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Damage Control: Adapting Transportation to a Changing Climate

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DAMAGE CONTROL: ADAPTING TRANSPORTATION TO A CHANGING CLIMATE

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INTRODUCTION

Sea level rise, extreme weather events, and other problems caused or exacerbated by a changing climate present the most serious long-term threats to transportation worldwide. Recent disasters have carried a hefty price tag, and forecasts call for more frequent and more costly damage to infrastructure and disruptions of services that are central to trade, jobs, food access, national security, health, and personal mobility. It is essential to reduce greenhouse gas pollution to lessen future damage to transportation; however, even if emissions are cut drastically at this point, the impacts of a changing climate will continue for decades. As a result, efforts must be made to plan for and adapt to a changing climate in order to minimize the financial burden and severity of impacts. Such efforts, though, have lagged. Although some important steps have been taken, much remains to be done to protect and enhance the resilience of freight and passenger transportation. A host of potential policies and practices are available at the federal, state, regional, and local levels to reduce the climate risk to transportation, including assessing and retrofitting existing infrastructure, modifying design standards for new projects, promoting a broader range of transportation options, and curbing new projects that encourage development in vulnerable areas. Policies and projects should be chosen to ensure an equitable distribution of investments in adaptation measures. In addition, priority should be given to efforts that not only help adapt to a changing climate, but that simultaneously reduce the significant greenhouse gas emissions from transportation.

This Article summarizes key aspects of climate change and examines the growing damage and threat to transportation. It then explores some of the efforts to begin adapting transportation to a changing climate and identifies policy steps that can reduce future damage and risk.

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I. A CHANGING CLIMATE: THE THREAT TO TRANSPORTATION

A. Extreme Weather, Sea Level Rise, and Other Climate Changes

The overwhelming consensus among climate scientists is that the climate is changing worldwide—in large part due to human activities—and that it is already causing serious impacts, and that tremendous additional changes lie ahead.[1]

The basic mechanics of global warming are well understood. Increasing amounts of greenhouse gases such as carbon dioxide (CO_2) and methane in the atmosphere cause the planet to warm by trapping more of the solar energy that reaches the Earth near the surface of the planet, intensifying the natural greenhouse effect.[2] The levels of these pollutants have soared. Carbon dioxide levels have grown by 40% since the Industrial Revolution began, and over half of that elevation has occurred since 1970.[3] As a recent report observed, "for the past 800,000 years up until the 20th century, the atmospheric CO_2concentration stayed within the range 170 to 300 parts per million (ppm), making the recent rapid rise to nearly 400 ppm over 200 years particularly remarkable."[4]

Greenhouse gas levels are continuing to ascend. Apparently for the first time in millions of years, average carbon dioxide levels rose above 400 parts per million for an entire day in 2013,[5] and in 2014 surpassed this threshold for an entire month throughout the Northern Hemisphere.[6]

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[1] *See*, *e.g.*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SUMMARY FOR POLICY MAKERS, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, IPCC (2013) [hereinafter IPCC, PHYSICAL SCIENCE REPORT], http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf; THE ROYAL SOC'Y AND U.S. NAT'L ACAD. OF SCI., Climate Change: Evidence and Causes, CLIMATE CHANGE AT THE NATIONAL ACADEMIES (2014), http://nas-sites.org/americasclimatechoices/events/a-discussion-on-climate-change-evidence-and-causes/, *archived at* http://perma.cc/UY4G-6QC6; U.S. GLOBAL CHANGE RESEARCH PROGRAM, Overview: Climate Change Impacts in the United States, U.S. NATIONAL CLIMATE ASSESSMENT (2014), http://www.globalchange.gov/nca3-downloads-materials, *archived at* http://perma.cc/U5KD-PJEX.

[2] *A blanket around the Earth*, NASA: VITAL SIGNS OF THE PLANET, https://climate.nasa.gov/causes/ (last visited Jan. 15, 2015), *archived at* http://perma.cc/V67L-SQ8K.

[3] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 7–8.

[4] THE ROYAL SOCIETY AND U.S. NATIONAL ACADEMY, *supra* note 1, at 9.

[5] Justin Gillis, *Heat Trapping Gas Passes Milestone, Raising Fears*, N.Y. TIMES (May 10, 2013), http://www.nytimes.com/2013/05/11/science/earth/carbon-dioxide-level-passes-long-feared-milestone.html?pagewanted=all&_r=0, *archived at* http://perma.cc/B7X-YZ42.

[6] *Press Release No. 991*: *CO2 concentrations top 400 parts per million throughout northern hemisphere*, WORLD METEOROLOGICAL ORG. (May 26, 2014), http://www.wmo.int/pages/mediacentre/press_releases/pr_991_en.html, *archived at* http://perma.cc/F864-U9VF.

Moreover, the increase in CO_2 levels between 2012 and 2013 of 2.9 ppm was the largest jump in a single year in decades.[7]

Escalating concentrations of greenhouse gases are already changing the climate throughout the world. The Intergovernmental Panel on Climate Change ("IPCC") has concluded that "[w]arming of the climate system is unequivocal."[8] Global average surface temperatures have increased by approximately 1.5°F (0.8°C) since 1880, with much of this warming taking place in the last four decades.[9] In the United States, the most recent National Climate Assessment concluded that average temperature in this country rose by 1.3 to 1.9°F since 1895, with the majority of this change occurring since 1970, and that "the most recent decade was the nation's and the world's hottest on record."[10]

Higher temperatures are just one aspect of a changing climate. Although there can be wide regional variations, a warming atmosphere and oceans appear to be causing more frequent extreme weather events—such as severe droughts, heat waves, and stronger storms—as well as increased sea level rise, coastal flooding, melting glaciers and polar ice, and other far-reaching changes.[11]

The role of human activities in these changes is becoming clearer. The Royal Academy and U.S. National Academy of Sciences concluded that, "[i]t is now more certain than ever, based on many lines of evidence, that humans are changing Earth's climate."[12] According to the IPCC, it is extremely likely that human activities have been the dominant cause of warming "since the mid-20th century."[13] Burning fossil fuels such as oil, gas, and coal to run vehicles and power plants is the primary behavior generating greenhouse gas emissions, followed by emissions from deforestation and other land use changes.[14]

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[7] World Meteorological Org. and Global Atmosphere Watch, *The State of Greenhouse Gases in the Atmosphere Based on Global Observation through 2013*, WMO GREENHOUSE GAS BULLETIN VOL. 10 (Sept. 9. 2014), http://www.wmo.int/pages/mediacentre/press_releases/documents/1002_GHG_Bulletin.pdf; *see also*, Joby Warrick, *CO2 levels in atmosphere rising at dramatically faster rate, UN report warns*, WASH. POST (Sept. 9, 2014), http://www.washingtonpost.com/national/health-science/co2-levels-in-atmosphere-rising-at-dramatically-faster-rate-un-report-warns/2014/09/08/3e2277d2-378d-11e4-bdfb-de4104544a37_story.html, *archived at* http://perma.cc/U6PR-Q42K.

[8] IPCC, PHYSICAL SCIENCE REPORT, *supra* note 1, at 4.

[9] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 23–24.

[10] *Id.* at 8.

[11] THE ROYAL SOCIETY AND U.S. NATIONAL ACADEMY, *supra* note 1, at 15–16.

[12] *Id.* at I; *see also*, U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 2, 8.

[13] IPCC, PHYSICAL SCIENCE REPORT, *supra* note 1, at 17.

[14] *Id.* at 11–12; U.S, GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 2, 8.

If these activities continue, greenhouse gas emissions will continue, and thus the climate will continue to change. Most estimates project that climate changes will accelerate. Average temperatures in the United States, for example, are projected to increase 2 to 4°F over the next few decades.[15] Globally, an increase of an additional 4.7 to 8.6°F (2.6–4.8°C) is projected by 2100 if greenhouse gas levels keep growing at the present rate.[16] The current scientific consensus is that sea level rise is very likely to accelerate; and sea levels may climb another 0.5 to 1 meter (1.5 to 3 feet) by 2100 due to water expanding as the oceans absorb heat, as well as melting glaciers and ice sheets that add water to the world's oceans.[17] This would inundate many coastal cities, and some models predict global sea level rise will be even greater, reaching 6 feet or higher by 2100.[18] A litany of other climate changes are projected unless greenhouse gas emissions are sharply curtailed, including changes in precipitation as dry areas get drier and wet areas get wetter, and a surge in the frequency and intensity of certain extreme weather events.[19]

There are numerous areas of uncertainty, both in assessing the current pace and extent of climate change and in developing and applying the models used to make future projections. Multiple factors influence the timing and magnitude of projected changes, as well as regional variations, and certain areas of climate science are still not well understood. Among other things, estimates of future emission levels, assumptions about the ability of the biosphere and oceans to absorb carbon, and the impact of warming on certain weather events are all areas that are open to debate and in need of further study.

In contrast to these areas of uncertainty, a variety of efforts have questioned and attacked the scientific basis for climate change, rejecting both the existence of climate change and thus policies to reduce greenhouse

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[15] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 8.
[16] THE ROYAL SOCIETY AND U.S. NATIONAL ACADEMY, *supra* note 1, at 18.
[17] Darryl Fears, *IPCC report says humans almost certainly cause global warming*, WASH. POST (Sept. 27, 2013), http://www.washingtonpost.com/national/health-science/ipcc-says-humans-cause-global-warming/2013/09/27/aae32880-275d-11e3-b3e9-d97fb087acd6_story.html, *archived at* http://perma.cc/CU3X-C4A8; IPCC, PHYSICAL SCIENCE REPORT, *supra* note 1, at 25.
[18] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 45.
[19] THE ROYAL SOCIETY AND U.S. NATIONAL ACADEMY, *supra* note 1, at 15. *But see* USDA, *Impacts of Rising Concentration of Greenhouse Gases*, 1, ERS.USDA.GOV, http://www.ers.usda/gov/media/873725/impactofrising.pdf (last visited Jan. 15, 2015) (explaining that although the overall global climate changes that are predicted to occur will be extremely damaging, most projections recognize that there may be beneficial effects in certain places for certain activities, such as extended growing seasons for crops in some areas).

gas emissions. Many of these efforts have been funded by fossil fuel companies with an obvious interest in continuing consumption of oil, gas, and coal.[20] These efforts have helped block meaningful action in the United States for decades. Senator James Inhofe (R-OK) has frequently referred to climate change as the "biggest hoax" and blocked adoption of a resolution acknowledging its existence.[21] The United States House of Representatives recently adopted provisions that would sharply limit Environmental Protection Agency ("EPA") regulation of greenhouse gas emissions from new fossil fuel–fired power plants,[22] as well as an authorization bill that would prohibit the Department of Defense from spending any appropriated funds to address climate change and directs the Department to ignore the findings of certain scientific assessments of global warming.[23] Efforts to deny climate change are occurring at the state level as well. For example, the North Carolina General Assembly passed legislation that prohibits the State Coastal Resources Commission from establishing a rate of future sea level rise that could be used in planning in the state for four years; the legislation was fueled by a recommendation by the Commission that an estimated increase of 39 inches by 2100 be assumed.[24] The chairman

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[20] *See* JOHN C. DERNBACH, "ACTING AS IF TOMORROW MATTERS: ACCELERATING THE TRANSITION TO SUSTAINABILITY" 216–20 (Envt'l Law Inst. 2012); JAMES HOGAN & RICHARD LETTLEMORE, CLIMATE COVER-UP: THE CRUSADE TO DENY GLOBAL WARMING (2009); ERIC POOLEY, THE CLIMATE WAR: TRUE BELIEVERS, POWER BROKERS, AND THE FIGHT TO SAVE EARTH (2010); *Global Warming Deniers Well-Funded*, NEWSWEEK, http://www.newsweek.com/global-warming-deniers-well-funded-99775 (last updated July 1, 2010), *archived at* http://perma.cc/8CBP-UBTX; Suzanne Goldenberg, *Secret funding helped build vast network of climate denial think tanks*, GUARDIAN (Feb. 14, 2013), http://www.theguardian.com/environment/2013/feb/14/funding-climate-change-denial-thinktanks-network, *archived at* http://perma.cc/UR48-XEX5.

