance market signals will be most effective, however, if federal and state governments do not intervene. Unfortunately, evidence to date indicates that politics will produce exactly the opposite result. Private insurance companies long ago gave up on 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.[346] Similarly, instead of listening to the market, the State of Florida stepped in to fill the 2005 insurance void, and homeowners'

341. Ari Phillips, *In Landmark Class Action, Farmers Insurance Sues Local Governments for Ignoring Climate Change*, THINKPROGRESS (May 19, 2014), https://archive.thinkprogress.org/in-landmark-class-action-farmers-insurance-sues-local-governments-for-ignoring-climate-change-19c31eef042e [https://perma.cc/K9A7-SXN9].

342. Christopher Flavelle, *California Bars Insurers from Dropping Policies in Wildfire Areas*, N.Y. TIMES (Nov. 5, 2020), https://www.nytimes.com/2020/11/05/climate/california-wildfire-insurance.html [https://perma.cc/VD64-VX7Y].

343. Rebecca Moybray, *Five Years After Hurricane Katrina, Home Insurance Prices Remain Astronomical*, NOLA.COM (June 25, 2019), https://www.nola.com/news/business/article_a6b466ee-28c4-5096-a6bf-0baa7565bd98.html [https://perma.cc/83TV-N6VS].

344. Ed Leefeldt, *Why Is Homeowners Insurance in Florida Such a Disaster?*, FORBES ADVISOR (Mar. 26, 2021), https://www.forbes.com/advisor/homeowners-insurance/why-is-homeowners-insurance-in-florida-such-a-disaster [https://perma.cc/4RZF-SRSJ].

345. Khristopher J. Brooks, *California Insurers are Dropping Homeowners Threatened by Wildfires*, CBS NEWS (Oct. 21, 2020), https://www.cbsnews.com/news/california-wildfires-home-insurers-dropping-homeowners [https://perma.cc/8N6W-SERG].

346. 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).

insurance in Florida remains a “disaster” fifteen years later.[347] Most recently, the California Legislature instituted a one-year freeze in November 2020, prohibiting insurance companies from discontinuing wildfire policies.[348]

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.[349] Such creative approaches to disaster insurance would both facilitate migration as it becomes necessary and ensure that the nation’s most vulnerable citizens are not 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 4°C nation.

a. Planning

If the discussions in Parts III and IV suggest anything, it is that redesign adaptation for a 4°C 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 a proper

347. Leefeldt, *supra* note 344.
348. Flavelle, *supra* note 342.
349. Craig, *supra* note 216.

governmental function, from land use planning and zoning on land[350] to marine spatial planning in the ocean.[351] 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[352]—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' penultimate Report Card on America's Infrastructure, in 2017, gave the nation's infrastructure an overall grade of D plus;[353] by 2021, it had improved only slightly to a C minus.[354] 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.[355] President Biden's January 2021 Climate Change Executive Order also included a substantial commitment to

350. *See* Village of Euclid v. Ambler Realty Co., 272 U.S. 365, 386–90, 395 (1926) (upholding the validity of local government zoning). *See generally* Fukuo Akimoto, *The Birth of 'Land Use Planning' in American Urban Planning*, 24 PLAN. PERSPS. 457 (2009) (tracing the development of urban land use planning in the United States into its broad acceptance in the 1950s and 1960s).

351. CRAIG, *supra* note 255, at 165–66; Charles N. Ehler, *Marine Spatial Planning, in* OFFSHORE ENERGY AND MARINE SPATIAL PLANNING 6–15 (Katherine L. Yates & Corey J.A. Bradshaw eds., 2018).

352. CRAIG, *supra* note 255, at 164–66.

353. *2017 Infrastructure Report Card: A Comprehensive Assessment of America's Infrastructure*, AM. SOC'Y CIV. ENG'RS 5 (2017), https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/2017-Infrastructure-Report-Card.pdf [https://perma.cc/UMD4-KCRG]. 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." *Id.* at 13; *see also Making the Grade: What Makes a Grade?*, AM. SOC'Y CIV. ENG'RS (2017), https://www.infrastructurereportcard.org/making-the-grade/what-makes-a-grade [https://perma.cc/FFB4-GAHM].

354. *2021 Report Card for America's Infrastructure: America's Infrastructure Scores a C-*, AM. SOC'Y CIV. ENG'RS. (2021), https://infrastructurereportcard.org [https://perma.cc/8K76-FTQZ].

