11 Built Environment, Urban Systems, and Cities

Federal Coordinating Lead Author
Susan Julius
U.S. Environmental Protection Agency

Chapter Lead
Keely Maxwell
U.S. Environmental Protection Agency

Chapter Authors
Anne Grambsch
U.S. Environmental Protection Agency (Retired)

Ann Kosmal
U.S. General Services Administration

Libby Larson
National Aeronautics and Space Administration

Nancy Sonti
U.S. Forest Service

Review Editor
Jesse Keenan
Harvard University

Technical Contributors are listed at the end of the chapter.

Recommended Citation for Chapter

Maxwell, K., S. Julius, A. Grambsch, A. Kosmal, L. Larson, and N. Sonti, 2018: Built Environment, Urban Systems, and Cities. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 438–478. doi: 10.7930/NCA4.2018.CH11

On the Web: https://nca2018.globalchange.gov/chapter/built-environment

11 Built Environment, Urban Systems, and Cities

Cleveland, Ohio

Key Message 1

Impacts on Urban Quality of Life

The opportunities and resources in urban areas are critically important to the health and well-being of people who work, live, and visit there. Climate change can exacerbate existing challenges to urban quality of life, including social inequality, aging and deteriorating infrastructure, and stressed ecosystems. Many cities are engaging in creative problem solving to improve quality of life while simultaneously addressing climate change impacts.

Key Message 2

Forward-Looking Design for Urban Infrastructure

Damages from extreme weather events demonstrate current urban infrastructure vulnerabilities. With its long service life, urban infrastructure must be able to endure a future climate that is different from the past. Forward-looking design informs investment in reliable infrastructure that can withstand ongoing and future climate risks.

Key Message 3

Impacts on Urban Goods and Services

Interdependent networks of infrastructure, ecosystems, and social systems provide essential urban goods and services. Damage to such networks from current weather extremes and future climate will adversely affect urban life. Coordinated local, state, and federal efforts can address these interconnected vulnerabilities.

Key Message 4

Urban Response to Climate Change

Cities across the United States are leading efforts to respond to climate change. Urban adaptation and mitigation actions can affect current and projected impacts of climate change and provide near-term benefits. Challenges to implementing these plans remain. Cities can build on local knowledge and risk management approaches, integrate social equity concerns, and join multicity networks to begin to address these challenges.

Executive Summary

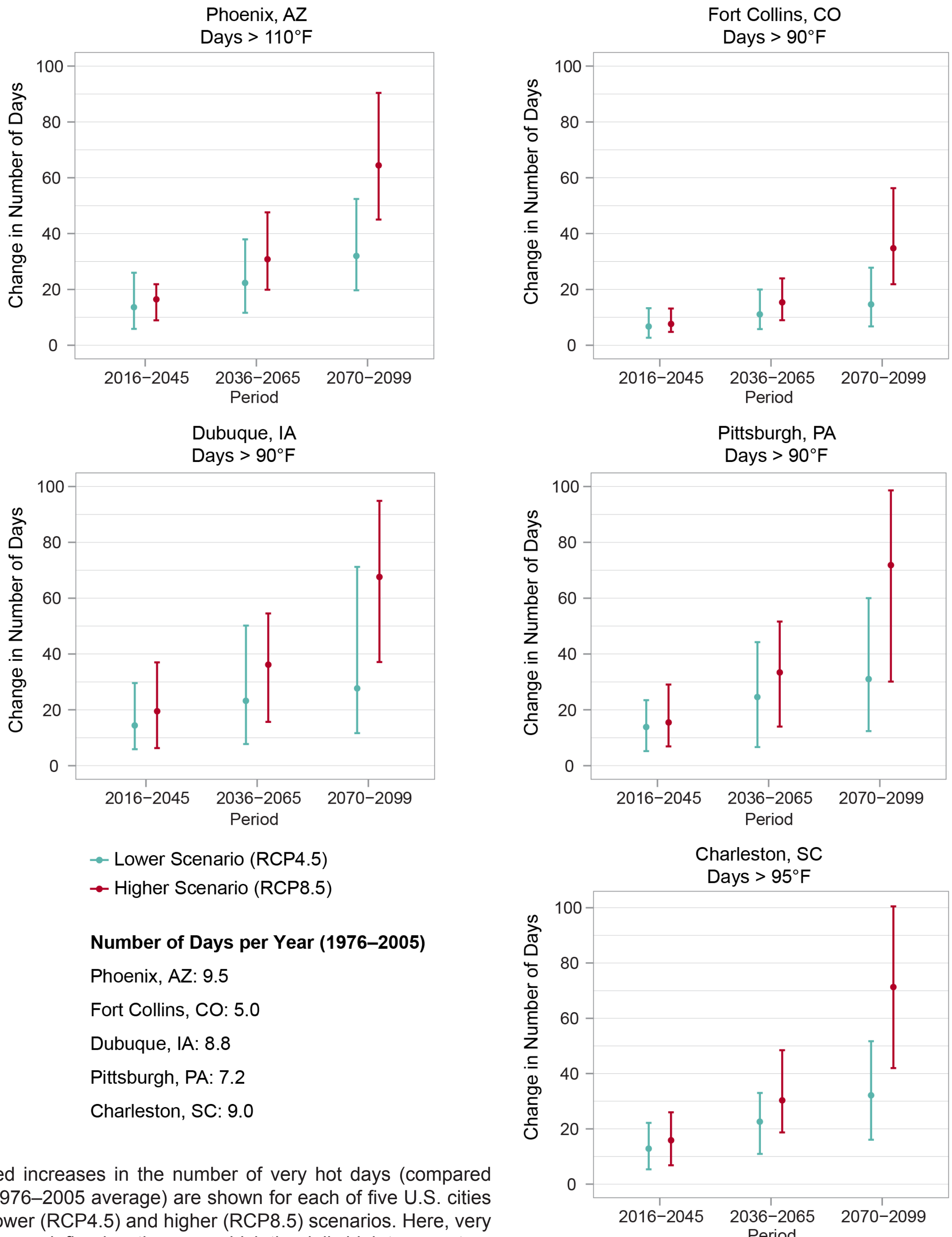
Urban areas, where the vast majority of Americans live, are engines of economic growth and contain land valued at trillions of dollars. Cities around the United States face a number of challenges to prosperity, such as social inequality, aging and deteriorating infrastructure, and stressed ecosystems. These social, infrastructure, and environmental challenges affect urban exposure and susceptibility to climate change effects.