[21] Ramsey Cox, *Inhofe blocks climate change resolution*, THE HILL (July 28, 2014), at http://thehill.com/blogs/floor-action/senate/213559-inhofe-blocks-climate-change-resolution, *archived at* http://perma.cc/UR48-XEX5.

[22] Electricity Security and Affordability Act, H.R. 3826, 113th Cong. (2014). *See* Pete Kasperowicz, *House votes to block EPA regs on coal-fired electricity plants*, THE HILL (Mar. 6, 2014), http://thehill.com/policy/energy-environment/200096-house-votes-to-block-epa-regs-on-electricity-plants, *archived at* http://perma.cc/VC4Y-X2F5.

[23] Howard P. `Buck' McKeon National Defense Authorization Act for Fiscal Year 2015, H.R. 4435, 113th Cong. (2014). *See* JC Sevcik, *House bans Pentagon from preparing for climate change*, UPI (May 23, 2014), http://www.upi.com/Top_News/US/2014/05/23/House-bans-Pentagon-from-preparing-for-climate-change/5391400882186/, *archived at* http://perma.cc/87VU-68TX.

[24] H.B. 819, 2011 Gen. Assemb. (N.C. 2012). *See* Elizabeth Harball, *Climate change experts become an endangered species along the N.C. coast*, CLIMATEWIRE (Apr. 2, 2014), http://www.eenews.net/stories/1059997151/print, *archived at* http://perma.cc/3KHF-XRSW;

of the group leading the effort to secure the bill said he does not trust climate scientists and that "CO2 is actually good for the Earth."[25]

Despite the political debates and continued uncertainty about the nature, extent, and pace of climate change, the evidence is steadily accumulating—and it is overwhelming. In fact, as the U.S. National Climate Assessment states, "It is notable that as these data records have grown longer and climate models have become more comprehensive, earlier predictions have largely been confirmed. The only real surprises have been that some changes, such as sea level rise and Arctic sea ice decline, have outpaced earlier projections."[26] There are active areas of debate and research, and the limitations of climate science need to be acknowledged and weighed in formulating policy, but the impacts that are already occurring and are projected to occur are too serious to ignore.[27] Increasingly, even people who deny the human role in a changing climate are recognizing the need to address problems like extreme weather events and sea level rise. As one elected official in a coastal locality remarked, "we're not prepared to debate whether or not there is climate change. We know there is sea-level rise, because we see it every day."[28]

B. Impacts of a Changing Climate on Transportation

As the United States Supreme Court has acknowledged, "[t]he harms associated with climate change are serious and well recognized."[29] EPA has concluded that climate change endangers "both the public health and the public welfare of current and future generations."[30] The impacts of present and projected changes include threats to water supplies, food supplies, ecosystems, infrastructure, property, national security, and

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Bruce Siceloff, *While the seas rise in the Outer Banks and elsewhere in NC, science treads war*, NEWSOBSERVER (Mar. 5, 2014), http://www.newsobserver.com/2014/03/15/3702235/while-the-seas-rise-science-waits.html, *archived at* http://perma.cc/TK4S-B7J9.

[25] Evan Lehmann, *In N.C., a political storm over rising seas*, CLIMATEWIRE (June 12, 2012) http://www.eenews.net/stories/1059965722, *archived at* http://perma.cc/DDY2-FM7Z.

[26] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 2.

[27] As President Barack Obama has stated, "Some may still deny the overwhelming judgment of science, but none can avoid the devastating impact of raging fires and crippling drought and more powerful storms." President Barack Obama, Second Inaugural Address (Jan. 21, 2013).

[28] Siceloff, *supra* note 24.

[29] Massachusetts v. EPA, 549 U.S. 497, 521 (2007).

[30] Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66496, 66496 (2009).

human health and lives.[31] Climate change also poses the most significant long-term threat to transportation worldwide.[32]

Climate, specifically a changing climate, impacts all aspects of transportation—planning, design, construction, operations, and maintenance.[33] It also impacts all modes of surface, air, and water transportation, from roads and bridges to railroads and transit systems to airports, ports, and waterways.[34] The Transportation Research Board of the National Academy of Sciences has concluded that "[e]very mode of transportation will be affected as climate change poses new and often unfamiliar challenges to infrastructure providers."[35]

Recent weather disasters have underscored the current vulnerability of transportation infrastructure as well as the future risks and costs that accelerating climate change would bring. These impacts consist of both temporary and permanent disruption of transportation services that are central to international, national, and local trade, access to food and health care, safety, and personal mobility.[36]

The two weather disasters with the greatest impact on public consciousness and debate in recent years are Superstorm Sandy and Hurricane Katrina. Sandy was a deadly, destructive storm in October 2012 that ultimately became the largest Atlantic hurricane ever, affecting at least 24 states and the Caribbean.[37] Sandy is estimated to have caused 159 deaths and $66 billion in damages,[38] higher water levels along the east coast of the United States from Florida to Maine, and heavy snow in the mountains from North Carolina to Pennsylvania.[39] New York and New Jersey were particularly hard hit by high winds, coupled with a storm surge up to 12.65 feet above normal tide levels and powerful waves that caused widespread flooding.[40] Record flooding extensively damaged

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[31] *Id.* at 66498–99, 66510, 66514.
[32] *See* TRANSP. RESEARCH BD., POTENTIAL IMPACTS OF CLIMATE CHANGE ON U.S. TRANSPORTATION 2–5 (2008).
[33] *Id.* at 2.
[34] *Id.* at 1.
[35] *Id.* at 20.
[36] *See id.* at 133.
[37] Nat'l Weather Service, *October 29, 2012—Hurricane Sandy: Event Overview*, NOAA (2012) http://www.erh.noaa.gov/mhx/EventReviews/20121029/20121029.php.
[38] *See* Nat'l Climactic Data Ctr., *Billion-Dollar Weather/Climate Disasters 1980–2013*, NOAA (2012) http://www.ncdc.noaa.gov/billions/events.pdf.
[39] ERIC S. BLAKE, TODD B. KIMBERLAIN, ROBERT J. BERG, JOHN P. CANGIALOSI & JOHN L. BEVEN II, NAT'L HURRICANE CTR., NOAA, TROPICAL CYCLONE REPORT: HURRICANE SANDY 9, 14 (2013) *available at* http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf.
[40] *Id.* at 8–10.

roads, bridges, locomotives, rail cars, transit stations, airports, and ferries.[41] The total damage to transportation systems is estimated to have been $7.5 billion in New York—including $5 billion of damage to the New York City Metropolitan Transit Authority—and $2.9 billion in New Jersey, and it took weeks to restore certain transportation services.[42]

Hurricane Katrina is considered to be "the single most catastrophic natural disaster and costliest hurricane in U.S. history."[43] It made landfall three times between August 25 and 29, 2005, and at its peak, hurricane-force winds reached 105 miles from the storm center while tropical storm force winds extended 230 miles.[44] High winds, a storm surge of almost 30 feet in some places, and the failure of levees and floodwalls after the storm resulted in widespread flooding along the Gulf Coast and left 80% of New Orleans up to 20 feet underwater.[45] Hurricane Katrina killed an estimated 1,833 people, displaced over one million, and caused $149 billion in damages.[46] Extensive damage to transportation infrastructure in Louisiana, Mississippi, and Alabama hampered or blocked evacuation and delivery of relief supplies, disrupted passenger and freight travel, and has cost billions of dollars to repair.[47] Transportation impacts involved the flooding and temporary closure of both New Orleans airports, and the destruction of bridges, roads, rail lines, and port facilities.[48] Large portions of the Twin Span Bridge of I-10 east of New Orleans collapsed and another 473 spans were damaged or displaced, completely closing the bridge for a month and a half, with estimated repair costs of almost $840 million.[49] CSX spent over five months

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[41] *See id.* at 17–18.
[42] *Id.* at 17–18.
[43] Fed. Emergency Mgmt Agency, *Louisiana Recovery Office*, FEMA (July 24, 2014) http://www.fema.gov/louisiana-recovery-office (last updated July 24, 2014), *archived at* http://perma.cc/JD4C-WQ3Q.
[44] NOAA'S NAT'L CLIMACTIC DATA CTR., HURRICANE KATRINA: A CLIMATOLOGICAL PERSPECTIVE 2 (2005, Updated 2006), *available at* http://www.ncdc.noaa.gov/oa/reports/tech-report-200501z.pdf.
[45] *Id.* at 4; RICKARD D. KNAB, JAMIE R. RHOME & DANIEL P. BROWN, NAT'L HURRICANE CTR., NOAA, TROPICAL CYCLONE REPORT: HURRICANE KATRINA 9–10 (2005), *available at* http://www.nhc.noaa.gov/pdf/TCR-AL122005_Katrina.pdf.
[46] Nat'l Climactic Data Ctr., *supra* note 38; FEMA, *supra* note 43.
[47] *See* Lance R. Grenzeback & Andrew T. Lukmann, Case Study of the Transportation Sector's Response to and Recovery from Hurricanes Katrina and Rita 8–9, 20, 41 (2007), *available at* http:://onlinepubs.trb.org/onlinepubs/sr/sr290GrenzebackLukmann.pdf.
[48] NOAA NAT'L CLIMACTIC DATA CTR., HURRICANE KATRINA (updated Dec. 29, 2005), *available at* http://www1.ncdc.noaa.gov/pub/data/extremeevents/specialreports/Hurricane-Katrina.pdf; Grenzeback and Andrew T. Lukmann, *supra* note 47.
[49] Grenzeback & Lukmann, *supra* note 47, at 9.

and $300 million to restore the most-damaged section of rail bridges and track washed out or undermined between Biloxi and New Orleans.[50]

It is difficult if not impossible to determine the precise influence of climate change on any one event. Unusual features of Sandy and Katrina have led some scientists to conclude that their direction and intensity, as well as the extent of the surge levels and flooding may have been influenced by global warming.[51] Other scientists, however, warn against drawing too many conclusions from any particular event, while nonetheless cautioning that rising sea levels and other trends that are clearly occurring can exacerbate the impacts of certain storms, that future scenarios suggest that even less powerful storms will produce similarly destructive impacts, and that major storms are likely to be more frequent and more intense.[52]

Extreme weather events other than high-profile hurricanes also highlight the threat a changing climate poses to transportation. For example, unprecedented heavy rains in middle and western Tennessee produced record flooding in 2010. The two-day rainfall totaled over 13 inches in Nashville, doubling the previous 48-hour record.[53] The storm dumped almost 20 inches of rain in other parts of the region, leading to flooding that caused an estimated $2 billion in damage in Nashville alone and killed 26 people in Tennessee and Kentucky.[54] Transportation impacts were widespread. High water—and in some cases mud, rockslides, and debris—shut down several highways and hundreds of roads and

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[50] *Id.* at 20.

[51] *See*, *e.g.*, Charles H. Greene, Jennifer A. Francis & Bruce C. Monger, *Superstorm Sandy: A Series of Unfortunate Events*, 26 OCEANOGRAPHY 1, 8–9 (2013), *available at* http://www.tos.org/oceanography/archive/26-1_greene.pdf; Jeffrey Kluger, *Is Global Warming Fueling Katrina?*, TIME, Aug. 29, 2005, http://content.time.com/time/nation/article/0,8599,1099102,00.html, *archived at* http://perma.cc/KQE8-5XPM.