355. Jeff Stein, *Trump's 2016 Campaign Pledges on Infrastructure Have Fallen Short, Creating Opening for Biden*, WASH. POST (Oct. 18, 2020), https://www.washingtonpost.com/us-policy/2020/10/18/trump-biden-infrastructure-2020 [https://perma.cc/63HX-GL8F].

infrastructure development,[356] which has since become operative in the Build Back Better Agenda[357] and especially its American Jobs Act, which focuses on increased infrastructure for renewable energy, leading to significant negotiations in Congress over the accompanying infrastructure authorization and finding legislation.[358] 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 4°C 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 (for example, a transition away from monocropping), to climate-adjusted health care 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 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.[359] Governments could then

356. BIDEN CLIMATE CHANGE E.O., *supra* note 265, at §§ 212, 213.

357. *The Build Back Better Agenda*, WHITE HOUSE, https://www.whitehouse.gov/build-back-better [https://perma.cc/4HZH-CN2W].

358. *Updated Fact Sheet: Bipartisan Infrastructure Investment and Jobs Act*, WHITE HOUSE (Aug. 2, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/02/updated-fact-sheet-bipartisan-infrastructure-investment-and-jobs-act [https://perma.cc/B53X-YRUM].

359. *See, e.g.*, Leefeldt, *supra* note 344 (detailing how major home insurers scaled back operations in Florida after the 2004–2005 hurricane season).

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 4°C 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 4°C 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[360]; the trick will be to prevent the attachment of stigma (for example, "welfare moms") to qualification for and/or acceptance of this relief.[361] 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.[362] Governance for 4°C redesign adaptation thus might strive to figure

360. *See, e.g.*, *A Quick Guide to SNAP Eligibility and Benefits,* CTR. ON BUDGET & POL'Y PRIORITIES (Sep. 1, 2020), https://www.cbpp.org/research/food-assistance/a-quick-guide-to-snap-eligibility-and-benefits [https://perma.cc/MSX4-XV6H] (explaining the requirements for access to food assistance).

361. Stigma associated with government aid can deter participation in those aid programs, potentially exacerbating the problem the program was trying to solve. Jennifer Stuber & Karl Kronebusch, *Stigma and Other Determinants of Participation in TANF and Medicaid*, 23 J. POL'Y ANALYSIS & MGMT. 509, 509–10, 526 (2004).

362. While it is always difficult to show that something is *not* happening, it is notable that the many articles focusing on COVID-related stigma focus on the disease itself, not the acceptance of government aid. *E.g.*, Laura K. Murray, Keri Althoff, Beth McGinty & Elizabeth Stuart, *COVID-19 and Stigma*, JOHNS HOPKINS BLOOMBERG SCH. PUB. HEALTH (Jan. 13, 2021), https://publichealth.jhu.edu/2021/covid-19-and-stigma [https://perma.cc/BV9Z-Y2BV]. The lack of stigma probably resulted in part from the semi-automatic nature of some of the relief, such as stimulus checks.

climate change as a common enemy that nevertheless hurts some people more than others through no real fault of their own.

Of course, other climate-relevant government subsidies and payment programs already exist.[363] These programs can change individual and business behavior[364]—although, admittedly, many operate as perverse incentives.[365] Crop subsidies are one obvious example of existing subsidies that government could retool to incentivize redesign adaptation far better. These subsidies already create perverse incentives;[366] the worsening of water pollution as a result of incentivizing crops for ethanol fuels is particularly well studied.[367] In redesign adaptation, agricultural subsidies could serve much more useful—if completely different—goals than they currently do, such as by reducing the economic risks to farmers who agree 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 finance that technological and management evolution outright.

Tax incentives, similarly, can help incentivize voluntary contributions to redesign adaptation. Conservation easements provide one

363. *See, e.g.*, BIDEN CLIMATE CHANGE E.O., *supra* note 265, at § 209 (seeking to end federal fossil fuel subsidies).

364. *E.g.*, Richard W. Willson & Donald C. Shoup, *Parking Subsidies and Travel Choices: Assessing the Evidence*, 17 TRANSPORTATION 141, 141, 152–57 (1990), (demonstrating that more employers drive to work solo when employers subsidize their parking); John S. Moot, *Subsidies, Climate Change, Electric Markets and the 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").

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

366. Kammer, *supra* note 365, at 14–41.

367. *Water Implications of Biofuels Production in the United States*, NAT'L RSCH. COUNCIL 27–35, 45–60 (2008) https://doi.org/10.17226/12039 [https://perma.cc/K8PQ-KNEG]; David Pimentel, *Ethanol Fuels: Energy, Balance, Economics, and Environmental Impacts are Negative*, 12 NAT. RES. RSCH. 127, 130–31 (2003); Renee Cho, *Ethanol's Impacts on Our Water Resources*, COLUM. CLIMATE SCH.: STATE OF THE PLANET (March 21, 2011), https://news.climate.columbia.edu/2011/03/21/ethanol's-impacts-on-our-water-resources [https://perma.cc/JUQ5-84ZS].

