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The Built Environment

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Chapter 6: The Built Environment

by Justin Gundlach[*] & Jennifer Klein[**]

Abstract

The built environment, which includes not only buildings but infrastructure, mediates several important climate impacts on public health and is also subject to diverse legal requirements. It is a subject of particular focus for policy efforts aimed at promoting adaptive responses to climate change on the part of institutions and individuals. This chapter presents key examples of public health impacts that arise from climate change but are mediated—possibly mitigated, possibly exacerbated—by elements of the build environment. It also describes the process and substance of adaptive responses to those impacts. Having presented these physical and policy contexts in its first Section, this chapter's second Section considers the role the law could play as individuals, organizations, and localities react to climate-driven harms and seek to adapt.

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Introduction

The built environment—meaning buildings and the infrastructure systems on which they and their occupants rely[1]—arises from layered human decisions.[2] In 2008, a team of public health researchers put it this way:

> Distinct from the natural environment, the built environment is comprised [sic] of manmade components of people's surroundings, from small-scale settings (e.g., offices, houses, hospitals, shopping malls, and schools) to large-scale settings (e.g., neighborhoods, communities, and cities), as well as roads, sidewalks, green spaces, and connecting transit systems. The development of the built environment involves many sectors, including urban planning, architecture, engineering, local and regional governments, transportation design, environmental psychology, and land conservation.[3]

They also noted, of course, that "[t]he built environment influences human choices, which in turn affect health," specifically, "physical activity, respiratory and cardiac health, injury risk, chronic disease risk, social connectedness, and mental health. . . ."[4] However, because *all* social and economic institutions rely to some degree on the built environment,[5] as climate change redraws shorelines and modifies seasons, temperatures, and weather patterns, the responsive changes to the built environment will implicate a host of interests, public health just one among them.

The chapter is divided into two sections. The first discusses key climate impacts on public health that are mediated in some way by the built environment. It also discusses the process and substance of adaptive responses to those impacts. The second part considers the role the law could play as individuals, organizations, and localities react to climate-driven harms and seek to adapt.

Before proceeding to those discussions, it is important to first define some key terms. Climate change is the basic cause of a large number of immediate and intermediate effects—that

[1] National Institute of Standards and Technology, Special Publication 1190, Community Resilience Planning Guide for Buildings and Infrastructure Systems vol. I, at 13 (May. 2016), https://perma.cc/ZVH7-GEJ2.
[2] William Cronon, Nature's Metropolis 62 (1991) (contrasting the natural environment, or "first nature," with "structures of the human economy," or "second nature").
[3] Margalit Younger et al., *The Built Environment, Climate Change, and Health: Opportunities for Co-Benefits*, 35(5) Am. J. Preventive Med. 517-26, 517 (2008).
[4] *Id.*
[5] National Institute of Standards and Technology, Special Publication 1190, Community Resilience Planning Guide for Buildings and Infrastructure Systems vol. II, at 27 tbl. 10-4 (Oct. 2015), https://perma.cc/ZVH7-GEJ2 (providing thorough list of links between institutions and buildings, including direct and indirect impacts arising from damage to buildings).

is, effects that cause further effects. The public health and disaster management communities have developed terminology that is useful to climate change adaptation policymakers who must sort through the problem of which effects/causes to address and how to track and coordinate adaptation efforts' success.[6] In this lexicon, *stressor* and *hazard* both refer to an underlying cause, such as rising ambient temperatures. Stressor tends to refer to chronic and slow-moving causes;[7] hazard is applicable both to slow-moving causes, such as drought, and sudden-onset causes such as destructive coastal storms. If drought or storms strike in a location far removed from human populations or development, then there is no *exposure* to them. The degree of exposure to a stressor or hazard varies with location and the ability of people or structures in that location to endure it without disruption—thus, someone with central air conditioning who works indoors might not be highly exposed to extreme heat even if her location experiences a heat wave.[8] Among the populations and assets that are exposed and cannot mitigate or avoid that exposure, some are more *sensitive*—that is, susceptible or unable to cope—than others. For instance, as noted in Chapter 3, children, the elderly, and the disabled are generally physically less able to endure hazards such as heat or air quality made worse by climate-driven stressors. Those who are both sensitive and exposed are *vulnerable*. Some populations that are vulnerable are also *resilient*, however, meaning that they are capable of recovering quickly from exposure to a hazard even though they are vulnerable to it.[9]

I. Adapting the built environment to address public health impacts of climate change

This sub-section begins with a description of key public health impacts of climate change that relate directly to the built environment. It is not meant to be exhaustive and seeks to avoid redundancy with the descriptions of impacts covered by other chapters. After providing that brief survey of impacts, it addresses the task of adapting the built environment in response to those impacts. It begins by noting how various frameworks would organize that task, and then

[6] B.L. Turner II et al., *A framework for vulnerability analysis in sustainability science*, 100 Proceedings Nat'l Academy Sci. 8074 (2003), 10.1073/pnas.1231335100; *see also* Janet L. Gamble et al., U.S. Global Change Research Program, *Populations of Concern*, *in* The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment 247, 249 (Alison Crimmins et al., eds., 2016).
[7] *But see* Office of Energy Policy and Systems Analysis, U.S. Dep't of Energy, A Review of Climate Change Vulnerability Assessments: Current Practices and Lessons Learned from DOE's Partnership for Energy Sector Climate Resilience 10–12 (May 2016), https://perma.cc/G3YB-R546 (referring to sudden and slow-onset climate-driven effects as "stressors").
[8] *See, e.g.*, Amiche Alcindor, *In Sweltering South, Climate Change Is Now a Workplace Hazard*, N.Y. Times, Aug. 3, 2017, https://perma.cc/4ULU-DXRQ ("They don't know what's going on . . . because they are in cool houses and in offices," Mr. Guerra said.").
[9] UNISDR, 2009 UNISDR Terminology on Disaster Risk Reduction (2009); *see also* UNISDR, The Sendai Framework for Disaster Risk Reduction 2015-2030 (2015), https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf; Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters, Extract from the final report of the World Conference on Disaster Reduction (A/CONF.206/6) (2005), http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf.

examines key elements of the process and substance of adaptation efforts focused on the built environment.

A. Key examples of climate-driven public health impacts transmitted by the built environment

Atop the list of issues that adaptation planning must address in the built environment are public health vulnerabilities traceable to the following hazards: too much water due to sea level rise and/or extreme precipitation; temperatures that are more variable and generally higher; too little water, i.e., drought; and extreme events such as storms and wildfires.[10] Exposure to these hazards takes a variety of forms. Some are direct, such as outdoor workers encountering long periods of hot and humid weather. Others, particularly where the climate-driven stressor interacts with other hazards, are indirect, such as outdoor or indoor air quality made worse by higher temperatures boosting air pollution levels, mold growth promoted by more heat and humidity in buildings, or exposure to toxic waste introduced into the environment by the flooding of a brownfield or a waste storage facility located on a coastline. Still other vulnerabilities that arise from indirect exposure to hazards owe to those hazards' disruption of infrastructure: transit systems, road networks, drinking water provision, wastewater management, and electricity distribution.[11]

Rather than attempting a comprehensive review of how climate change adaptation efforts respond to the diverse climate-driven hazards and vulnerabilities that bear upon and are mediated by the built environment, this chapter focuses on two hazards in particular: hotter ambient temperatures; and coastal flooding driven by sea level rise (SLR).[12]

1. Heat

Cities amplify the direct effects of hotter ambient temperatures driven by climate change; this phenomenon is termed the urban heat island effect.[13] In cities, asphalt, concrete, and other artificial surfaces with low albedo (reflectivity) absorb solar radiation and then express it as heat,

[10] Many of the climate-driven vulnerabilities related directly to the built environment are described at length in Chapters 3, 7 (heat), 8 (storms), 9 (infectious disease), and 10 (food and agriculture) of this volume. *See also* S.L. Cutter et al., Ch. 11: Urban Systems, Infrastructure, and Vulnerability, *in* Climate Change Impacts in the United States: The Third National Climate Assessment (J. M. Melillo et al. eds. 2014).

[11] *See* NOAA, U.S. Climate Resilience Toolkit: Built Environment, https://toolkit.climate.gov/topics/built-environment (accessed July 1, 2017).

[12] Riverine flooding driven by severe precipitation and early snowmelts, wildfires, and drought are all also examples of climate change-driven impacts that affect public health via the built environment. This chapter recognizes the importance and relevance of these impacts, *see, e.g.*, Dennis M. Knobloch, *Moving a Community in the Aftermath of the Great 1993 Midwest Flood*, 130 J. Contemporary Water Res. & Edu. 41 (Mar. 2005), https://perma.cc/39T9-VTTV, but space constraints put discussion of them beyond its scope.

[13] *See* Joyce Klein-Rosenthal + Jeffrey Raven, *Urban Heat And Urban Design — An Opportunity To Transform In NYC*, The Sallan Foundation: Snapshot, July 18, 2017, https://perma.cc/X45Q-RDRR (describing effect and its causes).

and the relative (or total) absence of vegetation often means that these surfaces are largely unshaded and are not cooled through the evapotranspiration of moisture. Cities' absorptive capacity for heat is compounded by urban layouts that obstruct cooling breezes, and by the presence of people, vehicles, and other heat sources—including, during warm seasons, air conditioning units.[14]

Within and beyond the bounds of cities, hotter temperatures also impair the functioning of transportation systems and electricity infrastructure.[15] Those systems' vulnerability to heat compounds the heat-related vulnerabilities of people and assets that rely on their smooth operation. Thus, these vulnerable systems can be the source of indirect adverse public health effects.

The other key indirect effects of hotter temperatures result from their contribution to poorer outdoor and indoor air quality—a leading scourge of public health.[16] This relates to the built environment because, as discussed in Chapters 3, 7, and 13, hotter temperatures promote ozone formation in places downwind of roads, power plants, and other sources of nitrogen oxides and volatile organic compounds[17]—a hazard to which children and the elderly are especially vulnerable.[18] More frequent or intense precipitation and/or flooding can also promote mold growth indoors, which in turn can visit an array of adverse public health impacts on residents.[19]

2. Coastal flooding

Recent events in the Northeast, Florida, and Louisiana illustrate the vulnerabilities traceable to the coastal flooding that is being made ever more severe and frequent by rising sea levels and intensifying coastal storms.

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[14] *Id.*

[15] Sofia Aivalioti, Electricity Sector Adaptation to Heat Waves (Jan. 2015), https://perma.cc/ZML6-3QVQ; Henry G. Schwartz, Michael Meyer, et al., *Ch. 5: Transportation, in* Climate Change Impacts in the United States: The Third National Climate Assessment 130, 132–33 (J. M. Melillo et al. eds. 2014) (noting effects of heat on roads, bridges, rails, and aircraft performance).

[16] Philip J. Landrigan, *Air pollution and health*, The Lancet: Public Health 2(1) e4-e5 (Jan. 2017) ("Air pollution is one of the great killers of our age."); Frank J. Kelly & Julia C. Fussell, *Air pollution and public health: emerging hazards and improved understanding of risk*, 37(4) Environmental Geochemistry & Health 631–649 (2015).

[17] James N. Galloway & William H. Schlesinger et al., *Ch. 15: Biogeochemical Cycles, in* Climate Change Impacts in the United States: The Third National Climate Assessment 350, 357 (J. M. Melillo et al. eds. 2014) ("Rates of ozone formation are ac- celerated by higher temperatures, creating a reinforcing cycle between rising temperatures and continued human alteration of the nitrogen and carbon cycles. Rising temperatures also work against some of the benefits of air pollution control.").

[18] Radley Horton & Gary Yohe et al., *Ch. 16: Northeast, in* Climate Change Impacts in the United States: The Third National Climate Assessment 371, 377 (J. M. Melillo et al. eds. 2014).

[19] George Luber & Kim Knowlton et al., *Ch. 9: Human Health, in* Climate Change Impacts in the United States: The Third National Climate Assessment 220, 222 (J. M. Melillo et al. eds. 2014).

Superstorm Sandy,[20] which struck the New Jersey and New York coasts in November 2012, drowned dozens of people, destroyed hundreds and damaged thousands of coastal homes and businesses, and wreaked damage and severe disruptions on transit and electricity systems, wastewater treatment plants, and other assets and infrastructure.[21] Acute public health impacts included injury, death, exacerbated illnesses, and "bypass events" (i.e., flows of raw sewage into coastal waters) resulting from the powering down of several wastewater treatment plants. Longer-term public health impacts included mold growth in flooded homes and various adverse mental and physical health effects of residents' displacement from their homes.[22] Consistent with the general distributional pattern of disasters' impacts, Sandy was disproportionately hard on poorer neighborhoods and people with disabilities.[23]

Miami Beach and Miami are among the cities most notoriously vulnerable to the slow-moving SLR-driven hazards of nuisance flooding and the salt water infiltration of groundwater resources,[24] though they are not alone.[25] Nuisance flooding visits substantial cumulative damage on stormwater and wastewater management systems, and can also facilitate transmission of infectious disease and exposure to toxic chemicals.[26] Infiltration of groundwater by saltwater can compromise drinking water systems relied upon by large populations.[27] Though these results of

[20] Although the storm's wind speed rated at the low end of Category 1 hurricanes, its pressure rating was comparable to that of a Category 3 hurricane. FEMA, Mitigation Assessment Team Report Hurricane Sandy in New Jersey and New York, at i (Nov. 2013), https://perma.cc/U5GH-LJ4M.

[21] CDC, Deaths Associated with Hurricane Sandy — October–November 2012, Morbidity and Mortality Weekly Report 62(20); 393-397, May 24, 2013, https://perma.cc/RH2M-K8GM; FEMA, 6 Months Report: Superstorm Sandy from Pre-Disaster to Recovery, Apr. 25, 2013, https://perma.cc/SA37-QGN3.

[22] John Manuel, *The Long Road to Recovery: Environmental Health Impacts of Hurricane Sandy*, Environmental Health Perspectives 121:A152–A159 (2013), https://perma.cc/D6VE-VXE9 ("Of the long-term health threats posed by Sandy, the most significant is mold growth in homes that were not properly remediated after flooding."). Recent research highlights that the total costs of recovery from storms like Sandy greatly exceed those classified as disaster aid in scale and duration, and that non-disaster costs arise from healthcare needs. Tatyana Deryugina, *The Fiscal Cost of Hurricanes: Disaster Aid versus Social Insurance*, Am. Econ. J.: Economic Policy 9(3): 168–198 (2017), https://perma.cc/GLF6-J4TN.