[52] *See*, *e.g.*, U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 41–42; KLUGER, *supra* note 51; William Sweet, Chris Zervas, Stephen Gill & Joseph Park, *Hurricane Sandy Inundation Probabilities Today and Tomorrow*, *in* EXPLAINING EXTREME EVENTS OF 2012 FROM A CLIMATE PERSPECTIVE, S20 (Thomas C. Peterson, Martin P. Hoerling, Peter A. Scott & Stephanie C. Herring eds.), Special Supplement to the Bulletin of the American Meteorological Society (Sept. 2013), *available at* http://www.ametsoc.org/2012extremeeventsclimate.pdf.

[53] NAT'L WEATHER SERVICE, RECORD FLOODS OF GREATER NASHVILLE: INCLUDING FLOODING IN MIDDLE TENNESSEE AND WESTERN KENTUCKY MAY 1–4, 2010 6 (Jan. 2011), *available at* http://www.nws.noaa.gov/os/assessments/pdfs/Tenn_Flooding.pdf; *see also Flood of 2010, West and Middle Tennessee, May 1–2, 2010*, TENNESSEE STATE LIBRARY AND ARCHIVES, http://www.tennessee.gov/tsla/exhibits/disasters/floods2.htm, *archived at* http://perma.cc/6AC8-JWYS.

[54] NAT'L WEATHER SERVICE, *supra* note 53, at 3, 6.

bridges,[55] a sinkhole 25 feet wide and 25 feet deep opened up in one interstate,[56] and a landslide triggered by the heavy rains caused the collapse of almost three miles of a state highway that sank roughly 20 feet.[57] Rail lines and airports were also damaged and closed, over 30 percent of the regional transit fleet was severely damaged, and all bus service in the area was suspended for days.[58]

Again, it is difficult to demonstrate that the intensity of this storm was caused by climate change, but evidence suggests that heavy precipitation events with greater amounts of rain falling in a short period of time have begun to increase nationally and are predicted to be even more frequent as the climate changes.[59]

In addition to extreme weather disasters, less severe events can have an enormous impact on transportation infrastructure in areas that are not prepared for it or lack adequate transportation alternatives. A snowstorm of just over two inches in January 2014, for example, shut down much of the Atlanta metropolitan region—one of the ten largest regions in the United States. Thousands of people were stranded when highways and roads became jammed with drivers as the snow began to fall and businesses and schools closed.[60] The problem was exacerbated by the fact that the state and the region have spent heavily on roads but are dependent upon a few large interstates and has only funded a limited transit system. The lack of better road connections and alternatives to driving, combined with decades of sprawling development, required most

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[55] *Id.* at 13.

[56] Cindy Burbank, *Early Signs of Climate Change: 2010 Flooding in Tennessee, Rhode Island, and Iowa*, *in* TRANSPORTATION RESEARCH CIRCULAR E-C152: ADAPTING TRANSPORTATION TO THE IMPACTS OF CLIMATE CHANGE, STATE OF THE PRACTICE 2011 11 (2011).

[57] Tina Grady Barbaccia, *Road Into Bridge: A massive landslide causes Tennessee DOT to rethink its rebuilding*, BETTER ROADS (Feb. 17, 2012), http://www.betterroads.com/better-bridges-6/, *archived at* http://perma.cc/S79Z-84CU.

[58] NASHVILLE MAYOR'S OFFICE OF EMERGENCY MANAGEMENT, SEVERE FLOODING MAY 2010 AFTER ACTION REPORT AND IMPROVEMENT PLAN FOR THE METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY, 38–39 (2011), *available at* https://www.llis.dhs.gov/sites/default/files/AARIP.pdf.

[59] *See* Burbank, *supra* note 56, at 11; U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 36–37.

[60] *Thousands still stranded on Atlanta highways after snow catches South unprepared*, NBC NEWS (Jan. 29. 2014, 2:41 AM). http://usnews.nbcnews.com/_news/2014/01/29/22492664-thousands-still-stranded-on-atlanta-highways-after-snow-catches-south-unprepared?lite, *archived at* http://perma.cc/Y6QY-UZQG; Alexis Stevens, *A commute turns into a nightmare—and boredom—as storm paralyzes Atlanta*, ATLANTA JOURNAL-CONSTITUTION, http://www.ajc.com/news/news/winter-storm-warning-expanded-to-include-all-of-me/nc4ym/ (last updated Jan. 29, 2014, 1:59 AM), *archived at* http://perma.cc/Y6QY-UZQG.

people to take a relatively small number of roads as they tried to get home from work or pick up children from school.[61]

Some of the greatest threats to transportation from a changing climate do not come from extreme weather events but from gradual changes such as the persistent rise of sea levels and the impacts of that rise on storm surges and flooding.[62] As noted above, sea levels are projected to increase globally by roughly 1.5 to 6 feet by 2100 due to thermal expansion and melting glaciers and ice sheets.

The amount of change in sea level at any particular location, however, depends on a number of other factors. The Hampton Roads region of Virginia, for example, is a low-lying, heavily populated coastal area that is experiencing the highest sea level rise along the Atlantic Coast. Since 1900, global sea levels have climbed an estimated 1.7 millimeters per year,[63] while gauges in Hampton Roads show that water levels there have increased almost 4.5 mm/year (0.175 inches/year)[64] and are over one foot higher than they were 100 years ago.[65] Not only is sea level rising in the region, but the land is sinking, primarily as a result of groundwater withdrawal.[66] The net effect is a relative rise in sea level

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[61] Rebecca Burns, *The Day We Lost Atlanta: How 2 lousy inches of snow paralyzed a metro area of 6 million*, POLITICO (Jan. 29, 2014), http://www.politico.com/magazine/story/2014/01/atlanta-snow-storm-102839_full.html, *archived at* http://perma.cc/38WA-ZSPX.

[62] As one report noted: "Potentially, the greatest impact of climate change for North America's transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of global rising sea levels, coupled with storm surges and exacerbated in some locations by land subsidence." TRANSPORTATION RESEARCH BOARD, SPECIAL REPORT NO. 290, POTENTIAL IMPACTS OF CLIMATE CHANGE ON U.S. TRANSPORTATION 5 (2008).

[63] WILLIAM SWEET ET AL., NOAA TECHNICAL REPORT NOS CO-OPS 073, SEA LEVEL RISE AND NUISANCE FLOOD FREQUENCY CHANGES AROUND THE UNITED STATES 1 (2014), *available at* http://tidesandcurrents.noaa.gov/publications/NOAA_Technical_Report_NOS_COOPS_073.pdf.

[64] JOHN D. BOON, JOHN M. BRUBAKER & DAVID R. FORREST, VIRGINIA INSTITUTE OF MARINE SCIENCE SPECIAL REPORT NO. 425 IN APPLIED MARINE SCIENCE AND OCEAN ENGINEERING, CHESAPEAKE BAY LAND SUBSIDENCE AND SEA LEVEL CHANGE—AN EVALUATION OF PAST AND PRESENT TRENDS AND FUTURE OUTLOOK 18 (2010) *available at* http://www.vims.edu/GreyLit/VIMS/sramsoe425.pdf; CHRIS ZERVAS, NOAA TECHNICAL REPORT NOS CO-OPS 053, SEA LEVEL VARIATIONS OF THE UNITED STATES, 1854–2006 22 (2009), *available at* http://www.co-ops.nos.noaa.gov/publications/Tech_rpt_53.pdf.

[65] VIRGINIA INSTITUTE OF MARINE SCIENCES, RECURRENT FLOODING STUDY FOR TIDEWATER VIRGINIA 12 (2013), *available at* http://ccrm.vims.edu/recurrent_flooding/Recurrent_Flooding_Study_web.pdf [hereinafter VIMS 2013].

[66] *See* JACK EGGLESTON & JASON POPE, U.S. GEOLOGICAL SURVEY CIRCULAR 1392, LAND SUBSIDENCE AND RELATIVE SEA-LEVEL RISE IN THE SOUTHERN CHESAPEAKE BAY REGION, 10–15 (2013), *available at* http://pubs.usgs.gov/circ/1392/pdf/circ1392.pdf. Another cause

leading to retreating shorelines, flooding that covers a larger area during extreme weather events, and more frequent and longer lasting minor or "nuisance" flooding during high tides or smaller storms.[67] The City of Norfolk has already seen a tripling of the number of flooding events since 1970, and a recent study predicts that tidal flooding there will rapidly increase and will reach farther into the region.[68] An analysis of the projected impacts of future sea level rise concluded that over 500 miles of roads in Hampton Roads are at risk of inundation by 2100, using a mid-range estimate, and that 877 miles of roads could be underwater by the end of the century using a higher estimate.[69] Many other roads could be subject to temporary flooding,[70] closing roads and causing "deterioration and corrosion of infrastructure not designed to withstand frequent inundation or salt-water exposure."[71] Far more roads would be impacted by a major storm event on top of projected relative sea level rise.

In short, changes in temperature, precipitation, sea level rise, and other climate features, as well as extreme weather events such as flooding, heat waves, and intense storms, have already begun to impact the reliability and capacity of transportation infrastructure and systems. The impacts of a changing climate extend well beyond the examples provided here, and they are found throughout the country. Moreover, the potential for temporary and permanent disruptions of service, destruction of facilities, corrosion or weakening of materials, and the need for more frequent maintenance and repair will probably escalate with further

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of subsidence in this region is the settling of the Earth's crust after the melting of glaciers thousands of years ago that had pushed the land up in this region. There is disagreement regarding whether a third factor, the Chesapeake Bay Impact Crater, is also contributing to land subsidence in Hampton Roads.

[67] As the City of Norfolk's emergency preparedness director, Jim Redick, has been quoted as saying: "We're experiencing flooding just during our lunar high tide. It doesn't take a storm anymore." *Va. climate change panel convenes today*, DAILY PROGRESS, Sept. 10, 2014, http://www.dailyprogress.com/eedition/page-a/page_bb44a933-365e-5a39-a936-97becd2752aa.html, *archived at* http://perma.cc/H5S8-LUK3; *see also* SWEET *supra* note 63; ERIKA SPANGER-SIEGFRIED, MELANIE FITZPATRICK & KRISTINA DAHL, ENCROACHING TIDES: HOW SEA LEVEL RISE AND TIDAL FLOODING THREATEN U.S. EAST AND GULF COAST COMMUNITIES OVER THE NEXT 30 YEARS, UNION OF CONCERNED SCIENTISTS (2014), *available at* http://www.ucsusa.org/sites/default/files/attach/2014/10/encroaching-tides-full-report.pdf#page=44.

[68] SPANGER-SIEGFRIED, FITZPATRICK & DAHL, *supra* note 67, at 34–35.

[69] BENJAMIN J. MCFARLANE, CLIMATE CHANGE IN HAMPTON ROADS—PHASE III: SEA LEVEL RISE IN HAMPTON ROADS, VIRGINIA 40, 44 (2012), *available at* http://www.hrpdcva.gov/uploads/docs/HRPDC_ClimateChangeReport2012_Full_Reduced.pdf.

[70] *Id.* at 41.