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.[368] 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,[369] 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 encouraged people to live in Vermont while working for employers elsewhere.[370] 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,[371] improve its municipal drinking water treatment capacity,[372] and clean up open dumps,[373] among other noteworthy goals.[374]

368. 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); Jessica Owley, *Conservation Easements at the Climate Change Crossroads*, 74 L. & CONTEMP. PROBS. 199, 200, 218–23 (2011).

369. Andrew Hanson & Shawn Rohlin, *Do Location-Based Tax Incentives Attract New Business Establishments?*, 51 J. REG'L SCI. 427, 427–28 (2011) (noting the ubiquity of these incentives); Timothy A. Dunn, Note, *Business Tax Incentives: A Modern View Utilizing Tiebout-Hamilton Rationales*, 40 TEX. J. BUS. L. 235, 237–240 (2004) ("Tax incentive programs are now the norm, not the exception, [in America].").

370. State of Vermont, *Relocation Incentives*, VT. DEP'T ECON. DEVS.: THINKVERMONT, https://thinkvermont.com/relocation-incentives [https://perma.cc/7RGC-P3SM].

371. Clean Water Act, 33 U.S.C. §§ 1255, 1256, 1263a, 1281–1301, 1329, 1381–1388.

372. 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. ENV'T L. LETTER 5 (1997).

373. Resource Conservation and Recovery Act, 42 U.S.C. §§ 6931, 6947–6949.

374. These include air quality monitoring and improvement grants. *See* Clean Air Act, 42 U.S.C. §§ 7405, 7616.

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[375] and the far more successful goal of settling the West through Homestead Acts.[376] The two of us are *not* in any way suggesting that all federal public lands be converted to private ownership.[377] 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.

375. Mark A. Graber, *The Second Freedmen's Bureau Bill's Constitution*, 94 TEX. L. REV. 1361, 1362 (2016) (analyzing the Second Freedmen'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, 2015), https://www.npr.org/sections/codeswitch/2015/01/12/376781165/the-story-behind-40-acres-and-a-mule [https://perma.cc/2NBM-7URB]. 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*, U. VA. SCH. L. (Oct. 29, 2019), https://www.law.virginia.edu/news/201910/why-land-redistribution-former-slaves-unraveled-after-civil-war [https://perma.cc/DNW5-AEE2]. 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 white settlers, while the latter involved lands of poor quality and provided little support for the would-be new farmers. *See Homestead Act*, HISTORY (Mar. 2, 2021), https://www.history.com/topics/american-civil-war/homestead-act [https://perma.cc/XEU2-SYTX] (explaining how most of the land reserved in the Homestead Act went to speculators, cattlemen, railroads, lumbermen, and miners); Thomas W. Mitchell, *From Reconstruction to Deconstruction: Undermining Black Landownership, Political Independence, and Community Through Partition Sales of Tenancies in Common*, 95 NW. U. L. REV. 505, 525–26 (2001) (noting the overwhelming percentage of white applicants for land reserved under the Southern Homestead Act as well as the poor quality of the land).

376. Act of May 20, 1862, 12 Stat. 392; Act of Mar. 3, 1891, 26 Stat. 1097; Act of Feb. 8, 1908, 35 Stat. 6; *see also* Hannah L. Anderson, *That Settles It: The Debate and Consequences of the Homestead Act of 1862*, 45 HISTORY TCHR. 117, 118–20 (2011) (noting that 10% of the acreage of the United States was settled under the Homestead Act).

377. 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 CHANGE E.O., *supra* note 265, 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 value for recreation, coastal habitat and fisheries, aquaculture, transportation, and/or national security 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 (Detroit, for example) 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 4°C 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 fifty states into baseline protections of environmental quality and human health, but it also leaves each state free to enact more stringent protections.[378]

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, regarding 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 or phase in federal migration programs (like land swap offers or insurance buyout structures) at each stage, or both, while leaving each state free to 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—that is, training in skills that are likely to remain employable throughout the nation's adaptation curve, like the building and operation of wind farms and solar farms, or agricultural adaptation training. 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,[379] 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.[380]

In an ideal world, the economic dislocation from COVID-19 would provide the excuse to start this process more or less immediately, in

378. *E.g.*, Clean Water Act, 33 U.S.C. § 1370.