[23] Furman Center for Real Estate & Urban Policy at NYU School of Law, Sandy's Effects on Housing in New York City (Mar. 2013), https://perma.cc/2V4A-E4AV (reporting housing-related impacts of storm surge, broken down by income level); *see also* Adrien A. Weibgen, *Note: The Right To Be Rescued: Disability Justice in an Age of Disaster*, 124 Yale L.J. 2406 (2015) (discussing plight of elderly and disabled during Sandy and in the storm's aftermath).

[24] David Smiley, *Mainland Miami ponders returning neighborhoods to nature in order to survive rising seas*, Miami Herald, June 9, 2017, https://perma.cc/4A9F-QE6W.

[25] William V. Sweet & John J. Marra, NOAA, 2015 State of U.S. "Nuisance" Tidal Flooding (June 2016), http://perma.cc/9PHH-2ZJ6 (reporting on prevalence and severity of phenomenon across U.S.).

[26] Stephanie Kruel, *The Impacts of Sea-Level Rise on Tidal Flooding in Boston, Massachusetts*, 32(6) J. Coastal Res. 1302-09, 1308 (Nov. 2016), https://perma.cc/3D2A-45K5 (listing among public health risks of recurrent flooding: transmission of infectious diseases, exposure to toxic chemicals, growth of mold in residences).

[27] Robin Kundis Craig, *A Public Health Perspective on Sea-Level Rise: Starting Points for Climate Change Adaptation*, 51 Widener L. Rev. 521 (2010); *see also* chapters 8 and 9 of this volume.

SLR are generally not a source of dramatic images or news stories, their cumulative impacts on infrastructure are often just as destructive.[28]

Populations in coastal Louisiana—rural and urban alike—face a combination of impacts, some of them climate-driven. Those populations endured the flooding that accompanied hurricanes Katrina and Rita in 2005, followed by the slower-emerging impacts of toxic spills resulting from those storms.[29] In addition, they continue to experience significant land loss due to rapid subsidence,[30] which has lately been exacerbated by oil spills' damage to coastal vegetation—a natural buffer to storms and source of coastal stability.[31] Thus SLR and more intense storms act as stressors on coastal Louisiana's existing vulnerabilities.[32]

B. Adapting to those impacts and others

The Intergovernmental Panel on Climate Change, having examined examples of adaptation efforts around the world, stated that "[t]here is no single approach to adaptation planning because of the complex, diverse, and context-dependent nature of adaptation to climate change."[33] This makes it difficult to distill a general description of adaptation efforts down to a brief summary. However, it is possible—and useful—to take note of the key dimensions of adaptation efforts identified by researchers examining numerous programs funded by the U.N.'s Global Environment Facilities:

- timing relative to stimulus (anticipatory, concurrent, reactive);
- intent (autonomous, planned);
- spatial scope (local, regional, national);
- form (e.g., technological, behavioral, financial, institutional); and

[28] Hamed R. Moftakhari et al., *Cumulative hazard: The case of nuisance flooding*, Earth's Future, 5,214–223 (2017), doi:10.1002/2016EF000494.
[29] Mark Schleifstein, *Extent of oil spills from Hurricanes Katrina and Rita is still being assessed*, Times-Picayune, Aug. 19, 2010, https://perma.cc/62D8-J6MP.
[30] Jaap H. Nienhuis et al., *A New Subsidence Map for Coastal Louisiana*, 27 GSA Today (May 2017), https://perma.cc/6G93-5W9A ("the fundamental culprit is the isolation of the sediment-delivery system (the Mississippi River) from its delta plain and the adjacent coastal zone due to the construction of flood-protection levees. As a result, the majority of the sediment carried by this system is funneled into the deep waters of the Gulf of Mexico, rather than offsetting the naturally occurring high subsidence rates.").
[31] U.S. Geological Survey, USGS, NASA Study Finds Widespread Coastal Land Losses from Gulf Oil Spill, Nov. 17, 2016, https://perma.cc/FU92-8DX8 (identifying oiling of shorelines from oil spill and erosion due to coastal storm as distinct, material causes of shoreline erosion).
[32] *Quantifying Vulnerability*, LSU College of Engineering News, Apr. 4, 2013, https://perma.cc/XSC7-QZ7V (discussing use of GIS mapping to identify where land subsidence is likely to compromise access to hurricane evacuation routes).
[33] Nobuo Mimura & Roger S. Pulwarty, et al., *Adaptation Planning and Implementation*, *in* Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (C.B. Field et al. eds. 2014) 869-898, 871.

- degree of necessary change (incremental, transformational).[34]

As this list implies, the scope of adaptation efforts focused on the built environment could encompass an enormous array of measures. One such might be a nationwide vulnerability assessment for airports or rail transportation systems conducted in anticipation of coastal flooding and heat waves that exceed parameters assumed by those systems' current engineering.[35] Another might be a municipality's adoption of a local ordinance that categorizes green roofs as stormwater management infrastructure so that their installation can be funded—like other capital expenses—using municipal bonds.[36] Examples of measures responsive to the impacts highlighted in part I.A.1 and 2 above are discussed in more detail in subpart I.B.3, below.

1. Process

There is broad consensus on how adaptation efforts should—and do, in practice—proceed;[37] one pair of authors have called the steps involved a "ladder."[38] The highly conventional steps include most or all of the following: identify hazards, assess vulnerabilities, specify objectives, explore options, plan, implement, and evaluate. A large and growing number of jurisdictions have undertaken at least some of these steps with respect to those portions of the built environment for which they are responsible. However, few climb the full ladder: many have identified hazards, fewer have assessed vulnerabilities, fewer still have translated the resulting insights into plans and plans into actions, and very few have evaluated the effectiveness of those actions.[39] Notably, larger cities—which have more resources and can more readily dedicate staff

[34] *See* Bonizella Biagini et al., *A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility*, 25 Global Environmental Change 97-108 (Mar. 2014) *Cf.* City and County of Denver, Climate Adaptation Plan (2014), https://perma.cc/FA34-H4XK (dividing adaptation activities into short, medium, and long-term).
[35] *Cf.* Henry G. Schwartz, Michael Meyer, et al., *Ch. 5: Transportation*, *in* Climate Change Impacts in the United States: The Third National Climate Assessment 130-49, 133-34 (J. M. Melillo et al. eds. 2014).
[36] *See* Justin Gundlach, *Putting Green Infrastructure on Private Property in New York City*, 28 ENVTL. L. IN N.Y. 140, 148 (Sept. 2017) (noting financing challenges arising from accounting treatment of green infrastructure).
[37] *See, e.g.*, NOAA, U.S. Climate Resilience Toolkit: Steps to Resilience, https://toolkit.climate.gov/#steps (accessed Aug. 4, 2017); Helge Bormann et al., *Guiding Regional Climate Adaptation in Coastal Areas*, *in* Handbook of Climate Change Adaptation 337, 350–52 (Walter Leal Filho ed. 2015); P.M. Groffman, et al., Ch. 8: Ecosystems, Biodiversity, and Ecosystem Services, in Climate Change Impacts in the United States: The Third National Climate Assessment (J.M. Melillo et al. eds. 2014) 195-219, 202; Timothy Carter et al., *Technical Guidelines for Assessing Climate Change Impacts and Adaptations*, in IPCC, Climate Change 1995—Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses 823 (Robert T. Watson et al. eds., 1995).
[38] E.M. Hamin & N. Gurran, *Climbing the Adaptation Planning Ladder: Barriers and Enablers in Municipal Planning*, *in* Handbook of Climate Change Adaptation (W. Leal Filho, ed. 2015).
[39] Several surveys of adaptation efforts by local governments report that many complete the initial steps of identifying hazards but fewer conduct vulnerability assessments, fewer integrate their findings into planning efforts, fewer still implement those plans, and very few evaluate those plans' effectiveness. *See* John Nordgren et al., *Supporting local climate change adaptation: Where we are and where we need to go*, 66 Environmental Science & Policy 344–52, 347 (Dec. 2016); Linda Shi et al., *Global Patterns of Adaptation Planning: Results from a global survey*, *in* The Routledge Handbook of Urbanization and Global Environmental Change 336, 341–43 (Karen C. Seto

to the task—are more likely than smaller localities to have undertaken a vulnerability assessment and planning effort.[40]

Identifying hazards. An effort to adapt necessarily begins by surveying the current and expected future climate in a particular area, and by identifying hazards potentially affecting the population, assets, or infrastructure located there. The process requires interpreting both historical data about the parameters of interest (e.g., temperature, flood risk) and data generated by climate models that predict future climatic circumstances. Data of the latter sort are challenging to derive with high degrees of accuracy for the Earth as a whole, and more so when "climate model downscaling" focuses in on the smaller geographic area involved in any given adaptation effort.[41] Predictions are also consequential to publish because they can inform land use and investment decisions.

Several publicly available tools can help an entity or jurisdiction identify hazards arising from SLR, temperature and humidity changes, or changes in precipitation patterns,[42] though these tools tend to yield coarse projections at smaller scales.[43] New York City's Panel on Climate Change (NPCC) has arguably set the gold standard for developing downscaled projections of SLR, temperature, and precipitation.[44] However, the NPCC is both an expensive endeavor and one that, notwithstanding its relative superiority, generates projections subject to large

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et al. eds. 2015) (reporting results from 2011 survey); National Association of Regional Councils, A Survey of Regional Planning for Climate Adaptation (2012), https://perma.cc/K3WA-WDDJ.

[40] Shi et al., *supra* note 39, at 341–43.

[41] G. Flato et al., *Evaluation of Climate Models*, *in* Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 741, 817 (T.F. Stocker et al. eds. 2013) (describing regional climate models as valid but emphasizing their sensitivity to imprecise inputs: "This underlines the importance of both the quality of the boundary conditions and the downscaling method.").

[42] *See, e.g.*, NOAA, Global and Regional Sea Level Rise Scenarios for the United States (Jan. 2017) (including regional projections), https://perma.cc/N9AG-8Y6S; NOAA Office for Coastal Management, Sea Level Rise Viewer, https://coast.noaa.gov/digitalcoast/tools/slr (accessed June 30, 2017); U.S. Climate Resilience Toolkit, MACA CMIP5 Statistically Downscaled Climate Projections, https://toolkit.climate.gov/tool/maca-cmip5-statistically-downscaled-climate-projections (last updated Jan. 5, 2017); *see also* Climate Central, Surging Seas, http://sealevel.climatecentral.org/ (accessed June 30, 2017).

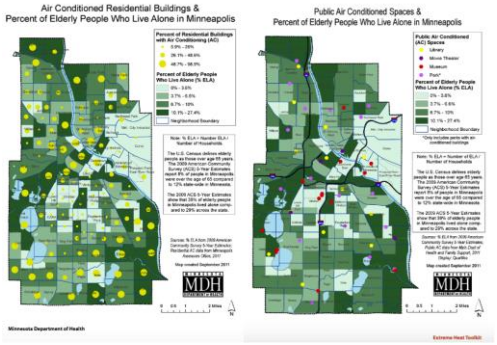
[43] The U.S. Climate Resilience Toolkit homepage cautions that "[c]limate projections are not predictions," that "[t]he increased spatial resolution of statistically downscaled projections available for temperature and precipitation may not be available for all parameters. In addition, increased resolution does not necessarily equate to greater fidelity or reliability." U.S. Climate Resilience Toolkit, MACA CMIP5 Statistically Downscaled Climate Projections, https://toolkit.climate.gov/tool/maca-cmip5-statistically-downscaled-climate-projections (last updated Jan. 5, 2017). It also counsels against DIY applications of downscaled modeling data: "For decisions involving the use of climate model projections, you may want to consider seeking expertise." *Id.*

[44] *See Building the Knowledge Base for Climate Resiliency: New York City Panel on Climate Change 2015 Report*, 1336 Annals of the New York Academy of Sciences (Jan. 2015). The third round of the panel's reporting, NPCC3, included sea level rise projections for three areas in southeastern New York State that have since been adopted by the Department of Environmental Conservation and so must be considered in future planning decisions. *See* 6 NYCRR 490 (2017), http://www.dec.ny.gov/regulations/103877.html.

uncertainties.[45] Whatever data are used, the climate scenarios generated by this step provide parameters useful to, for instance, departments of transportation that need to determine how high to build a bridge, electric utilities that need to design components that can operate even during long durations of high ambient temperatures, floodplain managers that want to guide land use and design decisions for long-lived assets, and municipal authorities that need to match the carrying capacity of a stormwater management system to the precipitation expected during its useful life.

Assessing vulnerabilities. This step builds on the previous one by identifying conflicts between projected climate parameters and the location or operation of existing people, assets, and infrastructure. Whether it is being undertaken by an electricity distribution utility,[46] a city, state, or federal agency,[47] or some other entity, it tends to involve the rendering in layers of several data sets over a geographic map. Consider the example in figure _, which excerpts just two of the multiple maps collated by the Minnesota Department of Public Health in the appendices of its *Extreme Heat Toolkit*.

Figure __. Map layers showing county-level vulnerability and adaptive capacity to heat.[48]



This pair of maps contains layers of information about the geographic density of a subpopulation that is especially vulnerable to extreme heat (elderly who live alone), average access to residential air conditioning across counties, and the location and availability of air conditioned public spaces in those counties. Integrating data like these with data sets that capture

[45] *See, e.g.*, New York City Panel on Climate Change 2015 Report [NPCC2]; Executive Summary, 1336 Annals of N.Y. Acad. Sci. 9-17 (2015): at ES-10, n.e (no probabilities assigned to projected mean temperatures because of multiple uncertain factors), ES-11 (frequency and intensity of coastal storms are "uncertain at local scales"), ES-13 (coastal flooding projections subject to multiple uncertainties).

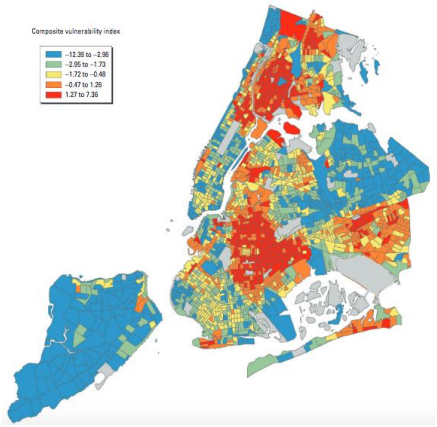
[46] Pacific Gas and Electric Company, Climate Change Vulnerability Assessment (2015), https://perma.cc/N2NR-S79A.