Urban areas are already experiencing the effects of climate change. Cities differ across regions in the acute and chronic climate stressors they are exposed to and how these stressors interact with local geographic characteristics. Cities are already subject to higher surface temperatures because of the urban heat island effect, which is projected to get stronger. Recent extreme weather events reveal the vulnerability of the built environment (infrastructure such as residential and commercial buildings, transportation, communications, energy, water systems, parks, streets, and landscaping) and its importance to how people live, study, recreate, and work.

Heat waves and heavy rainfalls are expected to increase in frequency and intensity. The way city residents respond to such incidents depends on their understanding of risk, their way of life, access to resources, and the communities to which they belong. Infrastructure designed for historical climate trends is vulnerable to future weather extremes and climate change. Investing in forward-looking design can help ensure that infrastructure performs acceptably under changing climate conditions.

Urban areas are linked to local, regional, and global systems. Situations where multiple climate stressors simultaneously affect multiple city sectors, either directly or through system connections, are expected to become more common. When climate stressors affect one sector, cascading effects on other sectors increase risks to residents' health and well-being. Cities across the Nation are taking action in response to climate change. U.S. cities are at the forefront of reducing greenhouse gas emissions and many have begun adaptation planning. These actions build urban resilience to climate change.

Projected Change in the Number of Very Hot Days



Projected increases in the number of very hot days (compared to the 1976–2005 average) are shown for each of five U.S. cities under lower (RCP4.5) and higher (RCP8.5) scenarios. Here, very hot days are defined as those on which the daily high temperature exceeds a threshold value specific to each of the five U.S. cities shown. Dots represent the modeled median (50th percentile) values, and the vertical bars show the range of values (5th to 95th percentile) from the models used in the analysis. Modeled historical values are shown for the same temperature thresholds, for the period 1976–2005, in the lower left corner of the figure. These and other U.S. cities are projected to see an increase in the number of very hot days over the rest of this century under both scenarios, affecting people, infrastructure, green spaces, and the economy. Increased air conditioning and energy demands raise utility bills and can lead to power outages and blackouts. Hot days can degrade air and water quality, which in turn can harm human health and decrease quality of life. *From Figure 11.2 (Sources: NOAA NCEI, CICS-NC, and LMI).*

Introduction

Recent extreme weather events reveal the vulnerability of the built environment (infrastructure, such as residential and commercial buildings, transportation, communications, energy, water systems, parks, streets, and landscaping) and its importance to how people live, study, recreate, and work in cities. This chapter builds on previous assessments of urban social vulnerability and climate change impacts on urban systems.[1,2,3] It discusses recent science on urban social and ecological systems underlying vulnerability, impacts on urban quality of life and well-being, and urban adaptation. It also reviews the increase in urban adaptation activities, including investment, design, and institutional practices to manage risk. Examples of climate impacts and responses from five cities (Charleston, South Carolina; Dubuque, Iowa; Fort Collins, Colorado; Phoenix, Arizona; and Pittsburgh, Pennsylvania) illustrate the diversity of American cities and the climate risks they face.

State of the Sector

Urban areas in the United States, where the vast majority of Americans live, are engines of economic growth and contain land valued at trillions of dollars. In 2015, nearly 275 million people (about 85% of the total U.S. population) lived in metropolitan areas, and 27 million (about 8%) lived in smaller micropolitan areas.[4] Metropolitan areas accounted for approximately 91% of U.S. gross domestic product (GDP) in 2015, with over 23% coming from the five largest cities alone.[5] Urban land values are estimated at more than two times the 2006 national GDP.[6] Urbanization trends are expected to continue (Figure 11.1), and projections suggest that between 425 and 696 million people will live in metropolitan and micropolitan areas combined by 2100.[7] All of these factors affect how urban areas respond to climate change.

Cities around the United States face a number of challenges to prosperity, such as social inequality, aging and deteriorating infrastructure, and stressed ecosystems. Urban social inequality is evident in disparities in per capita income, exposure to violence and environmental hazards, and access to food, services, transportation, outdoor space, and walkable neighborhoods.[9,10,11,12] Cities are connected by networks of infrastructure, much of which is in need of repair or replacement. Failing to address aging and deteriorating infrastructure is expected to cost the U.S. GDP as much as $3.9 trillion (in 2015 dollars) by 2025.[13] Current infrastructure and building design standards do not take future climate trends into account.[14] Urbanization affects air, water, and soil quality and increases impervious surface cover (such as cement and asphalt).[15,16,17] Urban forests, open space, and waterways provide multiple benefits, but many are under stress because of land-use change, invasive species, and pollution.[18] These social, infrastructure, and environmental challenges affect urban exposure and susceptibility to climate change effects.

Urban areas, where the majority of the U.S. population lives and most consumption occurs, are the source of approximately 80% of North American human-caused greenhouse gas (GHG) emissions, despite only occupying 1%–5% of the land. Therefore, changes to urban activities can have a significant impact on national GHG emissions.[19] Land use and land-cover change contribute to radiative forcing, and infrastructure design can lock in fossil fuel dependency, so urban development patterns will continue to affect carbon sources and sinks in the future (Ch. 5: Land Changes).[19,20,21] Many cities in the United States are working to reduce their GHG emissions and can be key leverage points in mitigation efforts.