[71] SWEET, *supra* note 63, at vi.

changes in the climate. As the National Climate Assessment recognized, "our society and its infrastructure were designed for the climate that we have had, not the rapidly changing climate we now have and can expect in the future."[72]

II. RESPONDING TO THE THREAT OF A CHANGING CLIMATE

A. Alternative Responses and the Limits of Adaptation

There are two principal responses to the threats posed by a changing climate—mitigation and adaptation.[73]

The goal of climate mitigation is to curb the amount of carbon dioxide and other greenhouse gas pollutants that are emitted, primarily by curtailing both the burning of fossil fuels and land use changes such as deforestation. Mitigation seeks to reduce or eliminate harmful emissions and the resulting increase in the concentration of greenhouse gases in order to avoid or minimize changes in the climate. There are a host of potential steps or measures that could reduce the greenhouse gases emitted by the transportation sector, such as increasing the fuel efficiency of motor vehicles to reduce the amount of fossil fuels burned per mile driven, developing and promoting vehicles that run off of electricity or other alternatives to fossil fuels, increasing the use of alternatives to driving that are less polluting (e.g., transit, rail, bicycling, and walking), lowering the number of vehicle trips through steps such as telecommuting and ridesharing, and reducing the length of vehicle trips by encouraging housing to be built in closer proximity to jobs and services, as well as other steps to better link transportation and land use.[74]

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[72] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 1.

[73] There are a host of sources summarizing or discussing various aspects of mitigation and adaptation approaches. *See*, *e.g.*, THE LAW OF ADAPTATION TO CLIMATE CHANGE: U.S. AND INTERNATIONAL ASPECTS (Michael B. Gerrard & Katrina Fischer Kuh, eds., 2012); U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1; INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY, CONTRIBUTION OF WORKING GROUP II TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2014); INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, A SPECIAL REPORT OF WORKING GROUPS I AND II OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION (2012).

[74] *See*, *e.g.*, Trip Pollard, *Transportation: Challenges and Choices*, *in* AGENDA FOR A SUSTAINABLE AMERICA (John C. Dernbach, ed. 2009) and Trip Pollard, *Driving Change: Public Policies, Individual Choices, and Environmental Damage*, 35 ENVTL. L. REP. 10791 (2005) for further discussion of many available measures to reduce transportation emissions.

Adaptation, on the other hand, seeks to prepare for and respond to the current and projected impacts of climate change. It focuses primarily on managing the risks of changing conditions by reducing vulnerability and by enhancing resiliency—the ability to recover rapidly from extreme weather and other climate events that do occur. Adaptation can be proactive and seek to adjust to projected changes, or it can be reactive, responding to changes after they happen. Adaptation steps are also often characterized as advancing one of three basic strategies: (1) fortify (or defend or resist); (2) adjust (or accommodate); and (3) retreat. For example, a highway in a coastal area experiencing rising sea levels and flooding could be protected by constructing a seawall or levee. Alternatively, steps could be taken to accommodate elevated water levels and to increase the ability of the facility to bounce back from flooding, including raising the level of the highway or installing improved drainage systems. Or the facility could be abandoned or relocated farther inland.

In short, mitigation efforts seek to reduce human impacts on the climate while adaptation typically seeks to reduce the impacts of a changing climate on humans.[75]

Until relatively recently, discussions and efforts to address climate change centered on mitigation rather than adaptation. Efforts to fashion an effective, meaningful international climate agreement have focused on cutting emissions in order to keep the rise in average global temperatures to less than 2°C (about 3.5°F) above pre-industrial times in order to avoid some of the most harmful consequences of climate change. Many countries have pledged to reduce their greenhouse gas pollutants by certain amounts, and President Obama has promised that the United States will reduce its greenhouse gas emissions to 17 percent below 2005 levels by 2020.[76] A number of states, regions, and localities have set emission reduction targets as the centerpiece of their climate plans.

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[75] There are alternative conceptions of adaptation, however, that also include efforts to increase the adaptive capacity of other species and ecosystems. *See*, *e.g.*, Robin Kundis Craig, *"Stationarity Is Dead"—Long Live Transformation: Five Principles of Climate Change Adaptation Law*, 34 HARV. ENVT'L L. REV. 9 (2010).

[76] This target was provisionally proposed in 2009. *See* Daniel Samuelsohn & Lisa Friedman, *Obama Announces 2020 Emissions Target, Dec. 9 Copenhagen Visit*, N.Y. TIMES (Nov. 25, 2009), http://www.nytimes.com/cwire/2009/11/25/25climatewire-obama-announces-2020-emissions-target-dec-9-22088.html?pagewanted=all, *archived at* http://perma.cc/CTN2-D49B. The President subsequently reaffirmed this commitment numerous times. *See* EXECUTIVE OFFICE OF THE PRESIDENT, THE PRESIDENT'S CLIMATE ACTION PLAN (June 2013), *available at* http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

There are multiple, often interrelated reasons to focus on reducing emissions rather than adapting to the impacts of climate change. For one thing, there has been a persistent concern that while mitigation tackles the root cause of climate change, adaptation would only address the symptoms. If greenhouse gas levels continue to rise, the climate will continue to change even if we are able to minimize some of the damages and manage some of the risks of this change. Moreover, if emissions are not limited, the adverse impacts of climate change are projected to accelerate and are likely to ultimately overwhelm even extensive adaptation efforts. For these and other reasons, adaptation has been seen as giving up on trying to halt the enormous potential damage and threat of climate change. In essence, "[a]daptation was seen as a sign of defeat."[77]

There is a related concern that emphasizing adaptation will weaken public and political support for the already challenging task of adopting the major policy changes needed to reduce greenhouse gas emissions—particularly steps to curb the burning of fossil fuels. Concentrating on adaptation is also seen by some as giving companies a license to continue polluting and sending a signal to individuals that it is not necessary to change any of their behavior, creating the illusion that the impacts of climate change can be managed so that there is no need to reduce fossil fuel consumption. This concern is heightened by the fact that some climate change deniers and opponents of mitigation have argued that reducing emissions is too expensive or that it is too late to prevent or slow climate change and that we should instead turn to coping with it.[78]

A further concern is that adaptation steps could have severe environmental impacts of their own.[79] For example, building miles of seawalls to protect coastal areas threatened by sea level rise could destroy habitat and alter ecosystems, as well as generate greenhouse gases in producing the materials used and in building the structures. Defensive steps to "harden" or "armor" a coastline can also aggravate coastal erosion, making the problem they are intended to address worse in the long run.[80] In addition, adaptation tends to focus on minimizing the harm of climate change to the built environment; many of the far-reaching impacts

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[77] Michael B. Gerrard, *Introduction and Overview*, *in* THE LAW OF ADAPTATION TO CLIMATE CHANGE: U.S. AND INTERNATIONAL ASPECTS, *supra* note 73, at 3–4.
[78] *See* Matthew D. Zinn, *Adapting to Climate Change: Environmental Law in a Warmer World*, 34 ECOLOGY L. Q. 61, 62 (2007). Moreover, fossil fuel companies have funded many of the figures taking such a position. *See supra* note 20 and accompanying text.
[79] Zinn, *supra* note 78, at 63.
[80] SPANGER-SIEGFRIED, FITZPATRICK & DAHL, *supra* note 67, at 42.

of climate change, such as loss of species and loss of habitat, may only be capable of being addressed by mitigation.

Finally, adaptation can raise serious equity and environmental justice issues.[81] Decisions may have to be made about what to protect, what types of projects get funded, and where they are located. Among the issues, as one article identified, are: "Where and how equitably will adaptation capital such as seawalls be deployed and financed? . . . For areas transforming with climate change, how will redevelopment and job creation play out across the community? If the only option is to move, how will low-income populations manage that?"[82] In the transportation context, additional issues include which roads will be raised above sea level and what transportation options will be provided to evacuate residents in case of an extreme weather emergency. These are inescapably political issues that will require value judgments and have substantial social justice impacts. Wealthier nations, states, regions, or communities can afford to fund more adaptation steps, and certain areas have greater political power than others. As has been suggested, "[a]daptation clearly exposes winners and losers in a reallocation."[83]

Despite these concerns and shortcomings, the adaptation approach has received far greater attention from scientists, legal scholars, public officials, and governmental agencies in recent years.[84] The growing

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[81] *See* BLACK CONG. CAUCUS FOUND., *African Americans and Climate Change: An Unequal Burden* (2014), *available at* http://www.rprogress.org/publications/2004/CBCF_REPORT_F.pdf; *see also* Alice Kaswan, *Domestic Climate Change Adaptation and Equity*, 42 ENVTL. L. REP. 11125 (2009); *see also* RACHEL MORELLO-FROSCH ET. AL., THE CLIMATE GAP: INEQUALITIES IN HOW CLIMATE CHANGE HURTS AMERICANS & HOW TO CLOSE THE GAP (2009), *available at* http://www.climateaccess.org/sites/default/files/Morello-Frosch_The%20Climate%20Gap.pdf.

[82] J.B. Ruhl, *Climate Change Adaptation and the Structural Transformation of Environmental Law*, 40 ENVTL. L. REV. 363, 405–09 (2010); *see also* Kaswan, *supra* note 81, at 11134 ("[O]ne of the most contested issues will be the choice between protection and retreat.").

[83] A. Dan Tarlock, *Now, Think Again About Adaptation*, 9 ARIZ. J. INT'L & COMP. L. 169, 171 (1992).

[84] See, e.g., the sources cited above in note 73. For recent publications on transportation adaptation, MEYER ET AL., *Strategic Issues Facing Transportation: Climate Change, Extreme Weather Events, and the Highway System*, 2 NAT'L COOP. HIGHWAY RESEARCH PROGRAM 750 (2014), *available at* http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_750v2.pdf; FED. HIGHWAY ADMIN., U.S. DEPT. OF TRANSP., FHWA-HEP-14-016, ASSESSMENT OF THE BODY OF KNOWLEDGE INCORPORATING CLIMATE CHANGE ADAPTATION MEASURES INTO TRANSPORTATION PROJECTS (2013), *available at* http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/transportation_projects/transportationprojects.pdf [hereinafter FED. HIGHWAY ADMIN, FHWA-HEP-14-016; MEYER, ET AL., *Integrating Extreme Weather Risk into Transportation Asset Management*

emphasis on adaptation is due in large part to the widespread failure to take sufficient mitigation measures. As noted above, greenhouse gas emissions are continuing to climb, and given the cumulative and persistent nature of these emissions, the scientific consensus is that "[m]ost aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped."[85] Quite simply, we are out of time to halt certain climate changes. Martin Parry, a climate scientist who co-chaired one of the IPCC working groups, was quoted as saying: "we cannot mitigate out of this problem. We now have a choice between a future with a damaged world or a severely damaged world."[86] Moreover, as the impacts of a changing climate become evident, what was once seen as an intangible, distant threat increasingly seems real, leading calls for adaptation efforts to multiply.

One commentator has proclaimed that "the cold war between mitigation and adaptation is finally thawing. Climate change is already happening, and more is yet to come no matter what, thus a consensus is building that mitigation needs adaptation, and vice versa, even if they fundamentally are different and sometimes competing policy thrusts."[87] Significant debate remains, however, regarding which mitigation steps and which adaptation steps should be taken, as well as the appropriate balance between them. Nevertheless, there is growing support for adaptation measures, at least to address certain impacts, and an increasing recognition that at this point both mitigation and adaptation are required.

(2012), *available at* http://climatechange.transportation.org/pdf/extrweathertamwhitepaper_final.pdf; *Adapting Transportation to the Impacts of Climate Change: State of Practice 2011*, TRANSP. RESEARCH CIRCULAR E-C152 (Aug. 2011), *available* http://onlinepubs.trb.org/onlinepubs/circulars/ec152.pdf; *see also* FTA OFFICE OF BUDGET AND POLICY, NO. 0001, FLOODED BUS BARNS AND BUCKLED RAILS: PUBLIC TRANSPORTATION AND CLIMATE CHANGE ADAPTATION (2011), *available at* http://www.fta.dot.gov/documents/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf; FED. HIGHWAY ADMIN., U.S. DEPT. OF TRANSP., INTEGRATING CLIMATE CHANGE INTO THE TRANSPORTATION PLANNING PROCESS (2008), *available at* http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/integrating_climate_change/climatechange.pdf [hereinafter FED. HIGHWAY ADMIN., INTEGRATING CLIMATE CHANGE]; Gregory E. Wannier, *Infrastructure*, *in* THE LAW OF ADAPTATION TO CLIMATE CHANGE: U.S. AND INTERNATIONAL ASPECTS 173, 173 (Michael B. Gerrard & Katrina Fischer Kuh, eds., 2012).