379. For an overview of these programs, see *The New Deal: FDR's Alphabet Soup*, USHISTORY.ORG, https://www.ushistory.org/us/49e.asp [https://perma.cc/TCG6-F8W4].

380. BIDEN CLIMATE CHANGE E.O., *supra* note 265, at §§ 214–219.

concert with President Biden's infrastructure bill.[381] 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. With 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)[382] 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 (for example, 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,[383] albeit in more explicitly climate-ready and environmentally friendly directions.

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

381. *See, e.g.*, Jim Tankersley, *Biden Details $2 Trillion Plan to Rebuild Infrastructure and Reshape the Economy*, N.Y. TIMES (July 27, 2021), https://www.nytimes.com/2021/03/31/business/economy/biden-infrastructure-plan.html [https://perma.cc/L7ES-T2CD].

382. 42 U.S.C. §§ 9601–9675.

383. *Q&A with Aquaculture Policy Expert Kat Montgomery*, STRONGER AM. THROUGH SEAFOOD (Jan. 29, 2021), https://www.strongerthroughseafood.org/tipping-the-scales/2021/2/1/qampa-with-aquaculture-policy-expert-kat-montgomery [https://perma.cc/9A2W-J38G].

coverage would be beneficial. Food rationing, like during World War II,[384] may be necessary to ensure distributional equity and at least minimal food security. Personal migration financing may both become a new financial planning specialty, 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 in transitioning 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.[385] "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*."[386] As two examples, merchant shipbuilding mobilized to build the wartime fleet, and—albeit with more resistance—automobile companies converted to aircraft manufacturing.[387] The economic conversion was matched, moreover, by a new wartime administrative bureaucracy.[388] A number of financial innovations, including taxes and war bonds, also contributed to the effort.[389]

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 will arise if the government starts ordering people to move, just as there were constitutional challenges to the government's actions in World War II.[390] However,

384. Theien, *supra* note 307.

385. Christopher J. Tassava, *The American Economy During World War II*, EH.NET ENCYCLOPEDIA (Feb. 10, 2008), https://eh.net/encyclopedia/the-american-economy-during-world-war-ii [https://perma.cc/CM52-G8W5].

386. *Id.* (emphasis added).

387. *Id.*

388. *Id.*

389. *Id.*

390. These challenges took numerous forms, producing a range of Supreme Court decisions. Some of the decisions were regrettable and have since been overturned. *E.g.*, Korematsu v. United States, 323 U.S. 214, 217–19 (1944) (upholding the constitutionality of Japanese internment), *abrogated by* Trump v. Hawaii, 138 S. Ct. 2392, 2423

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.

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 multimodal 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 4°C 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."[391] 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.[392] Anticipatory governance depends heavily on constructing multiple plausible future scenarios, embraces rather than denies high levels of uncertainty, and seeks adaptive policy implementation tools to respond to changing conditions and knowledge over time.[393] Although some legal scholars have incorporated anticipatory

(2018). Others remain unremarkable. *See, e.g.*, 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).

391. Muiderman et al., *supra* note 22, at 1.

392. *Id.* at 5–6.

393. *Id.* at 3–10; *see also* 2021 NASEM GLOBAL CHANGE RESEARCH REPORT, *supra* note 168, at 49–52 (providing a description of scenario-based approaches to climate change research).

governance into law and policy for emerging technologies,[394] only a few have connected it to climate change adaptation policy.[395]

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.[396] 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 the collapse of regional water supply will 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 and transitional zones plod along at what still looks mostly like baseline change. That

394. Millie M. Georgiadis & Margaret Ryznar, *Regulating What Has Yet to Be Created: An Introduction*, 98 TEX. L. REV. ONLINE 71 (2019); Albert C. Lin, *Technology Assessment 2.0: Revamping Our Approach to Emerging Technologies*, 76 BROOK. L. REV. 1309 (2011).

395. 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).

396. For what we consider to be the most thoughtful argument for applying anticipatory governance to climate change adaptation, see Vervoort & Gupta, *supra* note 22.

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*. Table 1 provides 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.[397] 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 4°C 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,[398] many of which are expected to lead to

397. Some U.S. 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 22, at 499–505 (presenting case studies of Denver, New York, and Phoenix).

398. *See supra* Part II.