[47] *See, e.g.* U.S. Federal Highway Administration, The Gulf Coast Study, Phase 2: Assessing Transportation System Vulnerability to Climate Change: Synthesis of Lessons Learned and Methods Applied (Oct. 2014), https://perma.cc/N3R9-DEFN.

[48] Minnesota Department of Health, Extreme Heat Toolkit, Appendix H, H-5 & H-8 (June 2012), https://perma.cc/XM4X-2AQE.

relative temperature levels as well as factors correlated positively or negatively with vulnerability (e.g., density of residents receiving public housing assistance and density of tree cover) makes it possible to derive and map a Heat Vulnerability Index for a given jurisdiction. (See figure _.)

Figure _. Heat Vulnerability Index for New York City.[49]



Another factor for possible inclusion in urban heat vulnerability maps is the presence of ventilation corridors—channels through a cityscape that, if present, can allow the wind's passage to diminish ambient heat.[50]

Like the maps shown above, maps depicting flood-related vulnerabilities compile data on the hazard (i.e., water levels and wave action under different scenarios) and on the area's relevant features, including topography, toxics storage sites, and infrastructure such as bridges or electric grid substations. San Mateo County, California's *SLR Vulnerability Assessment*, for instance, includes "Asset Exposure Maps" that overlay the areas subject to flooding under different SLR scenarios with key components of the built environment.[51] (See figure _.)

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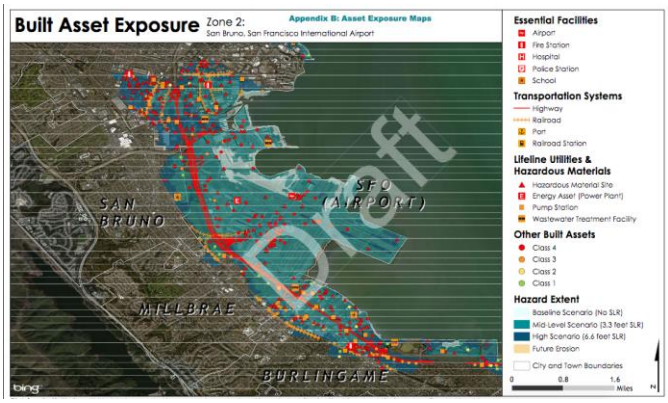
[49] Jaime Madrigano et al., *A Case-Only Study of Vulnerability to Heat Wave–Related Mortality in New York City (2000–2011)*, 123 Environmental Health Perspecitves 672, 675 fig.1 (July 2015), https://perma.cc/8D9A-LNT7 ("NYC census tracts according to composite heat vulnerability index. The index is composed of z-scores of the following variables: (+) proportion of homes receiving public assistance, (+) proportion of non-Hispanic black residents, (+) proportion of overall deaths occurring in the home, (+) relative surface temperature, (–) proportion of trees. A higher composite index score indicates a residential area with a higher risk of heat-related mortality."). The New York City Department of Health and Mental Hygiene based its own HVI on this one. New York City, Cool Neighborhoods NYC A Comprehensive Approach to Keep Communities Safe in Extreme Heat 9 fig.3 (2017), https://perma.cc/A3NZ-MR8D.

[50] *See* Hu, X. M., & M. Xue, *Influence of Synoptic Sea-Breeze Fronts on the Urban Heat Island Intensity in Dallas–Fort Worth, Texas*, 144(4) Monthly Weather Review 1487-1507 (2016); M. Roth, *Urban heat island*, *in* Handbook of Environmental Fluid Dynamics vol. 2, at 2 (2013).

[51] County of San Mateo, Sea Level Rise Vulnerability Assessment—Draft Report, Appendix B (Apr. 2017), https://perma.cc/3RUW-H45G (report without appendices), https://perma.cc/6ZXM-G5YW (Appendix B).

Figure _. San Mateo County's Built Asset Exposure Map, showing San Francisco International Airport.[52]



Assets located in projected flood zones are thus readily identified as potentially vulnerable.

Specifying objectives. In some instances, it can be relatively easy to specify feasible climate change adaptation objectives for the built environment and public health. For electricity distribution utilities, which are under a statutory obligation to provide a minimum level of service to a defined group of end-users, the obvious objective vis-à-vis public health is simply to meet those obligations in spite of foreseeable climate change-driven hazards and the vulnerabilities—for instance, substations not hardened against flooding[53]—arising from them. Similarly, the basic adaptation objective of a prison might be to provide adequately for the health and wellbeing of its inmates in spite of the effects of heat waves on indoor temperatures.[54] However, for institutions with a wider array of competing duties, such as municipalities, specifying broadly acceptable and realistic objectives can present challenges.[55] Furthermore,

[52] *Id.* at App. B-4.
[53] The experience of Superstrorm Sandy, flooding from which led to the explosive destruction of the 13th Street substation in lower Manhattan, led, among other things, to a thorough vulnerability assessment and plans to harden all low-lying substations in New York City against flood risk. *See* Consolidated Edison, 2015 Capital Work Plan: Storm Hardening–East 13th St 138kV & 345 kV Substation, https://perma.cc/63UV-D72S (accessed Aug. 13, 2017) ("Based on storm hardening evaluations, this project will raise the existing perimeter flood wall to elevation 18.2' to provide higher storm surge protection, relocate the grade level control room to a higher elevation on the second floor, replace the protection scheme of station equipment with new microprocessor relays and fiber optics communication in between relays, provide capability to raise transformer control cabinets during a flood event....").
[54] *See* Cole v. Collier, Case 4:14-cv-01698, at 40, 67 (S.D. Tex. July 19, 2017) (ordering prison to maintain indoor temperatures below heat index of 88°F despite testimony about high costs involved in providing air conditioning capacity adequate to the task, and citing Daniel W. E. Holt, Heat in U.S. Prisons and Jails: Corrections and the Challenge of Climate Change, Columbia Law School Sabin Center for Climate Change Law (Aug. 2015)).
[55] The Long-Range Transportation Plan (LRTP) developed by Hampton Roads following a grim vulnerability assessment is illustrative. As the Georgetown Climate Center explains: "The LRTP concludes that climate impacts, specifically sea-level rise, might eventually require the relocation or rebuilding of regional roadways. The LRTP explains why it may be difficult to adopt transportation adaptation strategies due to financial constraints, and emphasizes that policy alternatives to adapt transportation infrastructure to the impacts posed by hurricanes and flooding are limited. The LRTP does not provide for specific, concrete measures that should be taken to safeguard

where vulnerabilities are especially large relative to the capacity of the institution charged with their address—for instance, the government of a small coastal town[56]—setting out ambitious objectives can damage credibility.

Exploring options and planning. Whereas the foregoing steps do not necessarily require public engagement, exploring options for how to achieve adaptation objectives for the built environment and then planning how to do so means, inevitably, seeking the approval of a larger group of stakeholders.[57] Put another way, even if the previous steps are done in technocratic fashion, deciding what measures to take, how much should be spent on them, and how to pay for them involves weighing those measures against the competing priorities of other stakeholders or the public as a whole. This is so chiefly because the tools available to adapt (or to push others to adapt) the built environment take the form of laws and regulations that govern land use planning, infrastructure design, and building design and construction. All of these are highly significant to numerous and diverse stakeholders, and are subject to the purview of state or local government.

These tools lend themselves to "mainstreaming," that is "integrating climate adaptation into existing management plans (for example, hazard mitigation, ecosystem conservation, water management, public health, risk contingency, and energy)."[58] Researchers have found that "[m]ainstreaming prevents adaptation from becoming a solely environmental issue, reduces the risks of agenda sidelining and lowers administrative and implementation costs."[59] The alternative to mainstreaming would be to develop adaptation plans independent of land use or infrastructure planning processes, and then to implement those independent plans by altering the results of

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infrastructure against rising sea levels." Georgetown Climate Center, Adaptation Clearinghouse: Hampton Roads Climate Change Adaptation Project, https://perma.cc/2R7T-X8R7 (last updated July 7, 2016); *see also* Hampton Roads Transportation Planning Organization, 2034 Long Range Transportation Plan (June 2015).

[56] *See, e.g.*, Elisabeth M. Hamin et al., *Barriers to Municipal Climate Adaptation: Examples From Coastal Massachusetts' Smaller Cities and Towns*, 80 J. Am. Planning Ass'n 110-22 (Sept. 2014) ("The planners interviewed reported that barriers to adaptation actions tend to be interconnected; for example, the strength of private property interests often limits local political leadership on the issue. Without such leadership, it is difficult for planners to allocate time and/or money to adaptation activities.").

[57] Several how-to adaptation guides encourage adaptation planners to consider the "STAPLEE" categories of factors and the stakeholders concerned with each of them: social, technical, administrative, political, legal economic, environmental. *See* South Florida Regional Planning Council, Adaptation Action Areas: A Planning Guidebook for Florida's Local Governments Regional Climate Action Framework: Implementation Guide 63 (2015), https://perma.cc/2H39-7WUC; NOAA, Adapting to Climate Change: A Planning Guide for State Coastal Managers 52–53 (2010), https://perma.cc/E4M2-M6Y7. The STAPLEE list was first developed for the purposes of disaster mitigation planning. *See* FEMA, Developing the Mitigation Plan: Identifying Actions and Implementing Strategies (2003), https://perma.cc/56PU-K5CS (listing STAPLEE factors in detail).

[58] Rosina Bierbaum et al., *Ch. 28: Adaptation*, *in* Climate Change Impacts in the United States: The Third National Climate Assessment 670-706, 682 (J. M. Melillo et al., eds. 2014); *see also* Ebinezer R. Florano, *Mainstreaming Integrated Climate Change Adaptation and Disaster Risk Reduction in Local Development Plans in the Philippines*, *in* Handbook of Climate Change Adaptation 433, 435 tbl.1 (Walter Leal Filho ed. 2015) (noting numerous points of convergency between adaptation and disaster mitigation policies and arguing for "mainstreaming" of adaptation by unifying both policy areas).

[59] Linda Shi et al., *supra* note 39, at 337.

conventional planning processes. An example of mainstreaming helps to illustrate its strengths: the Boston Water and Sewer Commission (BWSC)'s three-year capital improvement programs for stormwater and wastewater have, since 2015, incorporated precipitation and sea level parameters based on not just historical weather patterns but also on projections of more severe future precipitation and sea-level rise.[60] They will thus steer design and procurement decisions in ways that better adapt the city's stormwater and wastewater infrastructure to a changing climate, and will also *avoid* maladaptive investments that could put the city's drinking water or wastewater management systems—and thus public health—at risk. These three-year programs reflect the parameters established by the climate change vulnerability assessment BWSC conducted from 2010 to 2015 as part of its most recent 25-year capital asset plan.[61]

Implementing and evaluating. Though implementation can mean various things in relation to different adaptation measures, in all cases it means the allocation of scarce resources to realize plans intended to respond to a climate-related vulnerability. Whether for small-scale programs like the deployment of temporary cooling centers, or larger-scale, transformational measures like the inland relocation of a coastal community, funds must be appropriated, decisions made, and work plans drafted and executed. Taking this step to respond to *future* risks can be difficult—harder, certainly, than assessing vulnerabilities. Unsurprisingly, the authors of the *Adaptation* chapter in the Third National Climate Assessment observed that the key barriers to effective adaptation efforts include a "lack of resources to begin and sustain adaptation efforts; fragmentation of decision-making; institutional constraints; lack of leadership; and divergent risk perceptions/cultures and values."[62] In instances where the scale of planned adaptation would be not just incremental but transformational, high absolute costs and uncertainty about costs and benefits rise to the top of the list of barriers.[63] Researchers and agencies alike advise that, to overcome at least some of these barriers, preference should be given to adaptation measures that are likely to yield co-benefits.[64] Investment in such measures will—the reasoning goes—be easier to justify and more likely to yield manifestly net-positive outcomes regardless of whether their adaptation benefits ever materialize.

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[60] Boston Water and Sewer Commission, Capital Improvement Program 2017-2019, at 7 (Nov. 2016), https://perma.cc/2JV3-5S3P ("Critical elements of this Plan include: . . . Assessment of the Commission's Service Goals and other factors affecting long-term planning including changing regulatory requirements, **climate change** and financial **conditions**;") (emphasis added).

[61] *See* Charlie Jewell et al., BWSC Climate Change Risk Assessment, Findings and Mitigation/Adaptation Strategies for Wastewater and Strom Drainage--NEWAE Conference Presentation (Jan. 28, 2015), https://perma.cc/384G-R8WC.

[62] Bierbaum et al., Ch. 28 in NCA 3, at 683–86.

[63] *Id.*; *see also* CITES RE BARRIERS TO ADAPTATION, ESPECIALLY TO IMPLEMENTATION.

[64] William H. Butler et al., *Low-Regrets Incrementalism: Land Use Planning Adaptation to Accelerating Sea Level Rise in Florida's Coastal Communities*, 36 Journal of Planning Education and Research 319-332 (May 2016), https://doi.org/10.1177/0739456X16647161 (describing examples of adaptation plans that seek to support co-benefits); June J. Cheng & Peter Berry, *Health co-benefits and risks of public health adaptation strategies to climate change: a review of current literature*, April 2013, Volume 58, Issue 2, pp 305–311.