Current and Projected U.S. Population

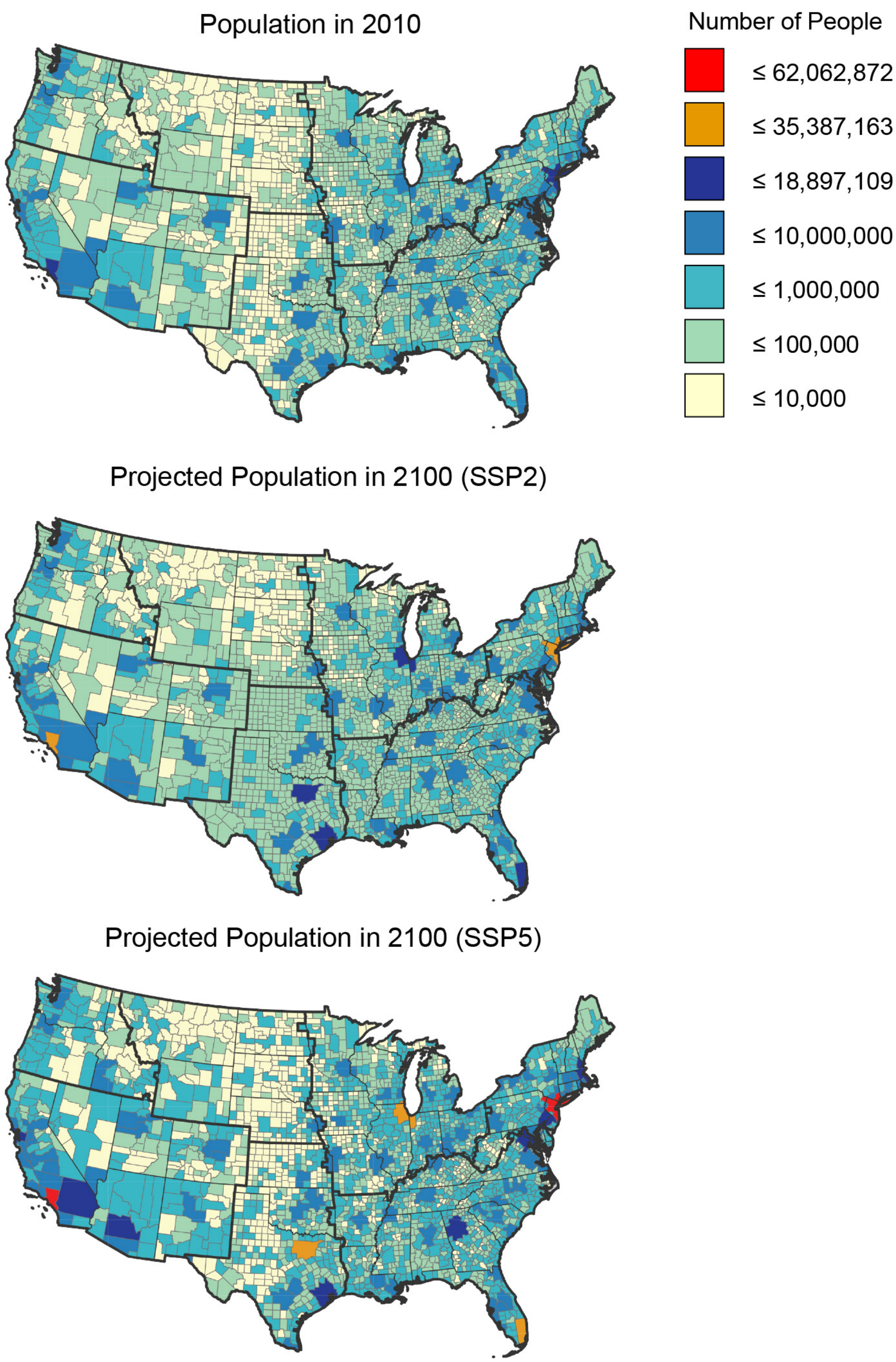


Figure 11.1: These maps show current population along with population projections by county for the year 2100. Projected populations are based on Shared Socioeconomic Pathways (SSPs)—a collection of plausible future pathways of socioeconomic development.[8] The middle map is based on demography consistent with the SSP2, which follows a middle-of-the-road path where trends do not shift markedly from historical patterns. The bottom map uses demography consistent with SSP5, which follows a more rapid technical progress and resource-intensive development path. Increasing urban populations pose challenges to planners and city managers as they seek to maintain and improve urban environments. Data are unavailable for the U.S. Caribbean, Alaska, and Hawai'i & U.S.-Affiliated Pacific Islands regions. Source: EPA