(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.[399] Anticipatory governance accepts that some aspects of the future are not knowable and builds that reality into planning.[400] 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.[401] Importantly, the future scenarios are "immediately used to test in-progress government policies and plans in order to ensure robustness in the face of future uncertainty."[402] That is where adaptation governance for a 4°C 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,[403] but the forces of change requiring redesign will transpire at all scales of planning, from local to international. It is not enough to model the impacts of climate change; models of how humans respond to those impacts are needed to gain a complete picture of how to govern redesign adaptation. Therefore, 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 multi-disciplinary, uniting

399. Silva Serrao-Neuman, Ben P. Harman & Darryl Low Choy, *The Role of Anticipatory Governance in Local Climate Adaptation: Observations from Australia*, 28 J. PLAN. PRAC. & RSCH. 440, 440 (2013). Notably, even just at the retreat stage, "engaging in bold, long-term visioning of adaptation futures to help stakeholders identify which aspects of the present should be preserved and which should be actively changed" is an important activity. Mach & Siders, *supra* note 39, at 1296. It becomes even more important at the redesign stage.

400. Quay, *supra* note 22, at 498.

401. Stefano Maffei, Francesco Leoni & Beatrice Villari, *Data-Driven Anticipatory Governance. Emerging Scenarios in Data for Policy Studies*, 3 POL'Y DESIGN & PRAC. 123, 125 (2020).

402. Vervoort & Gupta, *supra* note 22, at 108.

403. *See supra* Part III.

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, we propose that the research be anchored and directed through a new or expanded science-based research bureau or service within the federal government, akin to the U.S. Geological Survey, rather than as a multi-agency task force between existing agencies sending representatives to periodic meetings.[404] The work product cannot be a splashy task-force report, destined to collect headlines followed by dust, but rather a continuous

404. As we were completing this Article, the National Academies of Science, Engineering, and Medicine published its report advising the U.S. Global Change Research Program (USGCRP) on how to shape its research program for the next ten years. 2021 NASEM GLOBAL CHANGE RESEARCH REPORT, *supra* note 168. NASEM's advice mirrors ours in several respects. For example, NASEM advised that the USGCRP:

> center their next decadal plan, and the resulting priorities and activities, using an integrated [sic] riskframing approach—that is, one that considers the risks to human and natural systems posed by climate change, and when appropriate, climate change together with other global changes. The committee also recommends focusing on and communicating the vulnerabilities and capacities of exposed systems and how these could shift over time, taking into account the multiple interconnections of projected changes, responses, and effects in human and natural systems.

Id. at 3. This emphasis on scenario-building is similar to what we advocate. Moreover, NASEM emphasized the importance of interdisciplinary research and insights, as we do, noting, for example, that "[a]dvances in fundamental and applied Earth system science over the next decade will be significantly more useful and useable by increased integration of natural and social sciences, improving the balance among physical climate research, ecosystems research, and human systems research." *Id.* at 5. We also largely agree with NASEM's assessment of adaptation research needs:

> Research and coordination are needed to better understand: (1) the efficacy of adaptation practices implemented at local, state, federal, and tribal scales, and applied by industry and other actors; (2) what additional efforts are needed, today and in the future; (3) current and projected economic and social consequences of policy choices; (4) the processes of decision-making to manage synergies and tradeoffs over multiple scales; and (5) synergies and trade-offs between different adaptation and mitigation options.

Id. at 6. Finally, we applaud and similarly emphasize NASEM's focus on equity and social justice. *Id.* at 7.

Nevertheless, NASEM's recommendations encompass a shorter time horizon than ours and remain focused on state and local adaptation efforts. *Id.* at 2–3, 7. In addition, by federal statute, the USGCRP coordinates the research of other mission-driven federal agencies, *id.* at 4–5, and hence does not necessarily embrace either the significant interdisciplinary and transdisciplinary insights we advocate nor the independence from specific resource-focused goals that we consider critical to the new agency or thinktank that we envision.

and rigorous development and dissemination of foresight for redesign adaptation.

To some extent, our proposal resurrects the spirit behind the National Climate Service Act of 2009, which would have established a bureau within NOAA to study the impacts of climate change and "support development of adaptation and response plans by Federal agencies, State, local, and tribal governments, the private sector, and the public."[405] However, our proposal differs in three key respects. First, our proposed new bureau would not create models of climate change impacts. It would be a consumer of them, using their findings to inform the development of future scenarios of redesign adaptation that incorporate models of human responses to the projected impacts. Second, its work product would end at scenario building. From there, other public and private institutions, including federal, state, and local legislatures and agencies developing and supporting adaptation policies, would use the scenarios to begin to build redesign adaptation policies. Third, the sole focus of the new bureau would be on the "beyond 2°C" world and the need it presents for redesign adaptation. The merits of a consolidated, comprehensive climate service were debated in connection with the 2009 proposal.[406] We take no position on that issue; instead, our proposal, in essence, is to create a "beyond 2°C" think tank devoted exclusively to anticipating redesign adaptation. In short, the bureau would consume climate impact models that other scientific research entities develop, using them to produce science-based redesign adaptation models for use by policy-making entities.[407]