Evaluation is no mere procedural formality: because the future is uncertain, planners cannot safely assume that parameters relevant to their decisions—from the rate of sea level rise to the range and seasonality of infectious disease vectors—will be consistent with multi-decadal projections. Thus, because effective adaptation efforts are necessarily "dynamic iterative learning processes,"[65] they should assume that more information about climate-driven hazards and vulnerabilities will be revealed over time, and that preliminary decisions should be evaluated as new information corrects earlier assumptions—whether about the environment or the measure's design.[66] Notably, however, while this "adaptive management" approach is widely considered a best practice,[67] "[t]here is little literature evaluating the effectiveness of adaptation actions," and most efforts at evaluation "to date, have focused on the creation of process-based rather than outcome-based indicators."[68] Evaluations of hazard mitigation efforts not expressly oriented to climate change are more numerous and can serve as models for evaluating adaptation efforts, which often involve similar measures and goals.[69]

2. Substance

Hundreds of cities and smaller localities have engaged in some version of the process described above,[70] in some instances on their own initiative and in others steered or supported by state and/or federal law or policy.[71] Many of the resulting adaptation measures have been demonstrated to reduce vulnerability to climate change-driven impacts.[72] Some do so by reducing exposure to hazards, for instance by retreating from a coastline or elevating coastal

[65] Mimura & Roger S. Pulwarty, et al., *supra* note __, at 871.
[66] *See* Sierra C. Woodruff, *Planning for an unknowable future: uncertainty in climate change adaptation planning*, 139 Climatic Change 445-459 (Dec. 2016), doi:10.1007/s10584-016-1822-y.
[67] *See, e.g.*, Elisabeth Hamin and Nicole Gurran, Climbing the Adaptation Planning Ladder: Barriers and Enablers in Municipal Planning, *in* Handbook of Climate Change Adaptation 839, 843–44 (Walter Leal Filho ed. 2015); Kristi L. Ebi, *Overview: Adaptive Management for the Health Risks of Climate Change*, *in* Climate Change Adaptation in Developed Nations 121–31 (James D. Ford & Lea Berrang-Ford eds. 2011).
[68] Bierbaum et al., NCA3 at 682.
[69] *See, e.g.* FEMA, Reducing Losses through Higher Regulatory Standards: Best Practices and Cost-Effective Strategies Report (2015), https://perma.cc/HT6S-5VJJ.
[70] Two of the leading organizations devised to facilitate and coordinate cities' adaptation (and mitigation) efforts are ICLEI-Local Governments for Sustainability and the Compact of Mayors. *See* ICLEI-Local Governments for Sustainability USA, Our Members, https://perma.cc/2D3V-L9DU (accessed Aug. 15, 2017) (listing 191 member localities and noting that ICLEI's international membership includes over 1000 localities in 86 countries); Compact of Mayors, *Cities Committed to the Compact of Mayors*, (accessed Aug. 15, 2017) (indicating 142 members located in the U.S. and 668 in total committed to a program of self-reported goals, vulnerabilities, plans, and actions taken).
[71] For examples of state laws that have prompted and guided local adaptation planning, see, e.g., CRRA (NY); Peril of Flood (Fla). *But see also* Thomas Ruppert & Alexander Stewart, Summary and Commentary on Sea Level Rise Adaptation Language in Florida Local Government Comprehensive Plans and Ordinances 4 (July 2015), http://perma.cc/7VU6-ZGF4 (noting that most ordinances' language is not self-executing and that this "may result in situations in which comprehensive plan language appears more proactive than the tangible actions of a local government in day-to-day operations.").
[72] H. Anderson et al., CDC, Climate and Health Intervention Assessment: Evidence on Public Health Interventions to Prevent the Negative Health Effects of Climate Change (2017), https://perma.cc/P88P-E62E.

structures above the level of floodwaters expected during the structures' life. Others do so by reducing the hazards themselves, for instance by installing large amounts of urban green infrastructure to mitigate the urban heat island effect. And still others do so by increasing resilience, for instance by enlarging the capacity of stormwater management systems in anticipation of downpours that would otherwise leave streets temporarily flooded.

To explore these points with respect to the built environment, this subpart returns to the hazards described in part I.A. above and considers examples of adaptation measures—ranging from the immediate to the long-term, the local to the regional, and the incremental to the transformational—that are responsive to them.

1. Heat, especially in cities

Adaptive responses to heat range widely and are not reducible to as unified and straightforward a framework as adaptations to coastal flooding. As described below, they cover the full ranges of geographic scope, timeframe, degree of change, and other dimensions of adaptation measures listed in part I.A of this chapter.

Measures taken to cope directly with individuals' vulnerability over short time frames include: providing warnings on hot days, establishing and publicizing the presence of temporary cooling centers where vulnerable populations live or work, and creating community support networks like the "Be A Buddy" component of New York City's *Cool Neighborhoods* initiative, which links community organizations with vulnerable individuals and facilitates phone or in-person check-ins on hot days.[73] These measures generally do not alter the built environment, but instead identify and correct for instances where permanent features of the built environment fail to reduce a sensitive population's exposure to the hazard of heat—or exacerbate that exposure.[74]

Other measures reduce individuals' vulnerability indirectly by making changes to design specifications and maintenance protocols for electricity infrastructure and transit networks.[75] These changes generally modify the composition and operation of elements of the built environment—a bit like a house that remains adjacent to the shore but is raised on stilts in anticipation of flooding. They can also, however, be more transformative, for instance by relocating system components or reformulating the system's physical and operational features to support different capabilities, like the "islanding" of segments of an electricity distribution grid

[73] Cool Neighborhoods at 23–25.
[74] *See* notes __-__, above, and accompanying text, which discusses programs in Minnesota and New York City.
[75] U.S. Department of Energy, Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning 84 (Sept. 2016), https://perma.cc/63KM-R9GK (listing measures recommended by AVANGRID to improve resilience to heat waves); North Jersey Transportation Planning Authority, Climate Change Risk Assessment of New Jersey's Transportation Infrastructure 87 (2011) (listing heat ratings for rail system components and indicating risks of exceedance).

when transmission lines are inoperable. The geographic scope of these changes generally reflects the jurisdiction of the regulatory authority requiring and/or authorizing them.[76]

Finally, some measures seek to reduce the hazard itself by changing the materials and morphology of a cityscape. These include increasing the albedo of roofs, pavements, and walls;[77] replacing impervious surfaces with green infrastructure to increase both albedo and (under some circumstances) cooling action through evapotranspiration;[78] and preserving or creating wind corridors.[79] "Cool roof" programs are quick, low-cost examples of such measures that alter almost nothing about the built environment but achieve measurable temperature reductions on surfaces and within buildings covered by those surfaces.[80] Replacing impervious surfaces with green infrastructure, such as rain gardens and extensive (shallow) or intensive (deep) green roofs, is more involved than cool roofing and has a more complicated relationship to adaptation to the heat hazard. To begin, while some tree canopies clearly reduce air temperatures in their vicinity by raising albedo and performing evapotranspiration, small patches of greenery are less certain to do so,[81] which means that a city seeking to abate its urban heat island cannot expect success to follow from merely accumulating fragmented and disparate patches of low-cost green infrastructure. Furthermore, while green infrastructure has several justifications linked to public health, because its primary justification is often stormwater management, its design and placement tends to be oriented to detaining stormwater rather than cooling the ambient air. As for the preservation or creation of urban wind corridors, this is an especially clear example of transforming a cityscape on a permanent basis for the sake of adaptation to heat hazards.

2. Coastal flooding

[76] *See, e.g.*, Emerald Coast Utilities Authority, Wastewater Services, https://perma.cc/AD8D-VGWN (accessed Oct. 12, 2017) (describing relocation and redesign of water reclamation facility from near coastal flood zone to higher ground in Escambia County, Florida, following Hurricane Ivan).
[77] *See, e.g.*, Haley Gilbert et al., *Keeping California cool: Recent cool community developments*, 114 Energy and Buildings 20–26 (Feb. 2016) (describing school districts' and cities' cool pavements and cool roofs pilot programs and preliminary outcomes).
[78] Kieron Doick & Tony Hutchings, UK Forestry Commission, Research Note: Air Temperature Regulation by Urban Trees and Green Infrastructure 3 (2013), https://perma.cc/7T93-WQBC (describing mechanisms of cooling, including evaporative cooling and evapostranspiration).
[79] *See* Leyre Echevarría Icaza & Franklin van der Hoeven, *Regionalist Principles to Reduce the Urban Heat Island Effect*, 9 Sustainability 677, 679 (2017) (listing "creation of cool wind corridors" among measures used to mitigate UHI effect); Hu, X. M., & M. Xue, *Influence of Synoptic Sea-Breeze Fronts on the Urban Heat Island Intensity in Dallas–Fort Worth, Texas*, 144(4) Monthly Weather Review 1487–1507 (2016).
[80] Kevin Krajick, *New York Roofs: Brighter, Whiter, Cooler*, Earth Institute: State of the Planet (Mar. 7, 2012), (quoting physicist Stuart Gaffin regarding the use of white acrylic paint for cool roofing: "It's the lowest hanging fruit. It's very cheap to do; it's a retro-fit. You don't need a skilled labor force. And you don't have to wait for a roof to be retired."); *see also* Stuart R. Gaffin et al., *Bright is the new black: multi-year performance of high-albedo roofs in an urban climate*, 7 Environmental Research Letters 014029 (2012).
[81] Kieron Doick & Tony Hutchings, UK Forestry Commission, Research Note: Air Temperature Regulation by Urban Trees and Green Infrastructure 4 (2013), https://perma.cc/7T93-WQBC (describing scalar factors important to effectiveness of greenery for cooling).

Adaptive responses to encroaching seas and more intense coastal storms take one (or a combination) of three forms: protection, accommodation, or retreat.[82] Protection means interposing barriers—whether "hard armoring," such as sea walls, or "soft armoring," such as living shorelines[83]—between rising seas and landward assets and people with the goal of preserving existing patterns of development and activity. Accommodation means staying in the same place—"living with water"[84]—but changing local land uses and building and infrastructure design in ways that reduce vulnerability and improve resiliency to flooding. Concretely, this could include compelling real estate sellers to disclose vulnerability to flooding, elevating mechanical or electrical components within buildings, elevating whole structures, or up-rating machinery to endure inundation by saltwater.[85] Partial or full retreat, which involves abandoning land and assets made vulnerable by rising seas, is only simple conceptually; its planning and implementation are legally and politically complex.[86] Consider Miami Beach, where seawalls cannot prevent saltwater from flooding city streets by infiltrating via the porous bedrock.[87] Though retreat—managed or otherwise—appears inevitable, the City Engineer recently remarked: "When somebody says, 'How much are you willing to fall back?' I say, 'Not one inch.' We are defending this city at the shoreline. Miami Beach is only one mile wide. If we drop back a mile, we don't have a city."[88]

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[82] John R. Nolon, Protecting the Environment Through Land Use Law: Standing Ground 221 (2014).

[83] Robert Verchick & Joel Scheraga, *Protecting the Coast*, *in* The Law of Adaptation to Climate Change: United States and International Aspects 18–19 (Michael B. Gerard and Katrina Kuh, eds., 2012). Hard armoring tends to create expensive problems over time; soft armoring is generally favored by scientists, planners, and civil engineers, but is usually feasible only where development (i.e., asphalt, concrete foundations, structures, and infrastructure) can be displaced or has not encroached too close to the water's edge. Gary B. Griggs, *The Effects of Armoring Shorelines—The California Experience*, *in* Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009 (Hugh Shipman et al., eds. 2010), https://perma.cc/FN54-7425.

[84] Working together with water: A living land builds for its future—Findings of the Deltacommissie 2008, at 61 (2008), https://perma.cc/9TJH-A7Y2 (describing the Dutch Leven met Water research program).

[85] *See, e.g.*, City of New York Department of City Planning, Coastal Climate Resilience: Designing for Flood Risk 16–17 (June 2013), https://perma.cc/7VWS-BLFL.

[86] *See* C. Kousky, *Managing shoreline retreat: a US perspective*, 124 Climatic Change 9, 9 (2014), https://perma.cc/5MY2-NVP3 (discussing institutional factors that impede managed retreat by whole communities in the U.S.). The Quinault Tribe of Washington State is an exception that proves the rule. Their cohesive and homogeneous community will not repair the seawall that is currently losing its battle to protect Taholah village from a rising Pacific Ocean. Instead, the tribe, using federal funds, will move the 700-person village to higher ground at a cost of about $350,000 per person. NOAA, U.S. Climate Resilience Toolkit, *Case Studies: Quinault Indian Nation Plans for Village Relocation*, https://perma.cc/3PC4-79B3 (last updated Dec. 2, 2016); *see also* Quinault Indian Nation, Taholah Village Relocation Master Plan, https://perma.cc/3LA8-63UZ (updated May 16, 2017).

[87] Stan Cox & Paul Cox, *A Rising Tide: Miami is sinking beneath the sea—but not without a fight*, The New Republic, Nov. 8, 2015, http://bit.ly/21pwWBD. The city is planning to spend several hundred million dollars on a system of elevated streets and electrically powered pumps, but even these efforts at accommodation struggle to contain and expel seawater faster than it flows in. Joey Flechas et al., *Emily rain pounds South Florida and Beach pumps fail without power*, Miami Herald, Aug. 1, 2017, https://perma.cc/25YH-JNYX.

[88] Pam Radtke Russel, *Special Report: How Engineers Are Preparing for Sea-Level Rise: From Seattle to Cape Cod, see what's being done at 18 different locations*, Engineering News Record, Aug. 11, 2017, https://perma.cc/7JXL-X3VU.

Each of these approaches can take smaller-scale "incremental" forms that aim to cope with hazards, or larger "transformational" forms that aim to greatly reduce or even eliminate vulnerabilities. Protection: in contrast to a modest seawall or living shoreline seaward of one parcel of property, the State of Louisiana's Comprehensive Master Plan envisions wetland and barrier island restorations on a scale large enough to stem—and ideally offset—the rapid subsidence and erosion of the state's entire coastline.[89] Accommodation: like the elevation of a beach house, only on the scale of citywide infrastructure, Miami Beach has raised many of its streets and sidewalks by several feet, such that floodwaters inundate them less severely and less often.[90] Retreat: this approach is inherently transformational, but it can be undertaken in a disorganized fashion, as happened in the aftermath of Hurricane Katrina,[91] or in coordinated fashion, as has happened with state support and guidance on Staten Island and with federal support in Isle de Jean Charles, Louisiana and Taholah Village, Washington.[92]

Among the policy tools used to effectuate these categories of coastal adaptation are:

Land use rules and restrictions
- Conditional development;
- Conservation easements;
- Floodplain regulations;
- Hard- and soft-armoring permits;
- Land Trusts;
- Real estate disclosures;
- Rebuilding restrictions;
- Setbacks and buffers;
- Transferable development rights;
- Zoning and overlay zones.

Design prescriptions
- Building codes;
- Infrastructure design parameters.