[85] IPCC, PHYSICAL SCIENCE REPORT, *supra* note 1, at 27.

[86] David Adam, *How Climate Change Will Affect the World*, GUARDIAN (Sept. 18, 2007), http://www.theguardian.com/environment/2007/sep/19/climatechange, *archived at* http://perma.cc/AP9R-9ADD.

[87] Ruhl, *supra* note 82, at 369.

B. Transportation Adaptation Efforts to Date

Although recognition of the importance of adaptation measures has increased, efforts to implement these measures have lagged. The National Climate Assessment concluded in 2014 that "[d]espite emerging efforts, the pace and extent of adaptation activities are not proportional to the risks to people, property, infrastructure, and ecosystems from climate change; important opportunities available during the normal course of planning and management of resources are also being overlooked."[88] The steps taken so far primarily involve assessments of the need for adaptation and recommendations for action; for the most part, only modest, incremental steps have been implemented.

Transportation adaptation efforts are following a similar path. There has been greater recognition of the importance of addressing climate change, and an increase in federal, state, regional, and local efforts to assess the vulnerability of transportation infrastructure and systems to climate change, but thus far there has been an overall failure to plan for and invest in adaptation. Of course, transportation infrastructure and systems have in part taken climate factors into account and adapted to them for years. However, previous assumptions of temperature, precipitation, sea levels, and other climate features are becoming less valid and previous experience less relevant. If the pace of climate change quickens as predicted, transportation planning, design, construction, operations, and maintenance policies and practices will all have to be fundamentally altered.

1. Federal Efforts

Federal agencies have taken some steps to disseminate information and to promote adaptation planning over the past two decades. The pace of federal adaptation efforts began to pick up following a 2009 Executive Order by President Obama charging agencies with evaluating climate change risks and vulnerabilities that could impact their mission and operation and charging a task force with developing recommendations for federal agency adaptation planning.[89] Although rather general, the Executive Order, along with guidance from the Council on Environmental Quality to implement it[90] and recommendations from the inter-agency

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[88] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 687.
[89] Proclamation No. 194, 174 Fed. Reg. 52,117 (Oct. 8, 2009).
[90] COUNCIL ON ENVIRONMENTAL QUALITY, IMPLEMENTING CLIMATE CHANGE ADAPTATION

task force,[91] helped spark federal action. The White House's Climate Action Plan, released in June 2013, is another milestone in federal adaptation efforts. This plan expressly endorses an approach combining mitigation and adaptation, stating that "[a]s we act to curb the carbon pollution that is driving climate change, we must also prepare for the impacts that are too late to avoid."[92] Further, President Obama issued an Executive Order in November 2013 emphasizing climate change preparedness, including a directive to agencies to modernize federal programs to support and encourage more climate-resilient investments, and specifically mentioning infrastructure development.[93]

There has been a similar increase in federal transportation adaptation activities.[94] Among other things, in 2010 the Federal Highway Administration ("FHWA") provided funding to a handful of state and local agencies under a pilot program to conduct assessments of the vulnerability of infrastructure to climate change.[95] Building upon those pilots, FHWA produced a guidebook to help transportation agencies conduct vulnerability assessments, and that framework is being used in a second round of adaptation demonstration projects.[96] In 2013, the U.S. Department of Transportation released its first Climate Change Adaptation Plan, which sets forth strategies to modify their programs to

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PLANNING IN ACCORDANCE WITH EXECUTIVE ORDER 13514 (2011).

[91] *See* COUNCIL ON ENVIRONMENTAL QUALITY, FEDERAL ACTIONS FOR A CLIMATE RESILIENT NATION: PROGRESS REPORT OF THE INTERAGENCY CLIMATE CHANGE ADAPTATION TASK FORCE (2011), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ceq/2011_adaptation_progress_report.pdf; COUNCIL ON ENVIRONMENTAL QUALITY, PROGRESS REPORT OF THE INTERAGENCY CLIMATE CHANGE ADAPTATION TASK FORCE: RECOMMENDED ACTIONS IN SUPPORT OF A NATIONAL CLIMATE CHANGE ADAPTATION STRATEGY (2010), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf.

[92] EXECUTIVE OFFICE OF THE PRESIDENT, *supra* note 76.

[93] Proclamation No. 215, 78 Fed. Reg. 66,819 (Nov. 6, 2013).

[94] *See generally Adaptation*, U.S. DEP'T OF TRANSP., FED. HIGHWAY ADMIN., http://www.fhwa.dot.gov/environment/climate_change/adaptation/, *archived at* http://perma.cc/45ZR-VGDD; Wannier, *supra* note 84; Hyman et. al, *Federal Highway Administration Activities Related to the Adaptation of Transportation Infrastructure to Climate Change Impacts*, *in* ADAPTING TRANSPORTATION TO THE IMPACTS OF CLIMATE CHANGE 12 (Joyce Wenger ed., 2011).

[95] *Climate Change Resilience Pilots*, U.S. DEP'T OF TRANSP. FED. HIGHWAY ADMIN., http://www.fhwa.dot.gov/hep/climate/pilots.htm, *archived at* http://perma.cc/76RR-KKJK.

[96] FED. HIGHWAY ADMIN., U.S. DEP'T OF TRANSP., CLIMATE CHANGE & EXTREME WEATHER VULNERABILITY ASSESSMENT FRAMEWORK (2012), *available at* http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/vulnerability_assessment_framework/fhwahep13005.pdf.

consider climate risks, such as developing guidance to incorporate considerations of climate change and extreme weather events into coastal highway projects.[97] There has been some direct funding of adaptation projects as well. The Federal Transit Administration awarded almost $3.6 billion in competitive grants to improve the resilience of infrastructure damaged by Superstorm Sandy.[98] FHWA also has issued a memorandum clarifying that the federal government will share the costs of planning, designing, and building highways to adapt to climate change with states, metropolitan planning organizations, and localities, though it further made it clear that "no new funding is being added to address adaptation needs."[99]

These and other recent steps have created a framework that could reorient federal programs and policies to promote transportation adaptation planning and investments. Most of these steps have focused on providing information and technical resources. This is a useful start, but many provisions (such as those governing transportation planning to qualify for federal funding) and decisions (such as the assessment of the impact and alternatives to proposed transportation projects) need to be overhauled to improve consideration of climate vulnerabilities, risks, and adaptation strategies.[100] The extent of supportive federal funding and meaningful action to advance transportation adaptation planning and projects remains to be seen.

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[97] U.S. DEP'T OF TRANSP., ENSURING TRANSPORTATION INFRASTRUCTURE AND SYSTEM RESILIENCE, *available at* http://www.dot.gov/sites/dot.dev/files/docs/DOT%20Adaptation%20Plan.pdf.

[98] Press Release, Fed. Transit Admin., Transportation Secretary Foxx Announces Nearly $3.6 Billion to Make Transit Systems More Resilient in New York, New Jersey, and Beyond (Sept. 22, 2014) (Although it is noteworthy that resilience has played such a large role in the Sandy recovery funding, this funding is an anomaly in response to a record weather disaster.), *available at* http://www.fta.dot.gov/newsroom/news_releases/12286_16152.html, *archived at* http://perma.cc/R6X2-32ZT.

[99] Memorandum from Baxter et. al, on Eligibility of Activities to Adapt to Climate Change and Extreme Weather Events Under the Federal-Aid and Federal Lands Highway Program to Directors of Field Services, Directors of Technical Services, Division Administrators, Federal Lands Highway Division Engineers (Sept. 24, 2012), *available at* http://www.fhwa.dot.gov/federalaid/120924.cfm, *archived at* http://perma.cc/A298-MJH9.

[100] *See* Grow America Act, H.R. 4834, 113th Cong. § 1201 (2014), *available at* http://www.dot.gov/sites/dot.gov/files/docs/DOT_surface_reauth-FINAL.pdf (this proposed legislation would reauthorize the basic federal surface transportation law, and this section would address part of the current planning deficiencies).

2. State, Regional, and Local Efforts

There is a longer history of significant state, regional, and local adaptation efforts, and these efforts have also increased in recent years.[101]

California is a leader in climate policy worldwide. The Golden State has enacted comprehensive measures to reduce its greenhouse gas emissions, committing to reduce emissions to 1990 levels by 2020—about 30% lower than the business as usual forecast[102]—through reductions from a wide range of sources,[103] and to 80% below 1990 levels by 2050.[104] It subsequently enacted legislation that promotes improved transportation and land use planning to achieve these reductions.[105] California has been a leader in climate adaptation too, with a 2008 Executive Order requiring agencies to assess vulnerability and increase resiliency to sea level rise, and requiring preparation of a state adaptation strategy.[106] The resulting strategy is the most comprehensive state adaptation plan in the United States. Initially adopted in 2009, this plan examines the impacts of a changing climate, identifies vulnerabilities, and recommends actions to improve resilience.[107] The 2014 updated plan details climate risks to nine different sectors and provides sector-specific policy recommendations that would begin to shift from planning to

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[101] *See*, *e*.g., Vicki Arroyo et. al, *State and Local Adaptation, in* THE LAW OF ADAPTATION TO CLIMATE CHANGE: U.S. AND INTERNATIONAL ASPECTS, *supra* note 73, at 569; Paulsen, *State Departments of Transportation Working to Adapt to Climate Change*, *in* ADAPTING TRANSPORTATION TO THE IMPACTS OF CLIMATE CHANGE, *supra* note 94, at 27.

[102] CALIFORNIA AIR RESOURCES BD., CLIMATE CHANGE SCOPING PLAN: A FRAMEWORK FOR CHANGE (2008), *available at* http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf.

[103] Global Warming Solutions Act of 2006, Cal. A.B. 32, 2006 Cal. Stat., ch. 488 (codified at CAL. HEALTH & SAFETY CODE §§ 38500-38599).

[104] Cal. Exec. Order S-3-05 (June 1, 2005).

[105] S.R. 375, 2008 Leg. (The Sustainable Communities and Climate Protection Act of 2008 supports the greenhouse gas reduction goals of A.B. 32 through coordinated transportation and land use planning, calling on the California Air Resources Board to set regional targets for emissions reductions from passenger vehicles, requiring metropolitan planning organizations to prepare a "sustainable communities strategy" as part of its regional transportation plan that will guide transportation policies and investments to allow the region to meet its emission reduction targets); *see also* TOM ADAMS, AMANDA EAKEN & ANN NOTTHOFF, COMMUNITIES TACKLE GLOBAL WARMING: A GUIDE TO CALIFORNIA'S SB 375 14–23 (2009), *available at* http://www.nrdc.org/globalwarming/sb375/files/sb375.pdf.

[106] Cal. Exec. Order S-13-08 (Nov. 14, 2008).

[107] CAL. NATURAL RES. AGENCY, CALIFORNIA CLIMATE ADAPTATION STRATEGY 4 (2009), *available at* http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF.

implementation.[108] Transportation is one of the sectors analyzed, and the plan contains numerous specific recommendations regarding transportation. California's Department of Transportation ("Caltrans") has taken additional steps to advance adaptation,[109] including releasing a guidance document to help regional transportation entities incorporate climate change impacts into their plans and decisions[110] and adopting guidance for the Department's planning staff on how to incorporate sea level rise into state plans and designs.[111]

California's adaptation efforts also stand out in the extent to which plans have been implemented. A database developed by the Georgetown Climate Center found that most of the goals in California's plan have been completed or actions were underway to meet them.[112] Only 14 states have a finalized state adaptation plan, according to the database, and the majority of these states have only implemented a small percentage of the recommendations in their plans.[113] The failure of most states to adopt an adaptation plan, and of many states that have plans to do more to implement them, increases climate risk and future costs.