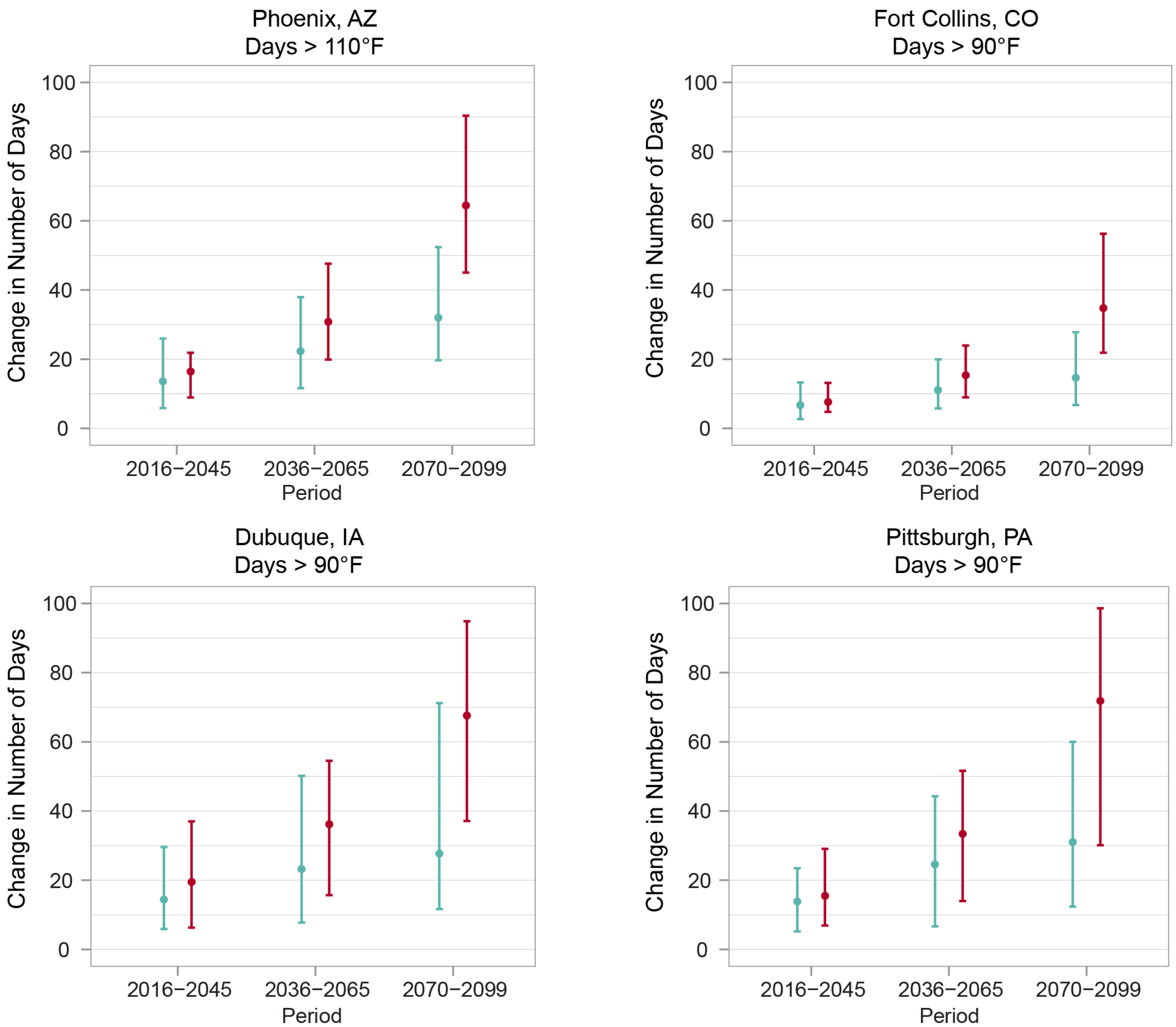
Regional Summary

Urban areas in the United States are already experiencing the effects of climate change. Across regions, U.S. cities differ in the acute and chronic climate stressors they are exposed to and how these stressors interact with local geographic characteristics.[1] In coastal areas, the built environment is subject to storm surge, high tide flooding, and saltwater intrusion (Ch. 8: Coastal, KM 1). Wildfires are on the rise in the West, lowering air quality and damaging property in cities near the wildland–urban interface (Ch. 6: Forests, KM 1; Ch. 13: Air Quality, KM 2; Ch. 14: Human Health, KM 1; Ch. 24: Northwest, KM 3; Ch. 25: Southwest, KM 2). In 2017, Los Angeles witnessed the largest wildfire in its history, with over 700 residents ordered to evacuate. The fire began during a heat wave and burned over 7,100 acres.[22] Key climate threats in the Northeast, on the other hand, are from precipitation and flooding: between 2007 and 2013, Pittsburgh experienced 11 significant flash flooding events[23,24] (Ch. 18: Northeast, KM 3). Heat waves (Figure 11.2) and heavy rainfalls (Figure 11.3) are expected to increase in frequency and intensity (Ch. 2: Climate KM 2 and 5).[25,26,27] The way city residents respond to such incidents depends on their understanding of risk, their way of life, access to resources, and the communities to which they belong.[28]

In other parts of the country, drought conditions coupled with extreme heat increase wildfire risk, and rainfall after wildfires raises flood risks.[21] In 2012 and 2013, fires destroyed hundreds of homes in the Fort Collins area of the Northern Great Plains region. In those same years, floods washed out transportation infrastructure and caused $2 billion (in 2013 dollars) in total damages.[34,35]

Despite these differences, U.S. cities experience some climate impacts in similar ways. For example, prolonged periods of high heat affect urban areas around the country.[21] Cities are already subject to higher surface temperatures because of the urban heat island (UHI) effect, which can also affect regional climate.[29] The UHI is projected to get stronger with climate change.[29] Another commonality is that most cities are subject to more than one climate stressor. Exposure to multiple climate impacts at once affects multiple urban sectors, and the results can be devastating.[30] Over a four-day period in 2015, the coastal city of Charleston in the Southeast region experienced extreme rainfall, higher sea levels, and high tide flooding. These impacts combined to cause dam failures, bridge and road closures, power outages, damages to homes and businesses, and a near shutdown of the local economy (Ch. 19: Southeast, KM 2).[31,32,33] These kinds of incidents are expected to continue as climate change brings a higher number of intense hurricanes, high tide flooding, and accelerated sea level rise (Ch. 8: Coastal, KM 1).[21]

Projected Change in the Number of Very Hot Days



- Lower Scenario (RCP4.5)
- Higher Scenario (RCP8.5)

Number of Days per Year (1976–2005)

Phoenix, AZ: 9.5

Fort Collins, CO: 5.0

Dubuque, IA: 8.8

Pittsburgh, PA: 7.2

Charleston, SC: 9.0

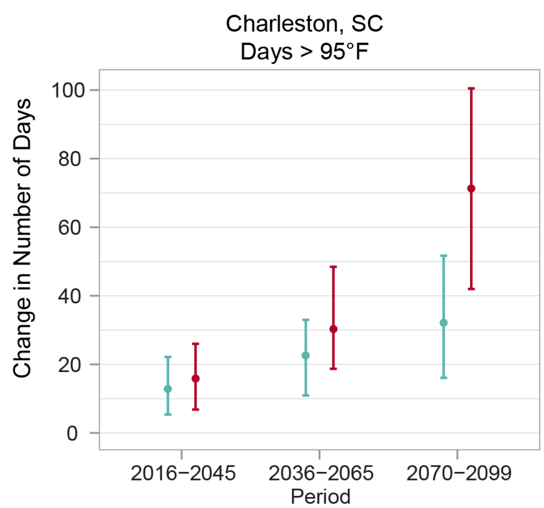
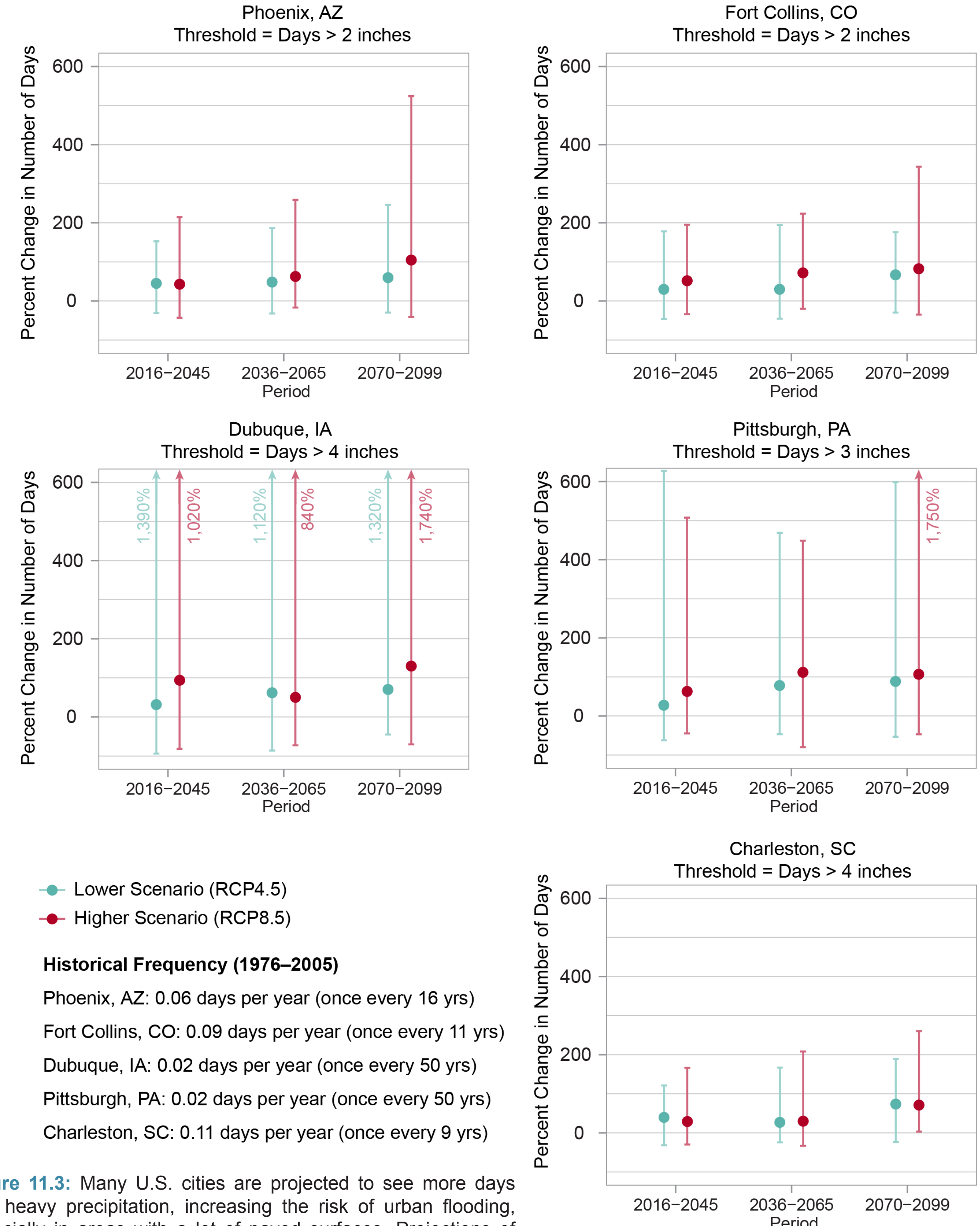