Fees and financing
- Coastal land acquisition programs;
- Flood insurance requirements;
- Impact fees;
- Level of service downgrades;
- Special assessments;
- Stormwater utility.

Each of these is described in greater depth elsewhere.[93] For this chapter's purposes, the key point to take from the list is that the tools for adapting to coastal flooding are the same as conventional

[89] *Id.* at 94–95, 100–102.
[90] Joey Flechas, *Miami Beach to begin new $100 million flood prevention project in face of sea level rise*, Miami Herald, Jan. 28, 2017, https://perma.cc/H9FB-LLG6.
[91] Elizabeth Maly et al., *Experience from the United States: Post-Katrina and Sandy*, *in* Land Use Management in Disaster Risk Reduction 79, __ (Dec. 2016).
[92] *Id.* at __; State of Louisiana, *Isle de Jean Charles Resettlement Project*, https://perma.cc/EG6T-VLVB (accessed Oct. 12, 2017); U.S. Climate Resilience Toolkit, *Quinault Indian Nation Plans for Village Relocation*, https://perma.cc/V58H-TP33 (last modified Jan. 17, 2017).
[93] *See, e.g.*, South Florida Regional Planning Council, Adaptation Action Areas: A Planning Guidebook for Florida's Local Governments Regional Climate Action Framework: Implementation Guide 63 (2015), https://perma.cc/2H39-7WUC; Anne Siders, Managed Coastal Retreat: A Legal Handbook on Shifting Development Away from Vulnerable Areas (Oct. 2013), https://perma.cc/Z5A2-ALQB (providing illustrative examples). For an example of how an ordinance can introduce downgrades to the level of service for a branch of networked infrastructure, see Thomas Ruppert et al., Environmentally Compromised Road Segments—A Model Ordinance, at

planning in coastal communities. Importantly, public health seldom factors directly into the use of these tools, which draw instead on inputs relating to land values, engineering specifications, and aesthetic preferences.

II. Legal Issues

The preceding section discusses policies and measures responsive to particular climate-driven impacts, but leaves discussion of legal requirements and constraints that those responses are sure to encounter for this section. This section's discussion is not comprehensive with respect to legal issues arising from efforts to adapt—it does not, for instance, discuss disputes among private actors, nor conflicts and entanglements arising from government-led adaptation efforts' intersecting with legal obligations imposed by federal laws, such as the Clean Water Act's requirements for stormwater management. Instead, it focuses on situations in which state or local governments run the risk of litigation brought by private actors. One such situation arises when governments' efforts to reduce adverse public health impacts by adapting land uses and the built environment to climate change cause some individuals to arguably be harmed economically by decreased property values or limitations on the use of their property. In such cases, people may attempt to sue the regulating entity to compensate them for their loss, or else to try to stop the project altogether. Another situation arises when a lack of action by governments to adapt to climate change impacts arguably causes injuries or property damage that could have been prevented by improved infrastructure or other measures. Thus governments can expose themselves to legal risk whether they take a passive or active role in adapting the built environment to climate change.

This section explores two types of claims litigants may bring against governments either for adapting to climate change or for failing to do so. First, it considers a "takings" claim, also known as an inverse condemnation claim, which may be brought by a property owner against a government where the government's actions diminish the property's value. Such claims can be expected when governments make decisions related to coastal infrastructure or land use in particular.[94] Next, it considers a negligence claim, which alleges that an entity or individual's actions fell below a reasonable standard of care, and therefore harmed the individual bringing the lawsuit. These are not the only legal theories that could be brought by parties seeking to challenge action or inaction related to climate change or its impacts, but they are among the most readily available to parties vying with government defendants. They thus provide a useful illustration of the legal risks governments face and the limits to redress available to plaintiffs in the context of a changing climate.

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para. 1, https://perma.cc/3RLM-DY7K (accessed Jan. 6, 2017) ("any road categorized as 'environmentally compromised' under this ordinance shall be the subject of a requested design/maintenance exception.").

[94] *See, e.g.*, Jordan v. St. Johns County, 63 So. 3d 835 (2011).

A. Takings Claims

The Takings Clause of the Fifth Amendment of the United States Constitution provides that "private property [may not] be taken for public use, without just compensation."[95] The Fourteenth Amendment extends this prohibition to states and municipalities.[96] Many state constitutions also contain a takings clause closely mirroring the federal clause[97] or providing broader protections by prohibiting the government from merely damaging private property without compensation.[98]

In the most clear-cut cases, a private property owner may sue the government for physically occupying his property or for completely depriving him of the economically beneficial use of his property.[99] Such cases are known as *per se* takings and, if proven, require the government to pay the owner "just compensation" for the deprivation.

In contrast, governments often institute regulations that decrease the range of uses available to a property owner, and possibly decrease property values, but do not completely deprive the owner of the use of his property. For example, in response to encroaching sea levels, a local government might impose a setback requirement, such that property owners cannot build on the portions of their plot closest to the shore. If an owner sued the local government for imposing the setback requirement,[100] his "regulatory takings" challenge would be governed by the multi-factor test announced in *Penn Central Transportation Co. v. New York City*.[101] The *Penn Central* test requires courts to inquire as to 1) the economic impact of the regulation on the property owner, 2) the character of the governmental action, and 3) the extent to which the regulation has interfered with the economic expectations of the property owner.[102] In other words, courts determining the merit of a regulatory takings claim must balance the interests of the parties, with a focus on the magnitude and character of the burden a particular regulation imposes upon private property rights.

1. Claims against governments in response to adaptation plans and policies

[95] U.S. Const. amend. V.

[96] *Chicago, Burlington & Quincy Railroad Co. v. City of Chicago*, 166 U.S. 226 (1897).

[97] *See, e.g.*, Conn. Const. art. I, § 11 ("The property of no person shall be taken for public use, without just compensation therefor"); Wis. Const. art. I, § 13 (same).

[98] *See, e.g.*, Alaska Const. art. I, § 18 ("Private property shall not be taken or damaged for public use without just compensation."); Ariz. Const. art. II, § 17 ("No private property shall be taken or damaged for public or private use without just compensation having first been made…"); Ark. Const. art. II, § 22 ("…private property shall not be taken, appropriated or damaged for public use, without just compensation therefor.")

[99] *Loretto v. Teleprompter Manhattan CATV Corp.*, 458 U.S. 419 (1982); *Lucas v. South Carolina Coastal Council*, 505 U.S. 1003 (1992).

[100] *See, e.g., A Piece of Paradise v. Borough of Fenwick Zoning Board of Appeals*. No. LNDCV136047679S, 2015 WL 10285888 (Conn. Super. Ct. Dec. 23, 2015)

[101] 438 U.S. 104 (1978)

[102] *Connolly v. Pension Ben. Guar. Corp.*, 475 U.S. 211, 212 (1986) (citing *Penn Central*, 438 U.S. at 124).

Several cases demonstrate the challenges that property owners face when bringing takings claims in response to climate change adaptation policies adopted by the federal or local government. In one such case, the Supreme Court of South Carolina rejected a takings claim brought by a property owner who had been prohibited from developing since its land was located within a floodplain.[103] This prohibition is an example of an adaptation measure designed to reduce exposure to hazards by decreasing the amount of development within an area likely to experience flooding. The developer, Columbia Venture, LLC, purchased more than 4,000 acres of land along a riverbank. At the time of purchase, the Federal Emergency Management Agency (FEMA) was in the process of designating most of the area a regulatory floodway. The South Carolina county in which Columbia Venture's property was located adopted the FEMA maps, and, through an existing local ordinance, restricted construction in the floodway. The County's land-use standards were more restrictive than those required by the federal government in recognition of FEMA's failure to project the likelihood of increased flooding due to climate change.[104]

A Special Referee was appointed to consider Columbia Venture's regulatory taking claim. Applying the *Penn Central factors*, the Special Referee concluded that FEMA's designation of Columbia Venture's property as a regulatory floodway caused a significant decrease in the property's value.[105] This factor was outweighed, however, by the fact that Columbia Venture's expectation of being able to develop the property was unreasonable in light of the foreseeable potential regulatory bar on floodplain development. Moreover, the county's floodplain regulations served an important purpose — flood protection.

The South Carolina Supreme Court affirmed the Special Referee's decision that the county's floodway development restrictions did not constitute a taking. With respect to Columbia Venture's investment-backed expectations, the court held that the developer faced an "uncertain path forward" in light of the pending FEMA flood maps and associated county regulations. The county was a long-time participant in federal flood planning programs, and the developer was a sophisticated party with notice of the county's floodplain development restrictions, as well as the pendency of FEMA's revised floodway designation. The planned development was, therefore "purely speculative in nature," and the developer's expectation of being able to successfully pursue the development was unreasonable. The Supreme Court also acknowledged "the important public purposes of mitigating the social and economic costs of flooding [] served by the County's ordinances."[106] Thus, the County was not responsible for

[103] *Columbia Venture, LLC v. Richland Cty.*, 413 S.C. 423, 431, 776 S.E.2d 900, 904 (2015), *reh'g denied* (Oct. 9, 2015), *cert. denied*, 136 S. Ct. 1458 (2016).
[104] *Id.* at 431, n.4.
[105] *Id.* at 441.
[106] *Id.* at 452.

paying the developer "just compensation," despite the impact of its floodplain regulations on the value of the property.[107]

As the court recognized in *Columbia Venture*, there is no "magic formula" for applying the *Penn Central* factors in determining whether a government regulation causing interference with property is a taking.[108] In light of the "nearly infinite variety of ways in which government actions or regulations can affect property interests," climate change adaptation policies' vulnerability to a takings claim will depend on the circumstances of the particular landowner's case. One conclusion that can be gleaned from *Columbia Venture*, however, is that governments choosing to pursue climate change adaptation policies should do so as soon as possible. As a report prepared by the University of Maine's Marine Law Institute observed in the context of a coastal retreat policy proposal, "[t]he earlier that the public is on notice of the…policy choice…, the more likely the regulations are to withstand legal challenge. Property that is purchased after the regulations are adopted will be bought subject to the expectations that the development restrictions will be applied…."[109]

2. Claims against governments for failure to adapt the built environment

Property owners may also initiate litigation against the government for taking private property where the government fails to prevent the impacts of climate change, thereby indirectly causing damage to the owner's property.[110]

For example: Starting in the 1950s, the United States Army Corps of Engineers (the Corps) built the Mississippi River Gulf Outlet (MRGO), a 76-mile channel between New Orleans and the Gulf of Mexico intended to provide a shorter shipping route.[111] Although MRGO was designed to be 500 feet wide, decades of use eroded the channel to more than triple its design width.[112] MRGO's increased width allowed the channel to carry a much greater

[107] A Connecticut court reached a similar result in *A Piece of Paradise v. Borough of Fenwick Zoning Board of Appeals*. No. LNDCV136047679S, 2015 WL 10285888 (Conn. Super. Ct. Dec. 23, 2015). In that case, the plaintiff owned a parcel of land on which it planned to build a single family home. The lot was located within a coastal boundary, which required the municipality to undertake a coastal site plan review. The lot owner applied for a variance from a fifty-foot setback requirement imposed by the local government, and the board denied the plaintiff's variance request. *Id.* at *4 The court held that the board's denial did not constitute a taking without just compensation. *Id.* at *8.

[108] *Columbia Venture* at 448.

[109] U.S. EPA, Office of Policy, Planning, & Evaluation, Anticipatory Planning For Seal-Level Rise Along the Coast of Maine (1995).

[110] For an extremely informative discussion of government liability under the Takings Clause for failure to act to protect private property, *see* Christopher Serkin, *Passive Takings: The State's Affirmative Duty to Protect Property*, 113 Mich. L. Rev. 345 (2014).

[111] Michael Gerrard, *Hurricane Katrina Decision Highlights Liability for Decaying Infrastructure*, New York Law Journal (May 10, 2012).

[112] *Id.*

volume of water, exposed a greater surface area to wind causing more severe waves, and carried saltwater inland, destroying buffer wetlands. When Hurricane Katrina hit New Orleans in 2005, several levees and storm walls surrounding MRGO were destroyed, and the city was devastated by the resultant flooding.[113]

In the aftermath of the hurricane, hundreds of plaintiffs sued the United States government to recover damages for flooded property. Although a series of cases brought under the Federal Tort Claims Act (FTCA) were unsuccessful because the government was found to be immune from suit,[114] a more recent decision in a case brought under the Takings Clause found in favor of the property owners.

In *Saint Bernard Parish Government v. United States*,[115] Judge Susan Braden of the United States Court of Federal Claims found that the Corps' negligent design and failure to maintain MRGO exacerbated flood damage in parts of New Orleans. The increased flooding, although temporary, wrongfully deprived landowners of the use of their property requiring compensation. Judge Braden's decision relied heavily on a 2012 Supreme Court case, *Arkansas Game and Fish Commission v. United States*, which held that temporary flooding caused by government action is not categorically exempt from Takings Clause liability.[116] The plaintiffs in *Saint Bernard Parish* avoided the sovereign immunity issues that prevented the FTCA litigants from recovering damages, because the United States has waived sovereign immunity for claims brought under the Takings Clause through the Tucker Act.[117]

That the government was held liable for inadequately preparing federally-constructed and maintained infrastructure for severe weather events in *Saint Bernard Parish* is significant in light of the increasing risk of such events due to climate change. Notably, *Saint Bernard Parish*, if it survives appeal, expands government liability from situations in which the government deliberately causes flooding, for example by releasing water from a dam, to include situations in which inaction by the government exacerbates flooding from severe weather through its failure

[113] *Id.*
[114] In those cases, the Fifth Circuit Court of Appeals at first affirmed the trial court's finding of liability, but then issued a subsequent ruling finding that the government was immune from the plaintiffs' claims, because its actions in connection with the design and maintenance of MR-GO were largely discretionary. *In re Katrina Canal Breaches Litigation*, 673 F.3d 381 (5th Cir. 2012) (finding the federal government liable for Hurricane Katrina flood damage caused by the Corps' failure to armor the banks of MRGO); *In re Katrina Canal Breaches Litigation*, 696 F.3d 436 (5th Cir. 2012) (reversing the Circuit Court's prior decision and finding the federal government immune from suit under the discretionary function exception to the FTCA).
[115] *St. Bernard Parish Gov't v. United States*, 121 Fed. Cl. 687 (2015). The case has been appealed to the Federal Circuit Court for Federal Claims. Notice of Docketing, St. Bernard Parish v. US, Case 16-2301 (Fed. Cir. July 6, 2016). As of August 2017, that proceeding is ongoing.
[116] *Arkansas Game & Fish Comm'n v. United States*, 133 S. Ct. 511, 515 (2012).
[117] 28 U.S.C.A. § 1491 (2012) (granting jurisdiction to the Court of Federal Claims for claims for "damages in cases not sounding in tort").

to properly design or maintain federally owned infrastructure.[118] Professor Christopher Serkin has argued that the Takings Clause can serve as a basis for affirmative governmental obligations to protect private property more generally and cites sea level rise as "an ideal illustration" of an environmental shift that could require governments to act.[119] While governments obviously do not have an obligation to protect all property from all intrusions, a duty arises where the state exercises regulatory control over the injury-causing condition or where the state is complicit in creating the conditions responsible for harm to the property.[120] This developing area of law will have broad implications for state governments seeking to prepare for – or deliberately deciding not to prepare for – climate change impacts.