Although our proposed foresight research bureau would be a science-oriented agency designed to produce scenario-based research for use by policy-makers, to accomplish its mission its scope of science would necessarily extend beyond biophysical sciences to include social sciences such as demography, economics, sociology, and

405. National Climate Service Act of 2009, H.R. 2407, 111th Cong. (2009).

406. *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-10-113, CLIMATE CHANGE ADAPTION: STRATEGIC FEDERAL PLANNING COULD HELP GOVERNMENT OFFICIALS MAKE MORE INFORMED DECISIONS 3, 51–3 (2009).

407. Within the anticipatory governance literature, foresight initiatives are depicted along a spectrum from neutral expert-driven modeling of plausible futures to more democratic processes with public participation in the design of desired futures. *See* Muiderman et al., *supra* note 22. Given how radically different and unpleasant conditions will be beyond 2°C, we believe it is critical to rely on science-based, expert-driven modeling of redesign adaptation scenarios and options. The scenarios this foresight initiative produces over time then can be used to develop redesign adaptation policies, which presumably will involve public participatory processes.

psychology.[408] Ideally, moreover, people with policy experience would also be key members of the research community, helping to shape the questions asked and research done so that both are immediately policy-relevant. It will also be essential that the research initiative ask uncomfortable questions, such as which areas should begin to prepare for substantial out-migration, and explore scenarios that would not be tolerated under current policy preferences, such as repurposing public lands for new human settlements.[409]

This foresight system initiative thus would address a broad array of questions relevant to the next step in anticipatory governance—namely, integrating the foresight into policy-making. 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?

408. Consistent with this theme, the National Academy of Sciences has recently advised that, while continued research on physics and biogeochemistry of the climate system is essential, climate change research "could evolve to approach global change research differently in the coming decades, stressing that the largest risks expected will likely arise from the interactions of multiple systems, such as the food-energy-water nexus in the context of a changing climate. In addition, the report stresses that effective responses will arise from integration of social and natural sciences." 2021 NASEM *Global Change Research Report*, *supra* note 168.

409. *See* Owley, *supra* note 44.

- 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, as unpleasant as they may be.

There is no way to put lipstick on the 4°C pig. To anticipate how to manage redesign adaptation in the "beyond 2°C" world, it will be essential for the new research bureau to abandon the assumption that adaptation will occur primarily in situ through resist, resilience, and retreat strategies.[410] Instead, it will need to build scenarios of national-scale social and economic responses that are not constrained by existing policy limits, and it must not be punished for doing so.

What policy-makers and the public do with the scenarios is a different story. In that respect, although in the previous section we suggested broad governance implications for different change modes,[411] 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.[412] Our nation can choose to go into that future blind and unprepared, or it can go into that future 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 us choose foresight and adaptive planning over winging it.

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,[413] translating it into a governance scenario that

410. *See* Quay, *supra* note 22, at 499–505.

411. *See supra* Part IV.D.

412. *See supra* Part II.

413. Indeed, throughout the writing and editing of this Article, the flow of bad news from science never ceased. Not a week went by without the publication of one or more new peer-reviewed scientific studies further supporting the likelihood of a "beyond 2°C world" and further describing its radical impacts on the environment and human society.

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.[414] 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 redesign 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[415] and could certainly become a governance strategy to cope with a 4°C world. The storming of the U.S. Capitol

414. President George W. Bush aggressively pursued federal pandemic planning starting in 2005. *See Pandemic Flu: Preparing and Protecting Against Avian Influenza*, WHITE HOUSE ARCHIVES, https://georgewbush-whitehouse.archives.gov/infocus/pandemicflu [https://perma.cc/9H5M-DQ6X]. The Centers for Disease Control and Prevention (CDC) began developing national influenza pandemic strategy plans, including recommending measures such as school closings and face masks. *See generally* CTRS. FOR DISEASE CONTROL, INTERIM PRE-PANDEMIC PLANNING GUIDANCE: COMMUNITY STRATEGY FOR PANDEMIC INFLUENZA MITIGATION IN THE UNITED STATES—EARLY, TARGETED, LAYERED USE OF NONPHARMACEUTICAL INTERVENTIONS (2007). A CDC website collecting planning documents it and other federal agencies developed, some dating to 2005 and others as recent as 2017, went dormant in June 2017. *See National Pandemic Strategy*, CTRS. FOR DISEASE CONTROL, https://www.cdc.gov/flu/pandemic-resources/national-strategy/index.html [https://perma.cc/YTU3-Z725] (showing last page review as June 15, 2017). For an engaging political history, see Dan Diamond, *Inside America's 2-Decade Failure to Prepare for Coronavirus*, POLITICO (Apr. 11, 2020), https://www.politico.com/news/magazine/2020/04/11/america-two-decade-failure-prepare-coronavirus-179574 [https://perma.cc/529J-3VX9].