Figure 11.2: Projected increases in the number of very hot days (compared to the 1976–2005 average) are shown for each of five U.S. cities under lower (RCP4.5) and higher (RCP8.5) scenarios. Here, very hot days are defined as those on which the daily high temperature exceeds a threshold value specific to each of the five U.S. cities shown. Dots represent the modeled median (50th percentile) values, and the vertical bars show the range of values (5th to 95th percentile) from the models used in the analysis. Modeled historical values are shown for the same temperature thresholds, for the period 1976–2005, in the lower left corner of the figure. These and other U.S. cities are projected to see an increase in the number of very hot days over the rest of this century under both scenarios, affecting people, infrastructure, green spaces, and the economy. Increased air conditioning and energy demands raise utility bills and can lead to power outages and blackouts. Hot days can degrade air and water quality, which in turn can harm human health and decrease quality of life. Sources: NOAA NCEI, CICS-NC, and LMI.

Projected Change in the Number of Days with Heavy Precipitation



Historical Frequency (1976–2005)

Phoenix, AZ: 0.06 days per year (once every 16 yrs)

Fort Collins, CO: 0.09 days per year (once every 11 yrs)

Dubuque, IA: 0.02 days per year (once every 50 yrs)

Pittsburgh, PA: 0.02 days per year (once every 50 yrs)

Charleston, SC: 0.11 days per year (once every 9 yrs)

Figure 11.3: Many U.S. cities are projected to see more days with heavy precipitation, increasing the risk of urban flooding, especially in areas with a lot of paved surfaces. Projections of percent changes in the number of days with heavy precipitation (compared to the 1976–2005 average) are shown for each of five U.S. cities under lower (RCP4.5) and higher (RCP8.5) scenarios. Here, days with heavy precipitation are defined as those on which the amount of total precipitation exceeds a threshold value specific to each city. Dots represent the modeled median (50th percentile) values, and the vertical bars show the range of values (5th to 95th percentile) from the models used in the analysis. Modeled historical values are shown for the same thresholds, for the period 1976–2005, in the lower left corner of the figure. Historical values are given in terms of frequency (days per year) and return period (average number of years between events). Sources: NOAA NCEI, CICS-NC, and LMI.

Another similarity cities share is that when climate stressors affect one city sector, cascading effects on other sectors increase risks to residents' health and well-being (Ch. 17: Complex Systems). Higher temperatures can increase energy loads, which in turn can lead to structural failures in energy infrastructure, raise energy bills, and increase the occurrence of power outages (Ch. 4: Energy, KM 1). These changes strain household budgets, increase people's exposure to heat, and limit the delivery of medical and social services. For all cities, the duration of exposure to a climate stressor determines the degree of impacts. In recent years in the Southwest region, California experienced exceptional drought conditions. Urban and rural areas saw forced water reallocations and mandatory water-use reductions. Utilities had to cut back on electricity production from hydropower because of insufficient surface water flows and water in surface reservoirs (Ch. 25: Southwest, KM 1 and 5).[36,37,38]

Urban areas are linked to local, regional, and global systems.[39,40,41] For example, changes in regional food production and global trade affect local food availability.[42] Likewise, urban electricity supply often relies on far-off reservoirs, generators, and grids. Situations where multiple climate stressors simultaneously affect multiple city sectors, either directly or through system connections, are expected to become more common.[12,43,44]

Cities in all regions of the country are undertaking adaptation and mitigation actions. Several cities have climate action plans in place (see Bierbaum et al. 2013 for a review of U.S. urban adaptation plans[45]). Pittsburgh made commitments to reduce GHG emissions. Fort Collins initiated the Fort Collins ClimateWise Program. Phoenix is taking measures to reduce the UHI effect. These actions build urban resilience to climate change.

Key Message 1

Impacts on Urban Quality of Life

The opportunities and resources in urban areas are critically important to the health and well-being of people who work, live, and visit there. Climate change can exacerbate existing challenges to urban quality of life, including social inequality, aging and deteriorating infrastructure, and stressed ecosystems. Many cities are engaging in creative problem solving to improve quality of life while simultaneously addressing climate change impacts.