Some legal scholars have expressed concern that *Saint Bernard Parish* and *Arkansas Game and Fish Commission* allow the takings doctrine to improperly invade the traditional domain of tort law.[121] The apparent expansion of takings liability ushered in by these cases, however, will likely be tempered by the fact specific analysis required in cases asserting claims for temporary takings due to flooding or other natural disasters. As Judge Braden explained, a plaintiff asserting a claim for a temporary taking must establish: (1) a protectable property interest under state law; (2) the character of the property and the owners' "reasonable-investment backed expectations"; (3) foreseeability; (4) causation; and (5) substantiality.

The first prong merely requires the plaintiff to show that he has an ownership interest in the property allegedly taken through government inaction.[122] With respect to the owners' reasonable investment backed expectations, as discussed in the previous section, courts inquire whether the plaintiff was aware of the risks facing his property. In *Saint Bernard Parish*, the court concluded that "although Plaintiffs' properties were in a floodplain and 'had experienced flooding in the past,' that flooding was not 'comparable' to the flooding during Hurricane Katrina and subsequent hurricanes and severe storms giving rise to the temporary takings claim

[118] Notably, Saint Bernard Parish is not the first case to support the idea that a government can commit a taking through the failure to act. An earlier case in Florida state court held that "government inaction – in the face of an affirmative duty to act – can support a claim for inverse condemnation." *Jordan v. St. Johns Cty.*, 63 So. 3d 835, 839 (Fla. Dist. Ct. App. 2011); *but see Harris Cty. Flood Control Dist. v. Kerr*, 499 S.W.3d 793, 799 (Tex. 2016), *reh'g denied* (Oct. 21, 2016) (rejecting landowners' takings claim where the defendant county allegedly caused their homes to flood by failing to fully implement a stormwater management plan and by approving private development upstream).

[119] Serkin, *supra* note __, at 388.

[120] *Id.*, at 377–78 (noting that "if the government…were responsible for global warming then the duty to act would be stronger still); *see also City of St. Petersburg*, *supra* note 46, at 1086 (once a governmental entity creates a known dangerous condition which may not be readily apparent to one who could be injured by the condition…the governmental entity must take steps to avert the danger or warn [of] that danger); *Teall v. City of Cudahy*, 386 P.2d 493 (Cal. 1963) (defendant city may be held liable if it created a dangerous or defective condition); Delarosa v. State, 21 Ariz. App. 263, 265, 518 P.2d 582, 584 (1974) (state not entitled to notice of a dangerous condition that it has created or caused to be created).

[121] John Echeverria, Takings Litigation: A blog about takings law, *Ruling in MR-GO Takings Lawsuit*, May 1, 2015, https://perma.cc/U9ZM-NKP9.

[122] *See St. Bernard Parish*, *supra* note __, at 719.

at issue."[123] Professor Serkin has posited that "an 'ecological change' can interfere with owners' expectations just as much as an explicit legal transition."[124] As climate change causes increasingly severe natural disasters, more courts could find that a property owner's past experience with severe weather does not adequately put him on notice of future risk.

The foreseeability prong of a temporary takings claim invites an inquiry into "the degree to which the [government's] invasion is … the foreseeable result of government action."[125] In *Saint Bernard Parish*, the court found that it was foreseeable that MRGO would intensify flooding in New Orleans based on a variety of environmental factors, including increased erosion on MRGO's banks and increased storm surge.[126] The plaintiffs were also able to establish a causal connection between the Corps' failure to maintain MRGO and flooding during Hurricane Katrina, since the Corps' inaction was the cause of the erosion, increased storm surge, and other exacerbating factors.[127] As discussed in the previous section, developing adaptation measures requires that governments assess vulnerabilities. As governments compile data and develop models projecting future vulnerabilities, potential impacts due to government action or inaction may become increasingly foreseeable.

Finally, a plaintiff alleging a temporary taking must show a sufficiently severe economic impact on his property to constitute a legally cognizable interference.[128] Moreover, the plaintiff must establish that the government's inaction caused the diminished property value; in other words, the government must have had the ability to protect the property at issue.[129] In *Saint Bernard Parish*, the Plaintiffs established this element by showing that their properties were flooded because of the Corps' negligent maintenance of MRGO and that they lost their ability to access or use their properties for a "significant" time period – ranging from a few weeks to a few months – following Hurricanes Katrina and Rita.[130]

In December 2016, the Corps appealed Judge Braden's ruling, arguing that the plaintiffs' case "would at most establish a potential tort claim, not a Fifth Amendment taking."[131] The Corps contends that flooding from Hurricane Katrina did not constitute a taking, because the government did not *intend* to flood plaintiffs' properties. Instead, according to the Corps, the

[123] *Id.*, at 720 (citing *Arkansas Game & Fish*, *supra* note __, at 522).
[124] Serkin, *supra* note __, at 352.
[125] *St. Bernard Parish*, *supra* note 126, at 720 (citing *Arkansas Game & Fish*, *supra* note 127, at 522).
[126] *Id.*, at 721–22.
[127] *Id.*, at 724–36.
[128] *Id.*, at 745 (citing *Penn Cent. Transp. Co. v. City of New York*, 438 U.S. 104, 124 (1978)).
[129] Serkin, *supra* note 45, at 382–83, 395 (noting that a taking does not occur where "the action that the government could have taken but did not would have been within the range of appropriate governmental actions" or where the action would not have been "financially plausibly considering the property").
[130] *St. Bernard Parish*, *supra* note 126, at 746.
[131] Juan Carlos Rodriguez, *Army Corps Asks Fed. Circ. To Undo Katrina Liability Ruling*, Law 360, Dec. 12, 2016, https://perma.cc/99X4-XPAT.

flooding was "the sort of 'incidental or consequential injury' that has never been regarded as a taking."[132]

Until the Corps' appeal is finally decided – and there is a good likelihood the case will go to the Supreme Court – there is reason to believe that the argument for using the Takings Clause to impose an affirmative duty to protect private property, at least in cases where the government's past actions create vulnerabilities to natural disaster risk, is emerging. Such cases could promote climate change adaptation by encouraging governments to weigh the costs and benefits of both action and inaction in the face of the increasing risk of natural disasters.

B. Negligence claims

On April 18, 2013, Illinois Governor Pat Quinn declared a state of emergency after heavy rain caused extensive flooding in Chicago and the surrounding area.[133] Residents of some Chicago suburbs were evacuated, and people were urged to reduce household water use to prevent further flooding at the Chicago River.[134] Tens of thousands of people lost power, a sinkhole swallowed cars, and hundreds of flights were canceled at O'Hare airport.[135]

Several months later, a group of insurance companies sued Chicago and over 100 nearby local governments in a series of class action lawsuits, claiming that the municipalities did not do enough to prevent the flooding.[136] The insurance companies argued that the local governments were negligent in failing to prepare for the impacts of climate change and sought to be reimbursed for claims paid to property owners.[137] The cases were quickly withdrawn,[138] but

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[132] *Id.*

[133] *Chicago Flooding: Heavy Rain Storm Prompts Emergency, Road Closures in Cook County*, HUFFINGTON POST CHICAGO (Apr. 18, 2013), https://perma.cc/N2MQ-L8A2.

[134] *Id.*

[135] *Id.*; Staff Report, *Storms Cause Damage, Power Outages*, NBC Chicago (June 13, 2013), *available at* http://www.nbcchicago.com/weather/stories/Storms-Chicago-Severe-Weather-211009451.html.

[136] *Illinois Farmers Insurance Company v. Metropolitan Water Reclamation District of Greater Chicago*, No. 14-CH-06608 (Ill. Cir. Ct. Cook Co.); Robert McCoppin, *Insurance company drops suits over Chicago-area flooding*, CHICAGO TRIBUNE (June 3, 2014) http://trib.in/2sPL9LY.

[137] *Illinois Farmers Insurance*, *supra* note __; *Illinois Farmers Insurance Company v. County of DuPage*, No. 14-L-385 (Ill. Cir. Ct. DuPage Co.); *Illinois Farmers Insurance Company v. County of Lake*, No. 14-L-281 (Ill. Cir. Ct. Lake Co.); *Illinois Farmers Insurance Company v. County of Will*, No. 14-L-314 (Ill. Cir. Ct. Will Co.). The plaintiffs' negligence claims were brought under an Illinois statute codifying the government's potential civil liability. Specifically, the plaintiffs claimed that the local government defendants violated: 1) 745 Ill. Comp. Stat. Ann. 10/3-102, which provides that "a local public entity has the duty to exercise ordinary care to maintain its property in a reasonably safe condition…" and 2) 745 Ill. Comp. Stat. Ann. 10/3-103, which provides that a local government may be liable where, after executing a plan to construct or improve public property, "it appears from its use that it has created a condition that is not reasonably safe." The plaintiffs also brought claims under the state and federal takings clause.

[138] McCoppin, *supra* note __.

similar suits have been brought in Illinois[139] and Australia.[140] If litigated, such cases would likely require inquiry into governments' efforts to implement various adaptation measures, such as requiring elevation of structures to reduce flooding or investing in green infrastructure to decrease by-pass events by draining severe rainfall.

1. Government Immunity

State governments are generally protected from litigation by the doctrine of "sovereign immunity."[141] Overcoming sovereign immunity presents a significant hurdle in negligence cases in both federal and state courts by virtue of their sovereignty.[142] Sovereign immunity extends both to the government entity itself and to government officials sued in their official capacities.[143] States may consent to be sued, and many have waived sovereign immunity under

[139] *E.g. Tzakis v. Berger Excavating Contractors, Inc.*, No. 09 CH 06159 (Ill. Cir. Ct. Cook Co.) (class action alleging, in part, that local governments caused flood damage to plaintiffs' property by failing to enact new standards reducing rainwater runoff despite the increasing risk of severe precipitation. *Tzakis* was ultimately dismissed on the basis of Illinois' Public Duty Rule, which provides that a public entity is not liable for its failure to provide adequate "governmental services," because the duty to provide such services is owed to the general public at large, and not to any particular plaintiff or plaintiffs).

[140] Several cases regarding the government's duty of care to protect citizens from risk, albeit not specifically from climate change risk, have been pursued in Australia, *See, e.g.*, *Brodie v Singleton Shire Council* (2001) 206 C.L.R. 512 (holding that in certain circumstances the government yields a special measure of control over the safety of citizens so as to impose a duty of care and an obligation to exercise its powers to avert a danger or to bring it to the knowledge of citizens); *Alec Finlayson Pty Ltd v. Armidale City Council* (1994) 123 A.L.R. 155 (holding that if a public authority creates or increases a risk to another person, he is obligated to take reasonable action to prevent injury unless statute precludes the duty to act).

[141] Although the Eleventh Amendment bar to suit against states in federal courts does not extend to counties and municipalities, local governments also enjoy some measure of immunity based on state statutory and common law. *Falk v. Perez*, 973 F. Supp. 2d 850, 861 (N.D. Ill. 2013) (citing *Mt. Healthy City Sch. Dist. Bd. of Educ. v. Doyle*, 429 U.S. 274, 280 (1977)); *Crouch v. City of Kansas City*, 444 S.W.3d 517, 521 (Mo. Ct. App. 2014) (municipalities are entitled to sovereign immunity only when engaged in governmental functions); *Am. Home Assur. Co. v. Nat'l R.R. Passenger Corp.*, 908 So. 2d 459, 478 (Fla. 2005) (state statute granted cities immunity from judgments above certain limits); *City of Chesapeake v. Cunningham*, 268 Va. 624, 634, 604 S.E.2d 420, 426 (2004) (Sovereign immunity protects municipalities from tort liability arising from the exercise of governmental functions).

[142] *United States v. Lee*, 106 U.S. 196 (1882) (doctrine is derived from the laws and practices of English ancestors); *Coll. Sav. Bank v. Florida Prepaid Postsecondary Educ. Expense Bd.*, 527 U.S. 666, 669 (1999); *Alden v. Maine*, 527 U.S. 706 (1999) (part of the very nature of sovereignty to be immune from unconsented suits).

[143] *HCMF Corp. v. Gilmore*, 26 F. Supp. 2d 873, 878 (W.D. Va. 1998) (Virginia's Eleventh Amendment immunity "extends to state officials when they are merely the nominal defendants and 'the state is the real, substantial party in interest.'"); *Illinois Health Care Ass'n v. Walters*, 303 Ill. App. 3d 435, 438, 710 N.E.2d 403, 405 (Ill. App. Ct. 1999) ("If a suit is brought against a state official, yet the judgment could operate to control the actions of the state or subject it to liability, then the suit is, in actuality, against the state."); *Olavarria v. Wake Cnty. Human Servs.*, 763 S.E.2d 18 (N.C. Ct. App.), *appeal dismissed, review denied*, 763 S.E.2d 394 (N.C. 2014) ("governmental immunity shields municipalities and the officers or employees thereof sued in their official capacities from suits based on torts committed while performing a governmental function.").

certain circumstances through legislative enactments. Waivers are, however, interpreted narrowly by courts.[144]

Nonetheless, it is sometimes possible to formulate a claim such that it falls outside the scope of state and local governments' immunity.[145] While the nuances of sovereign immunity vary from state to state, certain exceptions are common. First, while sovereign immunity generally bars suits seeking monetary damages against government agencies, actions for declaratory judgment or injunctive relief are permissible in some states.[146] Second, within certain jurisdictions, governmental immunity for tort claims is waived when the government purchases liability insurance covering such claims.[147]

Many states immunize discretionary functions, but allow suit against governments and government officials for "ministerial" actions.[148] In distinguishing between discretionary acts and ministerial functions, "the key factor is the presence of basic policy formulation, planning, or

[144] *New Orleans Tanker Corp. v. Dep't of Transp.*, 728 A.2d 673, 675 (Me. 1999) (we start from the premise that immunity is the rule and exceptions to immunity are to be strictly construed); *Lockwood v. City of Pittsburgh*, 751 A.2d 1136, 1139 (Pa. 2000) (exceptions to immunity are to be strictly construed); *Guillen v. City of San Antonio*, 13 S.W.3d 428, 433 (Tex. App. 2000) (the Texas Tort Claims Act is a limited waiver of absolute common law immunity…construed strictly on the side of preserving immunity).