Virginia provides a useful case study. Public support for adaptation steps has risen as the evidence and impacts of a changing climate have begun to be felt—particularly the impacts of sea level rise in tidal

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[108] CAL. NATURAL RES. AGENCY, SAFEGUARDING CALIFORNIA: REDUCING CLIMATE RISK 4–5 (2014), *available at* http://resources.ca.gov/docs/climate/Final_Safeguarding_CA_Plan_July_31_2014.pdf.

[109] Although Caltrans has taken some important additional steps to advance transportation adaptation, a recent external review is critical of its performance, among other things citing the need to better align the agency with the state's climate action goals. *See* STATE SMART TRANSP. INITIATIVE, THE CALIFORNIA DEP'T OF TRANSP.: SSTI ASSESSMENT AND RECOMMENDATIONS iii–iv (2014), *available at* http://www.calsta.ca.gov/res/docs/pdfs/2013/SSTI_Independent%20Caltrans%20Review%201.28.14.pdf.

[110] CAMBRIDGE SYSTEMATICS, ADDRESSING CLIMATE CHANGE ADAPTATION IN REGIONAL TRANSPORTATION PLANS: A GUIDE FOR CALIFORNIA MPOS AND RTPAS 1-1(2013), *available at* http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf#zoom=65.

[111] CAL. DEP'T. OF TRANSP., GUIDANCE ON INCORPORATING SEA LEVEL RISE: FOR USE IN THE PLANNING AND DEVELOPMENT OF PROJECT INITIATION DOCUMENTS 2(2011), *available at* http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/guide_incorp_slr.pdf#zoom=65.

[112] *California Climate and Energy Profile*, GEO. CLIMATE CTR., http://www.georgetownclimate.org/adaptation/state-information/overview-of-californias-climate-change-preparations (last visited Jan. 15, 2015), *archived at* http://perma.cc/EFY5-5TNE.

[113] *State and Local Adaptation Plans*, GEO. CLIMATE CTR., http://www.georgetownclimate.org/adaptation/state-and-local-plans (last visited Jan. 15, 2015), *archived at* http://perma.cc/Y7SM-E6A2.

areas. These impacts helped spur then-Governor Tim Kaine in 2007 to create a commission to develop a climate action plan.[114] The Commission's final report in December 2008 made more than 100 recommendations, including over two dozen steps to prepare for and adapt to climate change and over two dozen steps to cut transportation emissions.[115] A new governor, Bob McDonnell, was elected in November 2009; he did not continue the climate commission and effectively shelved the climate plan recommendations.[116] In July 2014, the current governor, Terry McAuliffe, issued an executive order establishing a new climate commission and charging it with determining which recommendations of the original commission have been implemented, updating and prioritizing the recommendations, and identifying funding sources to implement them.[117] Similarly, the state's long range transportation plan adopted during the Kaine Administration discussed the considerable threat to transportation posed by a changing climate,[118] while the updated plan adopted in the McDonnell Administration did not mention climate change.[119] These pendulum swings underscore both the ongoing political debate over climate change and the vulnerability of state plans.

Other state action on adaptation in Virginia has been limited. Overall, the General Assembly has resisted addressing climate change

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[114] Va. Exec. Order No. 59 (Dec. 21, 2007) (The Governor's Commission on Climate Change). Full disclosure: the author was a member of this commission.

[115] GOVERNOR'S COMM'N ON CLIMATE CHANGE, FINAL REPORT: A CLIMATE CHANGE ACTION PLAN 2–3, 8, 35, 56–57 (2008), *available at* http://leg2.state.va.us/dls/h&sdocs.nsf/By+Year/RD192009/$file/RD19.pdf. The transportation mitigation recommendations are particularly important since transportation is the largest source of CO2 emissions in Virginia. *See* TRIP POLLARD, NEW DIRECTIONS: LAND USE, TRANSPORTATION, AND CLIMATE CHANGE IN VIRGINIA 2(2007), *available at* https://www.southernenvironment.org/uploads/publications/new_directions_dec07.pdf.

[116] The Georgetown Climate Center database shows that only two of the Commission's goals have been fully implemented while a handful of others are in progress. *Virginia Climate and Energy Profile*, GEO. CLIMATE CTR., http://www.georgetownclimate.org/adaptation/state-information/overview-of-virginias-climate-change-preparations (last visited Jan. 15, 2015), *archived at* http://perma.cc/8NMX-BD3N.

[117] Va. Exec. Order 19 (July 1, 2004) (Convening the Governor's Climate Change and Resiliency Update Commission).

[118] OFFICE OF INTERMODAL PLANNING AND INV., VTRANS 2035 REPORT TO THE GOVERNOR AND GENERAL ASSEMBLY 19 (2010), *available at* http://vtrans.org/resources/VTrans_2035_Report.pdf. However, this plan did not contain any specific recommendations to address climate change.

[119] OFFICE OF INTERMODAL PLANNING AND INV., VTRANS 2035 UPDATE: AN UPDATE TO VIRGINIA'S MULTIMODAL LONG-RANGE TRANSPORTATION PLAN (2013), *available at* http://www.vtrans.org/resources/VTrans2035Update_Final_Draft_with_Appendices.pdf.

and opposed using the term, although it recently passed bills authorizing a study[120] and subsequently establishing a joint legislative subcommittee to develop recommendations to address recurrent flooding.[121] The legislature also established the Secure Commonwealth Panel,[122] an advisory body on emergency preparedness whose subpanel on recurring flooding has recommended establishing a state incident command system and flood resilience action plan.[123] The Virginia Department of Transportation has participated in some studies assessing the vulnerability of transportation infrastructure to climate change in Hampton Roads,[124] but it has placed little emphasis on adaptation, and its review of proposed projects consistently ignores or barely mentions the potential impacts of a changing climate, steps to minimize these impacts, or alternatives that might reduce them.[125]

Most of the adaptation activity in Virginia has been at the local and regional level. A number of localities have recognized sea level rise in their comprehensive plans and other planning documents, although as one review concluded, "tangible adaptation actions are uncommon, *ad hoc*, and at a small scale."[126] Several regional planning district commissions

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[120] S.J. Res. 76, 2012 Leg. (Va. 2012); H.R.J. Res. 50, 2012 Leg. (Va. 2012).

[121] S.J. Res. 3, 2014 Leg. (Va. 2014); H.R.J. Res. 16, 2014 Leg. (Va. 2014). The General Assembly also has required localities in tidal areas to include coastal resource management guidance developed by the Virginia Institute of Marine Science in their comprehensive plans, and specified that this guidance "shall identify preferred options for shoreline management and taking into consideration the resource condition, priority planning, and forecasting of the condition of the Commonwealth's shoreline with respect to projected sea-level rise." 2011 Va. Acts Ch. 885.

[122] Va. Code § 2.2-222.3.

[123] RECURRENT FLOODING SUB-PANEL, RECOMMENDATIONS TO THE SECURE COMMONWEALTH PANEL ON THE ISSUE OF SEA LEVEL RISE AND RECURRENT FLOODING IN COASTAL VIRGINIA 1–2 (2014), *available at* http://ccrm.vims.edu/SCPRecommendationsReport_Sept2014.pdf.

[124] *See*, *e.g.*, VA. DEP'T. OF TRANSP., ET AL., ASSESSING VULNERABILITY AND RISK OF CLIMATE CHANGE EFFECTS ON TRANSPORTATION INFRASTRUCTURE: HAMPTON ROADS VIRGINIA PILOT iii (2011), *available at* http://www.virginia.edu/crmes/fhwa_climate/files/finalReport.pdf.

[125] This occurs even in the most vulnerable areas of the state. *See*, *e.g.*, U.S. DEP'T. OF TRANSP., ENVIRONMENTAL ASSESSMENT: DOWNTOWN TUNNEL, MIDTOWN TUNNEL, MARTIN LUTHER KING FREEWAY EXTENSION (DT-MT-MLK) PROJECT 15–16 (2011), *available at* https://www.driveert.com/wp-content/uploads/2013/01/EnvironmentalAssessment-DowntownTunnel-MidtownTunnel-MLKExtensionProjectMarch2011.pdf (containing one sentence mentioning that a future forecast of one meter sea level rise by 2010 should be considered).

[126] William Stiles, Molly Mitchell, and Troy Hartley, *The Policy Climate for Climate Change in Virginia: Overview of Adaptation Policy, Planning and Implementation*

have undertaken studies and created tools local governments can use in planning.[127] The long-range transportation plan in Hampton Roads discusses climate change, but contains no recommendations,[128] while the region's transportation project prioritization process currently does not give any points to adaptation in ranking projects. Some localities have taken more comprehensive and direct steps. The City of Norfolk has become a national leader in planning for sea level rise, conducting flooding studies, adopting a coastal resilience strategy, and developing a billion-dollar package of floodwalls, tidegates, elevated roadways, and other projects to protect houses and infrastructure.[129] Funding for this entire package is beyond the capacity of the city, but it has begun to spend millions of dollars to adapt to tidal flooding by raising sections of streets.[130]

Numerous other localities nationwide have begun to increase adaptation activities. New York City has perhaps the most comprehensive and ambitious local effort, which even before Superstorm Sandy included the landmark PlaNYC long-term sustainability plan[131] and the establishment of a task force to develop strategies to adapt the city's

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Landscape, 5 SEA GRANT L. & POL'Y J. 15, 16 (2013).

[127] For the Hampton Roads Planning District and Transportation Planning Organization, *see*, *e.g.*, MCFARLANE, *supra* note 69; SAMUEL S. BELFIELD, HAMPTON ROADS MILITARY TRANSPORTATION NEEDS STUDY: ROADWAYS SERVING THE MILITARY AND SEA LEVEL RISE/STORM SURGE 5 (2013), *available at* http://www.hrtpo.org/uploads/docs/Roadways%20Serving%20the%20Military%20&%20Sea%20Level%20Rise-Storm%20Surge%20Report.pdf; BENJAMIN J. MCFARLANE, COASTAL RESILIENCY: ADAPTING TO CLIMATE CHANGE IN HAMPTON ROADS (2013), *available at* http://www.hrpdcva.gov/uploads/docs/07182013-PDC-E9I.pdf; BENJAMIN J. MCFARLANE, CLIMATE CHANGE IN HAMPTON ROADS—PHASE II: STORM SURGE VULNERABILITY AND PUBLIC OUTREACH 57–58 (2011), *available at* http://www.deq.virginia.gov/portals/0/deq/coastalzonemanagement/task12-04-09.pdf. The Middle Peninsula and Northern Virginia Planning District Commissions have undertaken a number of adaptation studies and outreach efforts as well.

[128] HAMPTON ROADS TRANSP. PLANNING ORG., 2034 LONG-RANGE TRANSPORTATION PLAN: NAVIGATING THE FUTURE 9-2 (2012), *available at* http://www.hrtpo.org/uploads/docs/Reports/Final_2034LRTP.pdf.

[129] CITY OF NORFOLK, COASTAL RESILIENCE STRATEGY, 10–11, *available at* http://www.norfolk.gov/DocumentCenter/View/16292, *archived at* http://perma.cc/NLG6-HLTR; *see also* Darryl Fears, *Built on sinking ground, Norfolk tries to hold back tide amid sea-level rise*, WASH. POST (June 17, 2012), *available at* http://www.washingtonpost.com/national/health-science/built-on-sinking-ground-norfolk-tries-to-hold-back-tide-amid-sea-level-rise/2012/06/17/gJQADUsxjV_story.html, *archived at* http://perma.cc/V6TL-9C5Z.