Cities are places where people learn, socialize, recreate, work, and live together. Quality of life for urban residents is associated with social and economic diversity, livelihood opportunities, and access to education, nature, recreation, healthcare, arts, and culture. Urban areas can foster economic prosperity and a sense of place. Yet, many cities in the United States face challenges to prosperity, including social inequality, aging and deteriorating infrastructure, and stressed ecosystems (Ch. 18: Northeast, KM 3).[13,18,46] These problems are intertwined. Climate change impacts exacerbate existing challenges to urban quality of life and adversely affect urban health and well-being.

Urban populations experiencing socioeconomic inequality or health problems have greater exposure and susceptibility to climate change.[12,47] Climate susceptibility varies by neighborhood, housing situation, age, occupation, and daily activities. People without access to housing with sufficient insulation and air conditioning (for example, renters and the homeless) have greater exposure to heat stress. Children playing outside, seniors living alone, construction workers, and athletes are also vulnerable to extreme heat (Figure 11.4).[12,48]

Threats from Extreme Heat

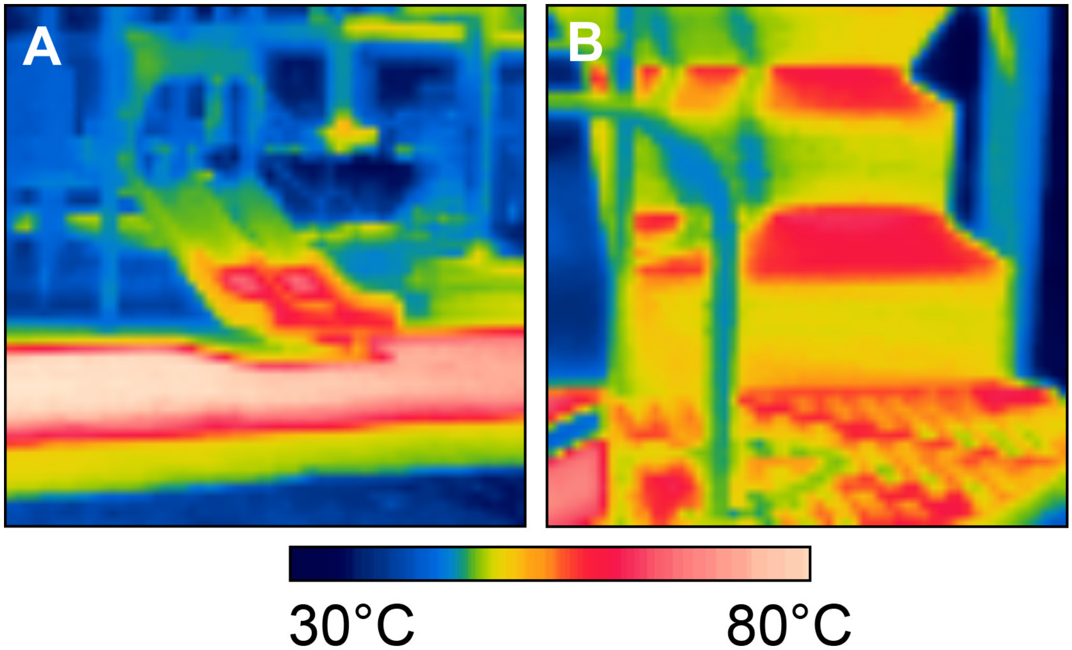


Figure 11.4: These images show surface temperatures of playground equipment in metropolitan Phoenix, Arizona. Children are particularly susceptible to high heat[12] and can be exposed through daily activities. (A) A slide and dark rubber surface in the sun (orange/red colors) are shown reaching temperatures of 71°C (160°F) and 82°C (180°F), respectively. The blue/green colors are under a shade sail. (B) Playground steps made of black powder-coated metal are shown reaching a temperature of 58°C (136°F) in the direct sunlight. Images use infrared thermography and were taken mid-day on September 15, 2014. Credit: Vanos et al. 2016.[49]

In addition to temperature extremes, climate change adversely affects urban population health through air and water quality and vector-borne diseases (Ch. 14: Human Health, KM 1). Urban residents feel economic impacts from food price volatility and the costs of insurance, energy, and water.[12,50] Climate change also threatens the integrity of personal property, ecosystems, historic landmarks, playgrounds, and cultural sites such as libraries and museums, all of which support an urban sense of place and quality of life (Ch. 24: Northwest, KM 2).[51,52,53] For example, historic landmarks in Charleston are at risk from sea level rise.[54] Urban ecosystems are further stressed by often unpredictable climate-related changes to tree species ranges, water cycles, and pest regimes.[55]

Coastal city flooding can result in forced evacuation, adversely affecting family and community stability, as well as mental and physical health (Ch. 14: Human Health, KM 1).[12] It also poses significant challenges to inland urban areas receiving these populations.[56,57] Many cities are undertaking creative problem solving to address climate change impacts and quality of life. They use approaches from urban design, sustainability, and climate justice.[58,59,60] For example, New York City's Trees for Public Health program targets street tree planting in neighborhoods of greatest need to improve the UHI effect, asthma rates, crime rates, and property values.[61]

Key Message 2

Forward-Looking Design for Urban Infrastructure

Damages from extreme weather events demonstrate current urban infrastructure vulnerabilities. With its long service life, urban infrastructure must be able to endure a future climate that is different from the past. Forward-looking design informs investment in reliable infrastructure that can withstand ongoing and future climate risks.

Urban infrastructure needs to perform reliably throughout its long service life. Infrastructure designed for historical climate trends is more vulnerable to future weather extremes and climate change. Impacts include changes in building enclosure vapor drive, energy performance, and corrosion of structures.[14,62] Above- and below-grade transportation systems are at increased risk from flooding and degradation that reduce expected service life (Ch. 12: Transportation, KM 1). Higher temperatures increase stress on cooling systems to perform as designed. High indoor temperatures reduce thermal comfort and office worker productivity, potentially requiring building closures. Over time, sea level rise and flooding are expected to destroy, or make unusable, properties and public infrastructure in many U.S. coastal cities (Ch. 8: Coastal, KM 1). Investor costs increase when infrastructure is degraded, damaged, or abandoned ahead of its anticipated useful life.[63,64]

Damages from extreme weather events demonstrate existing infrastructure vulnerabilities. Long-term, gradual risks such as sea level rise further exacerbate these vulnerabilities. Current levels of infrastructure investment in the United States are not enough to cover needed repairs and replacement.[13]

Infrastructure age and disrepair make failure or interrupted service from extreme weather even more likely.[13] Heavy rainfall during Arizona's 2014 monsoon season shut down freeways and city streets in Phoenix because key pumping stations failed.[65] Climate change has already altered the likelihood and intensity of some extreme events, and there is emerging evidence that many types of extreme events will increase in intensity, duration, and frequency in the future.[27,66,67,68,69] Projecting specific changes in extreme events in particular places remains a challenge.