[145] 6 Litigating Tort Cases § 66:2 ("whether immunity applies is often a matter of how the claim is characterized rather than the reality of the claim itself").

[146] *Atl. Specialty Ins. Co. v. Webster Cnty., Miss.*, No. 140-CV-23, 2014 WL 3437019, at *6 (N.D. Miss. July 11, 2014) (while municipalities are immune from certain claims for monetary damages, governmental immunity does not prevent plaintiffs from seeking declaratory relief); *Roland v. Epps*, 10 So. 3d 972, 974 (Miss. Ct. App. 2009) ("a state official may be sued for injunctive relief in his or her official capacity"); *Legal Capital, LLC. v. Med. Prof'l Liab. Catastrophe Loss Fund*, 750 A.2d 299, 302 (Pa. 2000) (sovereign immunity does not apply because it is not applicable to declaratory judgment actions); *Texas Dep't of Banking v. Mount Olivet Cemetery Ass'n*, 27 S.W.3d 276, 281 (Tex. App. 2000) (holding that sovereign immunity did not bar suit for declaratory relief); *Penland v. Redwood Sanitary Sewer Serv. Dist.*, 956 P.2d 964, 965 (Or. 1998) (discretionary immunity does not bar a suit for injunctive relief).

[147] *Napier v. Town of Windham*, 187 F.3d 177, 190 (1st Cir. 1999) (Under Maine law, if a governmental entity procures insurance that provides coverage in areas where the governmental entity is immune under the state's Tort Claims Act, the entity waives its immunity, but only to the limits of the insurance coverage); *City of Caddo Valley v. George*, 9 S.W.3d 481, 484 (Ariz. 2000) ("a municipal corporation's immunity for negligent acts only begins where its insurance coverage leaves off"); *Gilbert v. Richardson*, 452 S.E.2d 476, 481 (Ga. 1994) (Georgia Tort Claims Act waives only sovereign or governmental immunity of local governmental agency to extent of liability insurance coverage).

[148] *Trotter v. Sch. Dist. 218*, 733 N.E.2d 363, 375 (Ill. 2000); *Willow Creek Ranch, L.L.C. v. Town of Shelby*, 611 N.W.2d 693, 700 (Wis. 2000) (Under the Wisconsin Tort Claims Act, a municipality is immune from any suit for liability arising from discretionary acts); *Rivera v. City of Worcester*, No. 12-CV-40066, 2015 WL 685800, at *6 (D. Mass. Feb. 18, 2015) (in Massachusetts, the discretionary function exception bars government liability for claims based upon the exercise or performance or the failure to exercise or perform a discretionary function or duty); *Williams v. Mayor & City Council of Baltimore*, 753 A.2d 41, 60-61 (Md. 2000) (in Maryland, government actors generally immune from liability where tortious conduct occurred while performing discretionary as opposed to ministerial acts"); *Chirieleison v. Lucas*, 72 A.3d 1218, 1224 (Conn. App. Ct. 2013) ("a municipal employee is liable for the misperformance of ministerial acts, but has a qualified immunity in the performance of governmental acts").

policy decisions which are characterized by an exercise of a high degree of official judgment or discretion."[149] For example, a city exercises discretion when it selects and adopts a public improvement plan, but carrying out the plan involves ministerial actions that must be carried out in a reasonably safe manner.[150]

Notably, many states include a "dangerous conditions exception" to sovereign immunity in their tort claims acts, allowing law suits arising from a government entity's maintenance of property it owns.[151] For example, Pennsylvania waives immunity for tort claims arising out of its control of, among other things, "utility service facilities," which include storm water management systems.[152] Statutes carving out such an exception generally impose "a broad duty … to maintain safe public places."[153] Under this exception, however, the plaintiff must show that the government either created the dangerous condition causing the plaintiff's injury or should have known of the condition.[154]

2. Negligence elements

Once a plaintiff overcomes a sovereign immunity defense, a governmental entity is generally subject to the same rules of liability that apply to nongovernmental entities.[155] Litigants

[149] 6 Litigating Tort Cases § 66:47.

[150] *Trotter*, *supra* note 23.

[151] Dan B. Dobbs, Paul T. Hayden and Ellen M. Bublick, The Law of Torts § 336 (2d ed.) ("States also tend to eliminate immunity for injuries resulting from badly maintained government property."). Statutory exceptions to sovereign immunity for public property include: 42 Pa. Cons. Stat. Ann. § 8542 (a local entity may be liable for "the care, custody or control of real property in the possession of the local agency"); Colo. Rev. Stat. Ann. § 24-10-106 (sovereign immunity is waived by a public entity in an action for injuries resulting from a dangerous condition of any public property, including buildings, highways, and power facilities); Mo. Ann. Stat. § 537.600 (immunity of the public entity is expressly waived for injuries caused by the condition of a public entity's property); and Mich. Comp. Laws Ann. § 691.1406 (governmental agencies liable for injury resulting from dangerous condition of a public building if agency had knowledge of the defect and failed to remedy the condition or take action reasonably necessary to protect the public against the condition.).

[152] 42 Pa. Cons. Stat. Ann. § 8542(5); *Rooney v. City of Philadelphia*, 623 F. Supp. 2d 644, 653 (E.D. Pa. 2009).

[153] 6 Litigating Tort Cases § 66:66.

[154] *Bonilla v. Starrett City at Spring Creek*, 704 N.Y.S.2d 619, 620 (N.Y. 2000) ("To impose liability upon the defendants, there must be evidence tending to show the existence of a dangerous or defective condition and that the defendants either created the condition or had actual or constructive notice of it and failed to remedy it within a reasonable time); *Willis v. City of New Bern*, 529 S.E.2d 691, 693 (N.C. 2000) (granting summary judgment for the defendant city where the plaintiff did not offer proof that the city had notice of the defect causing her injury); *Isbell v. Maricopa Cnty.*, 9 P.3d 311, 314 (Ariz. 2000) (a plaintiff need not establish "notice" if a government agency itself creates or causes the dangerous condition.); *Hawks v. City of Westmoreland*, 960 S.W.2d 10, 15 (Tenn. 1997) (The government has "constructive notice" of a dangerous condition where it could have been discovered by proper diligence and it had a duty to inquiring into it.'").

[155] Indeed, courts have imposed liability on the basis of private property owners' failure to act to prevent damage from natural disasters. For example, in California, the owners of an unreinforced building were found to be negligent when they failed to retrofit the building, and two people inside were killed during an earthquake. *Myrick v. Mastagni*, 185 Cal. App. 4th 1082, 111 Cal. Rptr. 3d 165 (Cal. Ct. App. 2010).

seeking to establish a negligence claim against governments that refuse to prepare for climate change would need to show that 1) the official had a duty to prepare for extreme weather events; 2) the official breached that duty by failing to prepare or causing others to fail to prepare; 3) the litigant suffered harm; and 4) this harm was caused or worsened by the government official's breach of duty. While climate change adaptation litigation is a new phenomenon,[156] analyzing the elements of a negligence claim in this context does not require novel legal theories.[157]

First, the extent of a government's obligation to protect people and ecosystems from the impacts of climate change may be determined by state statute. For example, in Illinois and many other states, local governments have an explicit duty to exercise ordinary care to maintain public property in a reasonably safe condition.[158] Plaintiffs should consider basing allegations of government negligence for failing to prepare for climate change on this prevalent statutorily prescribed government obligation. Many states have enacted statutes enumerating the specific obligations of local and state governments.[159]

Courts may also consider "compelling policy concerns"[160] to expand the scope of the government's duty beyond those expressed in a state statute.[161] Such policy concerns include the foreseeability of harm to the plaintiff, the capacity of the parties to bear the loss, and the consequences to the community of imposing a duty to exercise care.[162] As scientists work to refine predictions of the risk of extreme weather and associated damage to life and property, as

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[156] Maxine Burkett, *Litigating Climate Change Adaptation: Theory, Practice, and Corrective (Climate) Justice*, 42 Envtl. L. Rep. News & Analysis 11144, 11156 (2012) (observing that no climate change adaptation cases had been filed through the end of 2012).

[157] *Id.*, at 11146 ("[T]ort law is well-equipped in both purpose and function to address the challenges of adapting.").

[158] 745 Ill. Comp. Stat. Ann. 10/3-102. For additional examples of statutes defining a state's duty to maintain public property, see note 26.

[159] *See* National Conference of State Legislatures, State Sovereign Immunity and Tort Liability, http://www.ncsl.org/research/transportation/state-sovereign-immunity-and-tort-liability.aspx (listing state tort claims acts); *see, e.g.*, Ill. Ann. Stat. ch. 745, §§ 5/1 *et seq.*; Pa. Cons. Stat. Ann. tit. 42, §§ 8521 *et seq.*; Cal. Gov. Code §§ 815, *et seq.*

[160] Maxine Burkett, *Duty and Breach in an Era of Uncertainty: Local Government Liability for Failure to Adapt to Climate Change*, 20 Geo. Mason L. Rev. 775, 786 (2013).

[161] *See Norris v. Borough of Leonia*, 734 A.2d 762, 768 (N.J. 1999) (Even in cases where a common law immunity has been incorporated into or codified by statute, it remains subject to judicial modification); *Donaca v. Curry Cnty.*, 734 P.2d 1339 (Or. 1987) (finding that a county's liability for failure to maintain the grass at an intersection where an automobile accident occurred depended on "the existence and magnitude of the risk at the intersection…[and the] feasibility and cost of avoiding the risk…."); *Fazzolari By & Through Fazzolari v. Portland Sch. Dist. No. 1J*, 717 P.2d 1210 (Or. Ct. App. 1986), *aff'd*, 734 P.2d 1326 (Or. 1987) (finding that a jury could reasonably conclude that a public school had a duty to protect a student who was attacked on school grounds, after another person had been raped on campus two weeks earlier); *Williams v. Mayor & City Council of Baltimore*, *supra* note 23 (in case against city, listing variables to be considered in determining if a duty exists, including the foreseeability of the harm and the burden on the city of imposing a duty to exercise care).

[162] *See, e.g.*, *Ameriwood Indus. Int'l Corp. v. Arthur Andersen & Co.*, 961 F. Supp. 1078, 1090 (W.D. Mich. 1997); *Torres v. Graves*, No. 92-CV-4449, 1993 WL 19753, at *5-6 (E.D. Pa. Jan. 26, 1993); *Vu v. Singer Co.*, 538 F. Supp. 26, 29 (N.D. Cal. 1981).

manifested in vulnerability assessments, these impacts are increasingly foreseeable. Moreover, governments will almost always have a greater capacity to bear losses than individuals. And imposing a duty on governments to prepare for climate change will generally yield positive outcomes for communities that will otherwise be vulnerable to devastation from natural disasters and other climate risks. In short, policy concerns may support the imposition of a governmental duty to act to protect citizens from potential harm by implementing appropriate climate change adaptation measures.[163]

Some jurisdictions adhere to the "public duty doctrine," which provides that governmental entities and their agents owe duties only to the general public, not to individuals, absent a "special relationship" or "special duty" between the entity and the injured party.[164] The Circuit Court of Cook County, Illinois did so in a case brought against several municipalities by plaintiffs alleging a failure to prepare for climate change: the court held that the city defendants did not owe a duty of care to the plaintiffs in connection with their performance of public duties.[165] A litigant may overcome this public duty defense by showing that the government voluntarily assumed a duty to the plaintiff in particular.[166] Doing so creates a special relationship between the plaintiff and a governmental agency and with it a duty of care towards the individual even for discretionary functions.[167] A special relationship may arise when the government performs an affirmative act, or makes a specific promise or representation that under the circumstances creates a justifiable reliance on the part of the person injured.[168] Notably, many states have abandoned the public duty doctrine altogether.[169] Given its potential application to

[163] *Duty and Breach*, *supra* note __, at 786.
[164] *City Of Toccoa v. Pittman*, 648 S.E.2d 733, 736 (Ga. Ct. App. 2007); *Stone v. N. Carolina Dep't of Labor*, 495 S.E.2d 711, 714 (N.C. 1998).

[165] *Tzakis*, *supra* note __, April 3 Order re PDR Decision as to LPES and other issues, https://perma.cc/LD7X-94QX (finding the public entity defendants immune under Illinois' Public Duty Rule (citing *Harinek v. 161 N. Clark St./Ltd Partnership*, 181 Ill. 2d 335, 345-47 (Ill. 1998)).
[166] 6 Litigating Tort Cases § 66:48; *see also Souder v. Cannon*, 235 S.W.3d 841, 852 (Tex. App. 2007).

[167] *Japan Airlines Co. v. Port Auth. of New York & New Jersey*, 178 F.3d 103, 111 (2d Cir. 1999) (there is no governmental immunity where a special relationship exists between the governmental entity and the injured party); *Hartley v. Floyd*, 512 So. 2d 1022, 1024 (Fla. Dist. Ct. App. 1987) (Once defendant agreed to perform certain tasks, "his actions ceased to be discretionary actions and became merely operational level activities which must be performed with reasonable care and for which there is no sovereign immunity.").
[168] 6 Litigating Tort Cases § 66:48; *1515-1519 Lakeview Boulevard Condo. Ass'n v. Apartment Sales Corp.*, 43 P.3d 1233, 1240 (Wash. 2002) (plaintiff demonstrated a special relationship with respect to the government's maintenance of a storm drain system by showing direct contact between a government official and herself, express assurances given by a public official, and justifiable reliance on those assurances.)