[130] CITY OF NORFOLK, *supra note* 129, at 4, 7.

[131] CITY OF N.Y., PLANYC: A GREENER, GREATER NEW YORK (2007); *see also* Edna Sussman et al., *Climate Change Adaptation: Fostering Progress Through Law and Regulation*, 18 N.Y.U. ENVTL. L.J. 55, 58 (2010).

infrastructure to a changing climate. Since Sandy, the city has developed a far more detailed adaptation plan that includes recommendations for eighteen transportation initiatives,[132] created an Office of Recovery and Resiliency to advance climate resiliency initiatives, and begun to move forward with implementing specific projects.[133]

Despite the increase in federal, state, regional, and local transportation adaptation efforts, these efforts have largely been limited to steps such as assessing the vulnerability of infrastructure and systems to climate change and making recommendations for adapting to future changes. Relatively few practices have changed, and it is uncertain how many of the recommendations that have been made will be implemented. Investments in adaptation steps are, thus far, even rarer. As one overview of adaptation efforts concluded, "many of our physical structures are quite vulnerable to entirely plausible future conditions. Precautions against these vulnerabilities have been taken in a few places, showing it can be done, but that is still very much the exception rather than the rule."[134]

III. MOVING FORWARD ON ADAPTATION

The mounting damage and the magnitude of risk to transportation from a changing climate will render the high cost of inaction increasingly clear and will likely fuel public concern, pressure for action, and opportunities to advance adaptation.

The focus of transportation adaptation efforts to date on assessing the vulnerability of existing infrastructure and on analyzing current and projected climate impacts on transportation are important building blocks for effective action. Efforts at the federal, state, regional, and local levels to develop, refine, and disseminate data and tools should be expanded and should be ongoing. In addition, many more jurisdictions need to begin work on these fundamental steps. The majority of the vulnerability and risk assessments to date have been conducted by coastal states and localities that have had direct experience with sea level rise, intense storms, and flooding. Yet impacts of a changing climate will affect

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[132] CITY OF N.Y., A STRONGER, MORE RESILIENT NEW YORK (2013), *available at* http://s-media.nyc.gov/agencies/sirr/SIRR_singles_Lo_res.pdf.
[133] CITY OF N.Y., PLANYC: PROGRESS REPORT 2014: A GREENER, GREATER NEW YORK, A STRONGER, MORE RESILIENT NEW YORK, *available at* http://www.nyc.gov/html/planyc2030/downloads/pdf/140422_PlaNYCP-Report_FINAL_Web.pdf.
[134] Gerrard, *supra* note 73, at 13.

transportation in areas that have done little or nothing to engage the issue. Each state should conduct a vulnerability assessment of its transportation facilities.

It also is imperative that a framework be created at each level of government to act on the climate risk data that is generated. Elements of such a framework include adopting a climate action plan based on robust input from the public and key stakeholders, building capacity to implement the plan, identifying a designated point person to oversee implementation, updating policies and issuing guidance, coordinating among different levels of government, coordinating across and within agencies at the same level of government, and communicating with the public.

Ultimately, climate change considerations should be integrated into all aspects of transportation—planning, design, siting, construction, operations, and maintenance. A host of additional potential policies and steps are available to help move toward this integration and to reduce climate risk to transportation.[135]

A. Address Climate Risk in Transportation Planning

One of the most important steps to advance transportation adaptation is for agencies to take climate risks into account in their planning and funding decisions. Federal law requires states[136] and metropolitan planning organizations[137] to undertake continuous, comprehensive, and collaborative planning and to develop both long-range transportation plans and shorter-term implementation plans. Currently, there is no express requirement that these plans consider climate change, and while there has been an increase in attention, many plans ignore or slight climate issues.[138] Federal law or regulations could be amended to require transportation plans to include consideration of vulnerability to climate change and adaptation steps. Even without this mandate, states and metropolitan areas can and should consider climate change in formulating their transportation plans to avoid crafting plans and spending funds

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[135] *See, e.g.*, FED. HIGHWAY ADMIN., FHWA-HEP-14-016, *supra* note 84, for a summary of adaptation strategies and best practices.
[136] 23 U.S.C. § 135 (2012); 23 C.F.R. § 450, Subpart B.
[137] 23 U.S.C. § 134 (2012); 23 C.F.R. § 450, Subpart C.
[138] *See, e.g.*, U.S. DEPT. OF TRANSP., VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER, TRENDS IN STATEWIDE LONG-RANGE TRANSPORTATION PLANS: CORE AND EMERGING TOPICS (March 2012), *available at* http://www.planning.dot.gov/documents/State_plans_report_508_A.PDF.

that ignore a major factor that could impact transportation safety and the cost and effectiveness of investments.[139] Similarly, local transportation plans should incorporate considerations of climate change.

Further, although federal law currently does not expressly require plans to consider climate change, the most recent federal surface transportation law does call for development of risk-based asset management plans to improve or preserve the condition of transportation assets.[140] Climate change certainly is a risk that affects transportation assets and thus should be addressed to meet this requirement. Federal law also requires consideration of alternatives to roads, highways, or bridges that repeatedly need repair or reconstruction in order to conserve federal resources and protect public safety and health.[141] These provisions should encourage greater adaptation planning as well.

Crafting a transportation plan to address current and potential climate impacts is complicated by uncertainty over the scope, scale, and pace of climate change and the precise impacts of a changing climate on transportation infrastructure and systems. Since information is incomplete and our understanding is evolving, the amount and type of adaptation necessary to reduce climate risk to transportation infrastructure and systems in a particular state, metropolitan area, or locality is not certain and can be hard to predict; this is a classic planning problem, however, rather than a reason for inaction. There is substantial information and understanding of certain aspects of climate change, and there are a number of tools and approaches that can be employed to help make decisions in the face of uncertainty and that incorporate climate considerations into transportation plans, such as scenario planning that allows risks to be managed by testing various alternatives.[142]

Another method of managing climate risk in light of incomplete information is to develop a portfolio of alternatives that permit flexibility in implementing transportation plans in response to future events and information. A report describing a flexible adaptation plan to address flooding gave the example that a "plan for road elevation could combine

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[139] A number of states and localities have begun to incorporate climate change into their long-range plans; however, most plans addressing climate deal primarily or solely with mitigation. *See* FED. HIGHWAY ADMIN., INTEGRATING CLIMATE CHANGE, *supra* note 84.
[140] Moving Ahead for Progress in the 21st Century (MAP-21) § 1106, 23 U.S.C. § 119 (2012).
[141] Moving Ahead for Progress in the 21st Century (MAP-21) § 1315b, 23 U.S.C. § 109.
[142] U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 1, at 682; FED. HIGHWAY ADMIN., INTEGRATING CLIMATE CHANGE, *supra* note 84, at 6.

incremental elevation with routine maintenance, targeting areas that are predicted to be impacted by flooding. . . . if sea level rises more slowly than predictions, the elevation portion of the program could be suspended with minimal effort."[143] Location-specific considerations and available resources will, of course, also influence which adaptation measures are pursued and whether a more aggressive or a more incremental approach is adopted.

B. Consider Alternatives in Project Review

Climate change should be considered in developing and reviewing specific transportation projects as well. One potentially valuable tool to accomplish this for certain projects is the National Environmental Policy Act ("NEPA").[144] Among other things, NEPA requires that a comprehensive environmental impact statement ("EIS") be prepared for major federal actions that may have a significant impact on the environment, and that this assessment analyze the environmental impacts of a proposed project, the adverse environmental effects that cannot be avoided, and the alternatives to a project.[145] As the Supreme Court has stated, "NEPA mandates "a set of 'action-forcing' procedures that require that agencies take a 'hard look' at environmental consequences . . . ."[146]

Arguably, NEPA mandates a hard look not only at the impacts of a proposed action on the environment, but also at the impacts of the environment upon a proposed action, especially if future climate changes would alter the environmental impacts of the proposed action.[147] This would provide an avenue for considering issues such as the effects of sea level rise on a proposed coastal highway. The Council on Environmental Quality ("CEQ"), which promulgates regulations implementing NEPA,[148] has released—but never finalized—draft guidance to agencies on addressing climate change in environmental reviews that recognizes that "[a]gencies can use the NEPA process to reduce vulnerability to climate change impacts, adapt to changes in our environment, and mitigate

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[143] VIMS 2013, *supra* note 65, at 50.
[144] National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–70.
[145] National Environmental Policy Act of 1969, 42 U.S.C. §§ 4332(C).
[146] Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 350 (1989) (internal quotation marks and citation omitted).
[147] *See* Katherine M. Baldwin, Note, *NEPA and CEQA: Effective Legal Frameworks for Compelling Consideration of Adaptation to Climate Change*, 82 S. CAL. L. REV. 769 (2009).
[148] *See* 42 U.S.C. § 4342 (2012); Exec. Order No. 11,991, 42 Fed. Reg. 26,967 (May 25, 1997).

the impacts of Federal agency actions that are exacerbated by climate change."[149]

Although NEPA necessitates a comprehensive analysis of a relatively small percentage of transportation projects, its emphasis on assessing impacts and considering alternatives offers a useful model to assess a broader range of transportation projects and potential adaptive measures. An example that illustrates the advantages of this type of approach and underscores the need for adaptive planning and improved project review is a proposed replacement of the aging Bonner Bridge that connects mainland North Carolina to Hatteras Island on the Outer Banks. The state proposed replacing the bridge in the same location, at the most unstable end of the shifting barrier island, ignoring persistent problems with the highway south of the bridge (NC 12) being washed out and overwashed by high tides or storms (including Tropical Storm Ida, Hurricane Irene, and Hurricane Sandy in the last six years)—at times covering the road with sand and water, and at other times washing chunks of it into the ocean.[150] High tides and storms, and the resulting damage to the highway, are all likely to increase as the climate changes. Sea level is already increasing faster along the Outer Banks than the global rate, and even minor storms now can cause flooding.[151] The road

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[149] Memorandum from Nancy H. Sutley, Chair, Council on Environmental Quality, Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions 2 (Feb. 18, 2010), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ceq/20100218-nepa-consideration-effects-ghg-draft-guidance.pdf. CEQ recently denied a petition to update its regulations to explicitly require federal environmental reviews to include an analysis of climate change. CEQ stated that existing NEPA regulations "already encompass consideration of climate effects," that courts have found that greenhouse gas emissions and climate change already need to be analyzed under the existing NEPA statute and regulations, and cited the draft guidance that is still under review. Letter from Michael J. Boots, Acting Director, CEQ (Aug. 7, 2014), *available at* http://energy.gov/esites/prod/files/2014/08/f18/CEQPetition_InclusionofClimateChangeAnalysisinNEPA_2014.pdf.

[150] *See* Margaret Newkirk, *Rising Seas Don't Stop North Carolina Bridge That Uses U.S. Cash*, BLOOMBERG BUSINESSWEEK (May 6, 2014), *available at* http://www.businessweek.com/news/2014-05-06/rising-seas-don-t-stop-north-carolina-bridge-that-uses-u-dot-s-dot-cash, *archived at* http://perma.cc/92PW-64AW; *see also* Cornelia Dean, *A North Carolina Lifeline Built on Shifting Sands*, N. Y. TIMES (Mar. 5, 2012), *available at* http://www.nytimes.com/2012/03/06/science/highway-12-outer-banks-lifeline-is-under-siege-by-nature.html?pagewanted=all&_r=0, *archived at* http://perma.cc/46XC-XD8C; *see also* Defenders of Wildlife v. NC Dept. of Transp., 762 F.3d 374 (4th Cir. 2014).