Costs are felt nationally as business operations, production inputs, and supply chains are affected.[70,71] Higher temperatures reduce labor productivity in construction and other outdoor industries.[12,44,72,73] Upgrades to buildings and the electrical grid are needed to handle higher temperatures.[74,75,76] Risk portfolios in the housing finance, municipal bond, and insurance industries may need to be adjusted.[44,72,77] Forward-looking design and risk management approaches support the achievement of design and investment performance goals.[78,79,80,81]

Incorporating climate projections into infrastructure design, investment and appraisal criteria, and model building codes is uncommon.[82,83,84,85,86,87,88,89] Standardized methodologies do not exist,[62,90,91,92] and the incorporation of climate projections is not required in the education or licensing of U.S. design, investment, or appraisal professionals.[80,93,94,95] Building codes and rating systems tend to be focused on current short-term, extreme weather. Investment and design standards, professional education and licensing, building codes, and zoning that use forward-looking design can protect urban assets and limit investor risk exposure.[83,96,97,98]

A handful of cities have begun to take a longer-term view toward planning.[99,100,101]

These cities have developed adaptation plans, resilience guidelines, and risk-informed frameworks. However, they do not yet have a portfolio of completed projects.[59,102] Adaptation planning is not always informed by technical analysis of changing hazards, climate vulnerability assessments, and monitoring and control systems.[79] U.S. cities can examine methods and learn from completed projects, such as those developed by Engineers Canada and UKCIP Design for Future Climate.[62,90] Managing climate risks promotes the integrity, efficiency, and safety of infrastructure to ensure reliable performance over the infrastructure's service life.[14,81]

Flash Flooding Impacts Urban Infrastructure and Well-Being

Figure 11.5: Flash flooding overwhelmed drainage systems and swamped roadways in Pittsburgh, Pennsylvania, in 2011. The flooding disrupted businesses and commutes, damaged homes, and caused four deaths. Photo credit: *Pittsburgh Post-Gazette*.

Key Message 3

Impacts on Urban Goods and Services

Interdependent networks of infrastructure, ecosystems, and social systems provide essential urban goods and services. Damage to such networks from current weather extremes and future climate will adversely affect urban life. Coordinated local, state, and federal efforts can address these interconnected vulnerabilities.

The essential goods and services that form the backbone of urban life are increasingly vulnerable to climate change. Cities are hubs of production and consumption of goods, and they are enmeshed in regional-to-global supply chains. They rely on local services and interdependent networks for telecommunications, energy, water, healthcare, transportation, and more (Ch. 4: Energy, KM 1; Ch. 3: Water, KM 1; Ch. 14: Human Health, KM 2; Ch. 12: Transportation, KM 2; Ch. 17: Complex Systems, KM 1). Gradual and abrupt climate changes disrupt the flow of these goods and services.[44] For example, the 2012 High Park Fire in Colorado had wide-reaching impacts on air and water quality. The city of Fort Collins experienced air quality that was seven times worse than the daily average (Ch. 13: Air Quality, KM 2).[103] Storms washed ash and debris into the Cache la Poudre River, polluting the city's drinking water source for residents and industries.[104] In another example, two inches of rain fell in a single hour in Pittsburgh in August 2011. Four people died in the resulting flash flood. Impervious surfaces and combined sewer systems contribute to urban flash flooding risks (Figure 11.5).[105] For similar examples of cascading impacts, see Chapter 17: Complex Systems, Box 17.1 on Hurricane Harvey and Box 17.5 on the 2003 Northeast Blackout.