415. *E.g.*, Sarah Sicard, *Will Coronavirus Lead to Martial Law?*, MIL. TIMES (Mar. 17, 2020), https://www.militarytimes.com/news/your-military/2020/03/17/will-coronavirus-lead-to-martial-law [https://perma.cc/YP9G-HKX8]; *False Claim: U.S. Coronavirus Response "Slowly Introducing" Martial Law*, REUTERS (Apr. 14, 2020), https://www.reuters.com/article/uk-factcheck-coronavirus-introducing-mar/false-claim-u-s-coronavirus-response-slowly-introducing-martial-law-idUSKCN21W250 [https://perma.cc/8Y8L-VMV7]; Joseph Nunn, *Can the President Declare Martial Law in Response to Coronavirus?*, BRENNAN CTR. FOR JUST. (Apr. 16, 2020), https://www.brennancenter.org/our-work/analysis-opinion/can-president-declare-martial-law-response-coronavirus [https://perma.cc/W78B-KYBR].

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.[416] 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,[417] hints of which also surfaced during the pandemic.[418]

Scholars and politicians alike could debate endlessly the amount and variety of cultural, social, political, and economic fracture lines in

416. 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 HIGHLIGHTS & ANALYSIS OF UNREST IN WASH., D.C. (Jan. 7, 2021), https://www.nbcnews.com/politics/congress/live-blog/2021-01-06-congress-electoral-vote-count-n1253179/ncrd1253367 [https://perma.cc/HXB3-YP96]. 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 Klobuchar*, *Siege of Capitol a "Tipping Point" for Those Who Have Stood by Trump*, CBS NEWS (April 7, 2021), https://www.cbsnews.com/news/amy-klobuchar-reacts-to-siege-of-capitol-by-trump-supporters [https://perma.cc/M3PJ-SFYE].

417. 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*, MORE IN COMMON 4 (2018), https://hiddentribes.us/media/qfpekz4g/hidden_tribes_report.pdf [https://perma.cc/7X4R-NAUP]; *see alsoGlobal Warming's Six Americas*, YALE PROGRAM ON CLIMATE CHANGE COMMC'N, https://climatecommunication.yale.edu/about/projects/global-warmings-six-americas [https://perma.cc/E5HM-BZS7]; Amy Chua & Jed Rubenfeld, *The Threat of Tribalism*, ATLANTIC (Oct. 2018), https://www.theatlantic.com/magazine/archive/2018/10/the-threat-of-tribalism/568342 [https://perma.cc/ZT9V-9AFU]. *See generally* COLIN WOODARD, AMERICAN NATIONS: A HISTORY OF THE ELEVEN RIVAL REGIONAL CULTURES OF NORTH AMERICA (2012).

418. 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, "[t]here 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 [https://perma.cc/6G8C-PDNH]; *see also* Yuval Levine, *Tribalism Comes for Pandemic Science*, NEW ATLANTIS (June 5, 2020), https://www.thenewatlantis.com/publications/tribalism-comes-for-pandemic-science [https://perma.cc/SE3A-X5B6]; Sarah Lahm, *Midwest Dispatch: Republican Tribalism Won't Protect Us from the Pandemic*, PROGRESSIVE (Nov. 17, 2020), https://progressive.org/dispatches/republican-tribalism-wont-protect-pandemic-lahm-201117 [https://perma.cc/D7QJ-HBEH].

the United States (and other nations)[419] and the relative importance of each to climate change adaptation. The more important point here, as the coronavirus pandemic deftly demonstrated,[420] 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 (such as drought in the Southwest) than are others (such as mass migration, collapse of basic infrastructure like drinking water and sewage systems, or 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.[421] 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.[422] Indeed, responses to the coronavirus epidemic in the United States exposed many of the weaknesses of this governance

419. For a sweeping discussion of the perilous state of democracy in the United States, see SANFORD LEVINSON & JACK M. BALKIN, DEMOCRACY AND DYSFUNCTION (2019).