[151] *See* N.C. INTERAGENCY LEADERSHIP TEAM, CLIMATE READY NORTH CAROLINA: BUILDING A RESILIENT FUTURE 30–31 (2012), *available at* http://climateadaptationnc.nemac.org/Climate_Ready_North_Carolina_Building_a_Resilient_Future.pdf(citing U.S. ENVIRONMENTAL PROTECTION AGENCY, COASTAL SENSITIVITY TO SEA LEVEL RISE: A FOCUS ON THE MID-ATLANTIC REGION, 2009).

has been characterized as "an extreme example of the difficulty of maintaining houses, condos, roads and other infrastructure in the face of a climate-driven rise in sea level."[152] As Stanley R. Riggs, a coastal scientist at East Carolina University said, maintaining the highway "is totally a lost cause."[153] Yet the state has spent millions of dollars in recent years to rebuild, repair, and maintain NC 12, proposes to spend hundreds of millions on a new bridge in the same location connecting to a road with an uncertain future, and rejected calls to build a longer bridge in a protected sound between the island and the mainland that avoids the unstable end of the island or to replace the bridge with ferries.[154]

Federal, state, and local laws and policies should clearly require an assessment of climate risk and adaptation alternatives during project review. In addition, new projects in vulnerable areas should be able to withstand projected climate changes—such as sea level rise, flooding, and storm surges—over the projected life of the project in order to qualify for funding.

C. Link Transportation and Land Use

Transportation investments influence land use decisions. The location, scale, and mode of transportation infrastructure that is built can impact the location, pace, and form of development for decades. For example, construction of a new highway may open up a corridor for sprawling development. As one court observed: "Highways create demand for travel and [suburban] expansion by their very existence."[155] Federal, state, and local transportation policies and investments have typically favored road construction and driving, while comparatively little has been spent on alternatives to driving, often promoting sprawl.[156] Yet reviews of transportation projects frequently pay scant attention to the land use impacts of such projects.[157]

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[152] Dean, *supra* note 150.
[153] *Id.*
[154] *Id.*
[155] Sierra Club v. Dep't of Transp., 962 F. Supp. 1037, 1043 (N.D. Ill. 1997)(citing Swain v. Brinegar, 517 F.2d 766, 777 (7th Cir. 1975)).
[156] See, e.g., Pollard, *Driving Change, supra* note 74 for further discussion of the impact public policies have had on transportation and land use trends; *see also* KENNETH T. JACKSON, CRABGRASS FRONTIER: THE SUBURBANIZATION OF THE U.S. (1985); Roberta F. Mann, *On the Road Again: How Tax Policy Drives Transportation Choice*, 24 VA. TAX REV. 587 (2005).
[157] TRANSP. RESEARCH BD., *supra* note 32, at 17.

In order to harmonize investments in transportation and efforts to minimize climate risk, it is essential to avoid putting more people in harm's way by encouraging development in areas threatened by a changing climate. Not surprisingly, "[o]ne of the most effective strategies for reducing the risks of climate change is to avoid placing people and infrastructure in vulnerable locations."[158]

The land use impacts of transportation proposals should be studied so that transportation and climate risk reduction are not working at cross purposes, such as building a new highway that opens an area prone to future flooding or a coastal region threatened by sea level rise to more intense development. Projects that would trigger development in vulnerable areas should not be funded.

D. Assess the Life-Cycle Cost of Alternatives

The potential futility of efforts to rebuild infrastructure in vulnerable areas and the potential harm to residents of development that new infrastructure can spur in places threatened by climate change highlights the importance of estimating the costs and benefits of transportation alternatives when developing and assessing infrastructure plans and projects.[159] On the other hand, as a review of best adaptation practices suggested, it is also important to understand the cost of not taking any action in order to "help show when investment in adaptation measures makes financial sense."[160] Decisions on building, retrofitting, or repairing facilities should be subject to a rigorous cost-benefit analysis, particularly since transportation infrastructure tends to have a long life.[161]

It is critical that the long term, life-cycle cost of alternatives be analyzed since the future cost of maintaining, repairing, or replacing infrastructure threatened by a changing climate can be substantial. In addition, it is important to consider the benefits of adaptation alternatives, such as increased safety and reduced disruption of passenger and freight trips.[162] Assessing the impacts, costs, and benefits of alternatives early in the planning process can help prioritize spending of limited funds and may lead to selecting an adaptation project or measures that

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[158] *Id.*
[159] FED. HIGHWAY ADMIN., INTEGRATING CLIMATE CHANGE, *supra* note 84, at 21.
[160] *Id.*
[161] *Id.*
[162] *Id.*

avoid far higher future costs due to climate change.[163] By contrast, certain transportation adaptation measures, like building a seawall or levee to protect a coastal highway from sea level rise, could carry enormous additional costs, such as harm to ecosystems or damage to homes by altering erosion patterns.[164] These costs obviously need to be considered as well.

There are hurdles to assessing the costs and benefits of adaptation options, including limitations on available data, the long time frame to be analyzed, and the uncertainty of future climate conditions.[165] However, a number of established methods can address these types of issues, and specific approaches are being developed to evaluate adaptation measures.[166]

E. Prioritize Lower Cost Alternatives

Although adaptation alternatives often can be expensive, particularly if new construction or extensive retrofitting of existing infrastructure is involved, lower cost options often are available to better protect transportation facilities and to improve system resilience—at least in the near-term.

As one report stated, "[t]he most cost-efficient adaptation measures are those completed in the course of business-as-usual maintenance, construction, repair, or replacement projects. In other words, the time when you are already working on your system is an opportunity to make that system more resilient."[167] Examples of such measures include upgrading road drainage systems when other road improvements are made, protecting bridge piers with riprap, clearing culverts more frequently, and using bridges rather than culverts to avoid flooding.[168]

Maintenance and construction practices, materials used in building infrastructure, and design and engineering standards can all be modified to help ensure that opportunities to make adaptation improvements are not missed when they arise. The U.S. Department of

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[163] *Id.*
[164] *Id.*
[165] FED. HIGHWAY ADMIN., INTEGRATING CLIMATE CHANGE, *supra* note 84, at 21.
[166] *Id.*; *see also* Nat'l Coop. Highway Research Program, *Benefit-Cost Methodology for Climate Adaptation Strategies* , 2 STRATEGIC ISSUES FACING TRANSPORTATION pt. I, app. B (2014).
[167] FED. HIGHWAY ADMIN., INTEGRATING CLIMATE CHANGE, *supra* note 84, at 18.
[168] TRANSP. RESEARCH BD., *supra* note 32, at 175–88.

Transportation's adaptation plan, for example, states that "incorporation of certain materials and building techniques will enable infrastructure to better withstand extreme temperatures."[169] Other steps include designing bridges to withstand higher winds, adopting new design criteria for culverts, and employing materials that can withstand more frequent storms and flooding.[170]

F. Address Equity Issues

Transportation investments can raise serious equity issues. Analyses of numerous metropolitan areas in the United States suggest that there is a "favored quarter," or portion of a region that receives a disproportionate share of investment in transportation and other infrastructure and experiences the largest growth in jobs and population.[171] As discussed above, adaptation can raise similarly serious issues of equity and environmental justice.[172] These issues should be considered in deciding what types of adaptation projects get funded, where they are located, and the provisions that are made for evacuation in the event of an emergency.

As one commentator argues, "equity considerations should play a vital role in emerging U.S. adaptation initiatives"[173] since "[v]ulnerable populations will be at much greater risk from climate change unless climate change adaptation policies grapple with the underlying socioeconomic inequities that exacerbate their vulnerability."[174]

To address potential equity issues, transportation adaptation investments should place a priority on the communities and households with the greatest need. California's climate adaptation strategy, for example, recognizes the importance of prioritizing protection of at-risk populations, stating that "[s]teps need to be taken to identify these

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[169] U.S. DEP'T OF TRANSP., *supra* note 97, at 3.
[170] For example, California's adaptation plan notes that Caltrans is working "to update drainage design criteria to consider potential sea level rise in conjunction with flooding events and high tides to ensure bridge and culvert infrastructure (in coastal areas) can adequately facilitate the movement of water under the highway without flooding the roadway." CAL. NATURAL RES. AGENCY , *supra* note 108, at 222.
[171] *See, e.g.*, MYRON ORFIELD, METROPOLITICS: A REGIONAL AGENDA FOR COMMUNITY AND STABILITY 5–9 (1997).
[172] *See* discussion accompanying notes 81–83.
[173] Kaswan, *supra* note 81, at 11126.
[174] *Id.* at 11127.

vulnerable populations and to ensure that California's most vulnerable people have access to information, services and resources to prepare and respond to climate risks."[175]

G. Capture Multiple Benefits

Certain adaptation measures provide important economic, health, social, or environmental benefits while reducing climate risk. Priority should be given to transportation adaptation steps that offer multiple benefits.

For one thing, providing a broader range of transportation choices can improve the overall resilience of a transportation system by offering redundancy that can aid in evacuation and subsequent repair if other parts of the system are impacted by an extreme weather event. If a road washes out in a heavy rainstorm, the availability of transit and rail service may enable people to get to work, to a store, or to a doctor by other routes or modes.[176] In addition to its adaptation benefits, building a more diverse transportation system that includes these cleaner, more fuel efficient options offers benefits such as reduced air pollution, less dependence on foreign oil, and enhanced mobility for elderly, young, and low income individuals who may not own a car or be able to drive.

Further, various transportation adaptation measures can provide additional environmental benefits. For instance, maintaining slopes along a road with vegetation to reduce flooding, building bioswales and bioretention systems using vegetation and soils to channel the flow of water away from a highway and collect it, or using planter boxes and trees along streets to store and absorb water all can improve water quality by capturing and filtering polluted runoff from roads.[177] Conserving and restoring forests, wetlands, and other natural areas can help protect adjacent transportation infrastructure from flooding, while at the same time reducing air and water pollution and providing wildlife habitat.[178]

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[175] CAL. NATURAL RES. AGENCY, *supra* note 108, at 12.

[176] EPA OFFICE OF SUSTAINABLE COMMUNITIES, SMART GROWTH PROGRAM, USING SMART GROWTH STRATEGIES TO CREATE MORE RESILIENT COMMUNITIES IN THE WASHINGTON, D.C., REGION 16, *available at* http://www.epa.gov/smartgrowth/pdf/mwcog-guidebook-final-508-111313.pdf.

[177] EPA's Green Infrastructure website has links to a host of publications exploring the water quality benefits of these and other measures, as well as descriptions and links to green infrastructure policies and projects nationwide. *See* http://water.epa.gov/infrastructure/greeninfrastructure, *archived at* http://perma.cc/59TJ-NKKM.

[178] *Id.*

Perhaps most importantly, transportation adaptation measures can act as mitigation measures as well. Forests and wetlands that are protected or restored to reduce flooding, for example, can also absorb and retain carbon. Providing cleaner transportation choices such as transit and rail to improve the overall resilience of a system reduces greenhouse gas emissions, and as the Supreme Court has recognized, the "United States transportation sector emits an enormous quantity of carbon dioxide into the atmosphere."[179] Adaptation measures that can reduce greenhouse gas emissions should be prioritized given the pressing need to curb these emissions and since adaptation costs will increase and be less likely to succeed unless emissions are reduced.

CONCLUSION

Climate change presents a substantial threat to transportation. The impacts of climate change are already being felt, and the risks are growing. Mitigation efforts to curb greenhouse gas emissions are essential, but the problems are now so significant that adaptation efforts are required as well. There are abundant opportunities, however, to transform transportation by reorienting policies and investments. Action is urgently needed to capitalize upon these opportunities and to address climate risk while moving to a more sustainable, more equitable transportation system.

[179] Massachusetts v. EPA, 549 U.S. at 524.