[169] *Jean W. v. Com.*, 610 N.E.2d 305 (Mass. 1993) (abolishing public duty doctrine in Massachusetts); *Adams v. State*, 555 P.2d 235, 243 (Alaska 1976) (abolishing public duty doctrine and applying traditional negligence analysis to government); *Ryan v. State*, 656 P.2d 597 (Ariz. 1982) (same); *Leake v. Cain*, 720 P.2d 152 (Colo. 1986) (public duty doctrine held no longer applicable in Colorado); *Commercial Carrier Corp. v. Indian River County*, 371 So. 2d 1010 (Fla. 1979) (holding governmental negligence to be determined by non-public entity standards); *Wilson v. Nepstad*, 282 N.W.2d 664 (Iowa 1979) (abolishing public duty doctrine); *Schear v. Board of County Comm'rs*, 687 P.2d 728 (N.M. 1984) (public duty doctrine abolished by statute); *Brennen v. City of Eugene*, 591 P.2d 719 (Or.

circumstances in which state or local government actors seek to protect individuals from heat waves or floods but fall short, climate change might push the remaining states to do so as well.

Establishing that a government has an affirmative duty to act is more difficult than establishing that the government must exercise due care when it chooses to act. For example, showing that the government was negligent for failing to build a levee may present greater challenges than showing that the government was negligent in building a levee that was poorly designed or inadequately maintained, since the former might be said to require a greater degree of discretion. Even where a litigant ostensibly seeks damages for a government's "failure to act," however, it may be possible to characterize the government's obligation in other terms.[170] Since state governments make decisions in the context of an existing web of infrastructure, such as sewer systems and levees, the distinction between the duty to maintain government-owned property and to build new structures can be blurry.[171]

Importantly, even where a government action is shielded by discretionary immunity, if that action ultimately creates a dangerous condition known to the government but not readily apparent to people who could be injured by the condition, the governmental entity must take steps to avert the danger or properly warn people of the danger.[172] For example, in *City of St. Petersburg v. Collom*, three individuals drowned when they fell into open storm drainage ditches owned by the city.[173] The court expressed doubt that the city defendant could be held liable for defects in its "overall plan for the drainage system," since such planning constitutes a discretionary function.[174] The *St. Petersburg* court held, nonetheless, that the plaintiffs had stated a cause of action against the city defendant for its failure to either warn people of the open drain hazard or to correct the dangerous condition by adding fences or other barriers around the ditches.[175] According to the *St. Petersburg* court, "a governmental entity may not create a known

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1979) (abolishing public duty doctrine); *Coffey v. Milwaukee*, 247 N.W.2d 132 (Wis. 1976) (same); *DeWald v. State*, 719 P.2d 643 (Wyo. 1986) (same).

[170] *See Jean W. v. Com.*, *supra* note __, at 312 (providing examples of cases that could be characterized either as cases of misfeasance or nonfeasance).

[171] *See* Christopher Serkin, *Passive Takings: The State's Affirmative Duty to Protect Property*, 113 Mich. L. Rev. 345, 348 (2014) (arguing, in the Takings Clause context, that "[p]reexisting regulatory intervention means that the government should not be able to wash its hands of responsibility now.")

[172] *City of St. Petersburg v. Collom*, 419 So. 2d 1082, 1086 (Fla. 1982); *Jezek v. City of Midland*, 605 S.W.2d 544, 548 (Tex.1980); *see also Larson v. Township of New Haven*, 165 N.W.2d 543, 546 (Minn. 1969); *Teall v. City of Cudahy*, 386 P.2d 493 (Cal. 1963); *Lowman v. City of Mesa*, 611 P.2d 943 (Ariz. App. 1980).

[173] *City of St. Petersburg*, *supra* note __.

[174] *Id.*, at 1086 ("defects inherent in the overall plan for an improvement, as approved by a governmental entity, are not matters that in and of themselves subject the entity to liability") (citing *Dep't of Transp. v. Neilson*, 419 So. 2d 1071 (Fla. 1982)).

[175] *Id.*, at 1085–87.

hazard or trap and then claim immunity from suit for injuries resulting from that hazard on the grounds that it arose from a judgmental, planning-level decision."[176]

Assuming that a government entity has a duty to take action to protect citizens from the impacts of climate change, what would constitute a breach of that duty? The failure to provide complete protection from harm clearly does not itself constitute a breach of duty.[177] Instead, establishing a breach of the duty to prepare for the impacts of climate change would likely require a showing that the government's inaction exposed people to unnecessary risks. In this context, significant deference to the government in weighing the costs and benefits of its actions is certainly appropriate. Deference should not, however, "amount to abdication of oversight in the context of either action or inaction."[178]

The well-known "Hand formula" is a useful starting point in determining whether a defendant has breached his duty of care,[179] but would likely be difficult for courts to apply amid climatic changes. Generally, the formula dictates that a person breaches his duty where the likelihood of harm multiplied by the magnitude of harm is greater than the cost of preventing that harm.[180] In the context of a case alleging failure to prepare for climate change, the likelihood of harm is the chance of a particular event, such as a heat wave or a 100-year flood,[181] at the time of

[176] *Id.*, at 1086; *see also Rooney, supra* note __ (finding that a city may not be held liable for an inadequate storm water management system, but it may be liable for damages resulting from negligence in the construction or maintenance of the sewer system).
[177] Instead, courts may find that a government has fulfilled its duty where its actions were justified by the information and resources available at the time of the action or omission at issue *Cootey v. Sun Inv., Inc.*, 718 P.2d 1086, 1090 (Haw. 1986) ("Government is not intended to be an insurer of all the dangers of modern life, despite its ever-increasing effort to protect its citizens from peril."); *Jean W. v. Com.*, supra note 43, at 314-15 ("Police departments are no more responsible for every harm that befalls victims of crime than fire departments are responsible for every sparking of a fire, and neither should be an insurer of every loss sustained in those contexts.").
[178] Serkin, *supra* note __, at 385.
[179] Dobbs, *supra* note 26 § 161 ("If the defendant's cost of preventing the harm is less than the expected value of the harm itself, he is definitely negligent and liable under the Hand formula"); Restatement (Second) of Torts § 291 (1965) ("Where an act is one which a reasonable man would recognize as involving a risk of harm to another, the risk is unreasonable and the act is negligent if the risk is of such magnitude as to outweigh what the law regards as the utility of the act or of the particular manner in which it is done.").
[180] *In re City of New York*, 475 F. Supp. 2d 235, 242 (E.D.N.Y. 2007), *aff'd*, 522 F.3d 279 (2d Cir. 2008) (applying the Hand Formula to determine whether the City of New York was negligent in connection with an accident on the Staten Island Ferry); *Bhd. Shipping Co. v. St. Paul Fire & Marine Ins. Co.*, 985 F.2d 323, 327 (7th Cir. 1993) (Under the Hand formula, a defendant is negligent if the burden (cost) of the precautions that he could have taken to avoid the accident…is less than the loss that the accident could reasonably be anticipated to cause…, discounted (i.e., multiplied) by the probability that the accident would occur unless the precautions were taken."); *Levi v. Sw. Louisiana Elec. Membership Co-op. (SLEMCO)*, 542 So. 2d 1081, 1087 (La. 1989) ("When the product of the possibility of [injury] multiplied times the gravity of the harm, if it happens, exceeds the burden of precautions, the failure to take those precautions is negligence"); *United States v. Carroll Towing Co.*, 159 F.2d 169, 173 (2d Cir. 1947) (L. Hand, J.) ("if the probability be called P; the injury, L; and the burden, B; liability depends upon whether B is less than L multiplied by P: i.e., whether B less than PL").
[181] FEMA defines a 100-year flood as a flood with a 1% likelihood of occurring or being exceeded in any given year, based on historical data. FEMA, Flood Zones, http://www.fema.gov/flood-zones. Climate change has increased the risk of a 100-year flood in many areas such that the actual chance of such a flood is great than 1%.

the event. Since climate change is causing global alterations in the frequency, severity, and geographic distribution of significant adverse events, historical data will become less predictive of future events' probabilities. Instead, best estimates of the likelihood of harm must also draw on expert weather and climate projections.[182] Moreover, the probability of a natural disaster should be based on its cumulative chance over a relevant period of time – perhaps from the time the government defendant should have been aware of the relevant climate projections to the date of the event – rather than in one particular year;[183] since resiliency measures are implemented for the long term, it is irrelevant to the question of breach whether a natural disaster occurs one year versus the next.

For the purposes of applying the Hand formula, the magnitude of the harm should be measured by the predicted loss of property and life likely to result from a particular event. Hurricane Sandy caused over $50 billion in damage,[184] and Hurricane Katrina left in its wake over $100 billion in damage.[185] Even if such events are infrequent, the extent of the devastation they cause justifies taking precautionary measures to minimize potential damage.[186]

Other factors may be relevant to whether a governments' failure to act was reasonable, including the precision and accuracy of available climate projections, access to technical and monetary resources, the extent to which the precautions would have reduced or eliminated the damage, any negative consequences of the precautionary measures beyond their expense, and alternative measures taken by the state or city to adapt to climate change. Ultimately, the plaintiff "need[s] to prove the unreasonableness of [the] defendant's actions in light of the well-

[182] Long-term projections of future weather and climate conditions often provide a wide range of possible outcomes. *See, e.g., See, e.g.*, C. Rosenzweig, W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, P. Grabhorn, Responding to climate change in New York State: the ClimAID integrated assessment for effective climate change adaptation, Ann. N. Y. Acad. Sci., 1244 (2011), pp. 2–649, https://perma.cc/KJ6X-3Y8L (predicting sea level rise in New York City between 15 and 75 inches by 2100). Some courts may be unpersuaded that governments should be held liable for failing to act on uncertain projections. Nonetheless, such projections may play a larger role in courts' liability determinations as scientists continue to refine climate models, increasing both their accuracy and precision.

[183] The cumulative risk of a particular event increases as the time span increases. For example, while the risk of a 100-year flood may be approximately 1% within the next year, there is at least a 26% chance of a 100-year flood over the next 30 years. United States Geological Survey, *100-Year Flood–It's All About Chance* (April 2010), https://perma.cc/9H5N-JFNE.

[184] U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Service Assessment Hurricane/Post-Tropical Cyclone Sandy, October 22–29, 2012 (May 2013), https://perma.cc/2F3B-H38Z.

[185] NOAA, The Deadliest, Costliest, And Most Intense United States Tropical Cyclones from 1851 to 2010 (and other frequently requested hurricane facts) (Aug. 2011), https://perma.cc/QCT6-KL6K.

[186] *In re City of New York*, *supra* note __, at 242 (comparing, without quantifying, "[t]he probability … of a scenario where the pilot [of the Staten Island Ferry] would become incapacitated … [with] [t]he gravity of … resulting injury to its passengers" against the burden of enforcing a safety measure that would have prevented the accident to finding New York City negligent); *Duty and Breach*, *supra* note __, at 781-82 ("Sandy also underscores the need for local governments to appreciate fully the costs of, to date, low probability yet unprecedented and devastating events.").

established science of climate change."[187] While certainly a "formidable task," increasing knowledge of climate change risks should increase the potential for liability.[188]

Establishing the damage element of a negligence claim in this context would not differ materially from a typical negligence case. A litigant would have to show that he suffered an injury to his person or property. These types of injuries are "especially present in the climate adaptation context."[189] For example, where flooding causes widespread property damage or a heat wave increases mortality rates, many people will have suffered a clear and legally cognizable injury. Nonetheless, some states impose statutory dollar limitations to limit the amount that can be recovered against a government entity.[190]

To establish the causation prong of a claim for negligent failure to prepare for climate change, the plaintiff would need to show, as in any negligence case, that the defendant's breach of duty was the proximate cause of the plaintiff's injury. The question in this context is whether the government's failure to take reasonable measures to protect people from the natural disaster at issue caused the damage.

The plaintiff must identify measures the government could have taken to prevent the injury.[191] Plaintiffs should challenge the city's failure to upgrade or build or upgrade specific infrastructure, rather than the city's failure to consider climate change impacts in its planning documents, since the latter theory would also require the plaintiff to establish that the infrastructure would have been upgraded if the planning had been carried out. The litigant would *not* need to show that the natural disaster at issue was caused by climate change.[192] Instead, the

[187] *Litigating Climate Change Adaptation, supra* note 156, at 11145.
[188] *Id.*; *see also* Attribution of Extreme Weather Events in the Context of Climate Change, National Academies of Sciences, Engineering, and Medicine (2016).
[189] *Id.* at 11148.
[190] *See, e.g.*, Colo. Rev. Stat. Ann. § 24-10-114; Ga. Code Ann. § 50-21-29; Minn. Stat. Ann. § 466.04.

[191] *See Rooney*, *supra* note 27 (plaintiffs' claim that city's negligent maintenance of sewer system caused flood damage survived summary judgment motion where plaintiffs presented evidence that clogged sewers caused the flooding and city had notice of the condition); *Gaylord ex rel. Gaylord v. Morris Twp. Fire Dep't*, 853 A.2d 1112, 1116 (Pa. Commw. Ct. 2004) (Municipal liability arising from real property ownership only available where the defect of the land itself causes the injury).

[192] Issues of causation raise more difficult questions in the context of a climate nuisance suit, since "current atmospheric levels of GHGs result from the cumulative emissions of millions or billions of emitters since the onset of the industrial revolution[, and] no specific injury can be attributed to any specific polluter." Michael Gerrard, *What Litigation of a Climate Nuisance Suit Might Look Like*, YALE L. J. ONLINE (Sept. 2011); *Litigating Climate Change Adaptation, supra* note 30, at 11145 (observing that "establishing the causal link between a defendant's emissions and the alleged harms" would be the most challenging task for a plaintiff seeking tort remedies from greenhouse gas emitters).

effect of climate change on the likelihood of the weather event would be a factor in the determination of breach and foreseeability, as discussed above.[193]

As natural disasters become more likely – and, therefore, more foreseeable – due to climate change, governments face the risk of being found liable for refusing to take reasonable actions to prepare for the impacts of climate change. This type of litigation can serve the duel purposes of compensating plaintiffs for injuries and encouraging governments to better adapt to climate change.

Conclusion

[193] *Litigating Climate Change Adaptation*, *supra* note __, at 11150 ("Attributing extreme weather events to climate change…will occur at the state of establishing defendant's breach of duty….").