420. *E.g.*, Tucker Doherty, Victoria Guida, Bianca Quilantan & Gabrielle Wanneh, *Which States Had the Best Pandemic Response?*, POLITICO (Oct. 15, 2020), https://www.politico.com/news/2020/10/14/best-state-responses-to-pandemic-429376 [https://perma.cc/B5HZ-6G84].

421. Constitutional takings and standing limitations on environmental protection provide two obvious examples at the federal level. For discussion of takings limitations, see generally, for example, 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. NW. J. ENV'T L. & POL'Y 215 (2014); ROBERT MELTZ, DWIGHT H. MARRIEN & RICHARD M. FRANK, THE TAKINGS ISSUE: CONSTITUTIONAL LIMITS ON LAND USE CONTROL AND ENVIRONMENTAL REGULATION (1999). For discussions of standing limitations, see generally, for example, Jeffrey T. Hammons, *Public Interest Standing and Judicial Review of Environmental Matters: A Comparative Approach*, 41 COLUM. J. ENV'T 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 (2007); Jeffrey W. Ring & Andrew F. Behrend, *Using Plaintiff Motivation to Limit Standing: An Inappropriate Attempt to Short-Circuit Environmental Citizen Suits*, 8 J. ENV'T L. & LITIG. 345 (1994).

422. 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 in the Outbreaks of Infectious Diseases and Zoonotic Diseases*, SCI. REPS., Mar. 1, 2018, at 1.

orientation at a moment when a strong national response to the crisis was required.[423] Multiple governments and levels of government issued uncoordinated and occasionally contradictory responses,[424] leading to costly "loss from anarchy."[425] 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.[426] Nationwide, there was a general disregard for public welfare, ranging from an inability or unwillingness to institute comprehensive COVID testing programs[427] to limited and only short-term social support measures that increased the pressures to go back to work.[428]

Nothing in this experience, fueled by an increasingly politically sectarian nation,[429] bodes well for envisioning how an individualistic

423. *See* George Packer, *We Are Living in a Failed State*, ATLANTIC (June 2020), https://www.theatlantic.com/magazine/archive/2020/06/underlying-conditions/610261 [https://perma.cc/G4H9-AKE7] ("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 & Michelle M. Mello, *Thinking Globally, Acting Locally—The U.S. Response to Covid-19*, N. ENG. J. MED., May 28, 2020, at 1.

424. James Brown, *America's Coronavirus Response 'Completely Uncoordinated'*, U.S. STUDY CTR. (Apr. 2, 2020), https://www.ussc.edu.au/analysis/americas-coronavirus-response-completely-uncoordinated [https://perma.cc/M8R9-23DK].

425. David Holtz, Michael Zhao, Seth G. Benzell , Cathy Y. Cao, M. Amin Rahimian, Jeremy Yang, Jennifer Allen, Avinash Collis, Alex Moehring, Tara Sowrirajan, Dipayan Ghosh, Yunhao Zhang, Paramveer S. Dhillone, Christos Nicolaides, Dean Eckles & Sinan Aral, *Interdependence and the Cost of Uncoordinated Responses to COVID-19*, 117 PROC. NAT'L ACAD. SCI. 19837, 19837 (2020). ("These results suggest a substantial cost of uncoordinated government responses to COVID-19 when people, ideas, and media move across borders.").

426. *See, e.g.*, Dakin Andone, *Health Officials Brace for a Surge in US COVID-19 Cases After the Holidays*, CNN (Dec. 26, 2020), https://www.cnn.com/2020/12/26/health/us-coronavirus-saturday/index.html [https://perma.cc/D8VE-EAND].

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

428. Andrew Stettner, Ellie Kaverman, Amanda Novello & Moshe Marvit, *Fighting for the Right to a Safe Return to Work During the COVID-19 Pandemic*, CENTURY FOUND. (July 29, 2020), https://tcf.org/content/report/fighting-right-safe-return-work-covid-19-pandemic [https://perma.cc/F5VE-LPY4] (describing decisions by some states to reopen economic activity).

429. Eli J. Finkel, Christopher A. Bail, Mina Cikara, Peter H. Ditto, Shanto Iyengar, Samara Klar, Lilliana Mason, Mary C. Mcgrath, Brendan Nyhan, David G. Rand, Linda J. Skitka, Joshua A. Tucker, Jay J. Van Bavel, Cynthia S. Wang & James N. Druckman,

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.

Political Sectarianism in America, 370 SCIENCE 533, 533–34 (2020) (noting that American sectarianism is increasing at the fastest rate among nine western democracies).