Cascading Consequences of Heavy Rainfall for Urban Systems

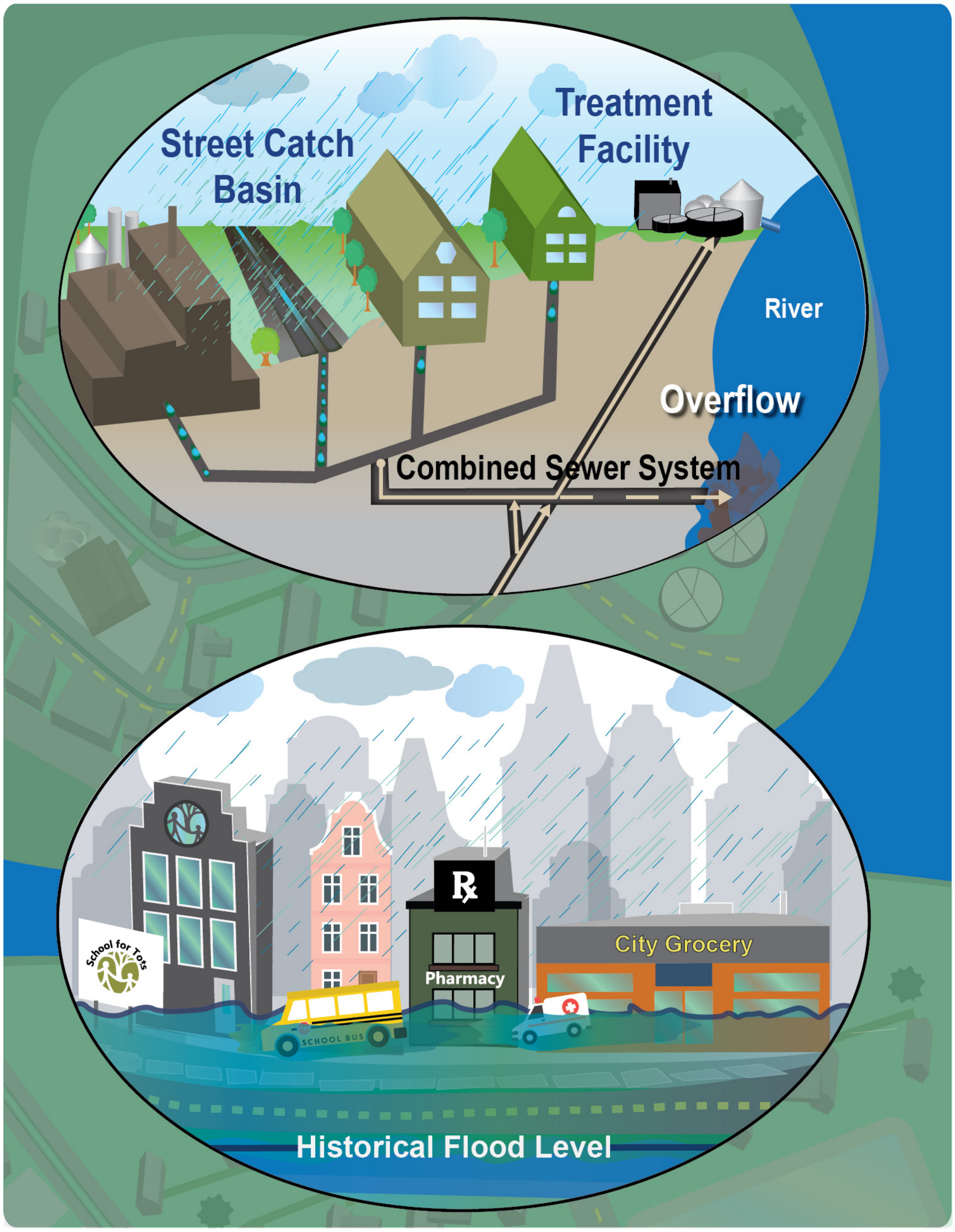


Figure 11.6: With heavy downpours increasing nationally, urban areas experience costly impacts. (top) In cities with combined sewer systems, storm water runoff flows into pipes containing sewage from homes and industrial wastewater. Intense rainfall can overwhelm the system so untreated wastewater overflows into rivers. Overflows are a water pollution concern and increase risk of exposure to waterborne diseases. (bottom) Intense rainfall can also result in localized flooding. Closed roads and disrupted mass transit prevent residents from going to work or school and first responders from reaching those in need. Home and commercial property owners may need to make costly repairs, and businesses may lose revenue. Source: EPA.

Figure 11.6 describes how heavy rainfalls, which are projected to increase with climate change, can disrupt the flow of goods and services to urban residents through increased runoff and localized flooding.

As interconnections among sectors increase, urban areas are more vulnerable to disruptions.[106] For example, energy and water systems are closely intertwined (Ch. 3: Water; Ch. 4: Energy; Ch.17: Complex Systems). Both higher water temperatures and extreme weather that causes power outages affect urban drinking water treatment and distribution. Higher air temperatures increase urban energy demand for cooling and water demand for landscaping. Elevated water temperatures affect cooling for electricity production. Higher river temperatures during periods of low flow can require power plants to shut down or curtail power generation to stay within defined regulatory temperature limits. Higher energy loads raise the risk of power outages. Flooding can drown electrical substations. Disruptions to water and power supplies can result in problems—such as unsafe drinking water, limited access to money systems, no functioning gas stations, few available modes of transportation, no air conditioning or heating, and limited ability to communicate with others—that pose risks to urban dwellers.

Climate change also threatens food security in urban areas.[107,108] Loss of electricity from extreme weather leads to food spoilage. Transportation disruptions along the supply chain limit food mobility. Heat effects on agricultural labor impact product availability. Changes to the food supply generally lead to price volatility and food shortages, affecting household budgets and nutrition, cultural foodways, and food service profits. Urban populations who already experience food insecurity are likely to be affected the most.

Targeted coordination that addresses interconnected vulnerabilities can build urban resilience to climate change.[109,110,111] Coordination may involve municipal offices, public–private partnerships, or state and local agencies. The Charleston Resilience Network, for example, brought together public safety and health services, business organizations, and the state transportation department to discuss their performance during the region's October 2015 floods and to identify best practices to improve resilience.[112]

Key Message 4

Urban Response to Climate Change

Cities across the United States are leading efforts to respond to climate change. Urban adaptation and mitigation actions can affect current and projected impacts of climate change and provide near-term benefits. Challenges to implementing these plans remain. Cities can build on local knowledge and risk management approaches, integrate social equity concerns, and join multicity networks to begin to address these challenges.

Cities across the United States are taking action in response to climate change for a number of reasons: recent extreme weather events, available financial resources, motivated leaders, and the goal of achieving co-benefits.[113,114,115,116] One strategy being used is to mainstream adaptation and mitigation into land-use, hazard mitigation, development, and capital investment planning.[45,115,117] Municipal departments from public works to transportation play roles, as do water and energy utilities, professional societies, school boards, libraries, businesses, emergency responders, museums, healthcare systems, philanthropies, faith-based organizations, nongovernmental organizations, and residents. City governments use a variety of policy mechanisms to achieve adaptation and mitigation goals. They adopt building codes, prioritize green purchasing, enact energy conservation measures, modify zoning, and buy out properties in floodplains. Nongovernmental stakeholders take action through voluntary protocols, rating systems, and public–private partnerships, among other strategies.

U.S. cities are at the forefront of reducing greenhouse gas (GHG) emissions (Ch. 29: Mitigation, KM 1). Urban mitigation actions include acquiring high-performance vehicle fleets and constructing energy efficient buildings. A number of cities are conducting GHG inventories to inform decisions and make commitments to reduce their emissions. Comprehensive urban carbon management involves decisions at many levels of governance.[19]

Many U.S. cities have also begun adaptation planning. A common approach is to enhance physical protection of urban assets from extreme weather. For example, protection against sea level rise and flooding can involve engineering (such as seawalls and pumps) and ecological solutions (such as wetlands and mangroves) (Ch. 8: Coastal, KM 2).[118] Green infrastructure lowers flood risk by reducing impervious surfaces and improving storm water infiltration into the ground.[72,119] Green roofs use rooftop vegetation to absorb rainfall. Urban drainage systems can be upgraded to handle increased runoff.[72] Climate-resilient building and streetscape design reduces exposure to high temperatures through tree canopy cover and cool roofs with high albedo that reflect sunlight. Ensuring that critical urban infrastructure, such as drinking water systems, continues to provide services through floods or droughts involves a combination of technology, physical protection, and outreach (Ch. 3: Water, KM 3; Ch. 19: Southeast, KM 1).[120,121,122]

Social and institutional changes are central to urban responses to climate change (Figure 11.7).[59,114] Urban development patterns reflect social, economic, and political inequities. As such,

Urban Adaptation Strategies and Stakeholders

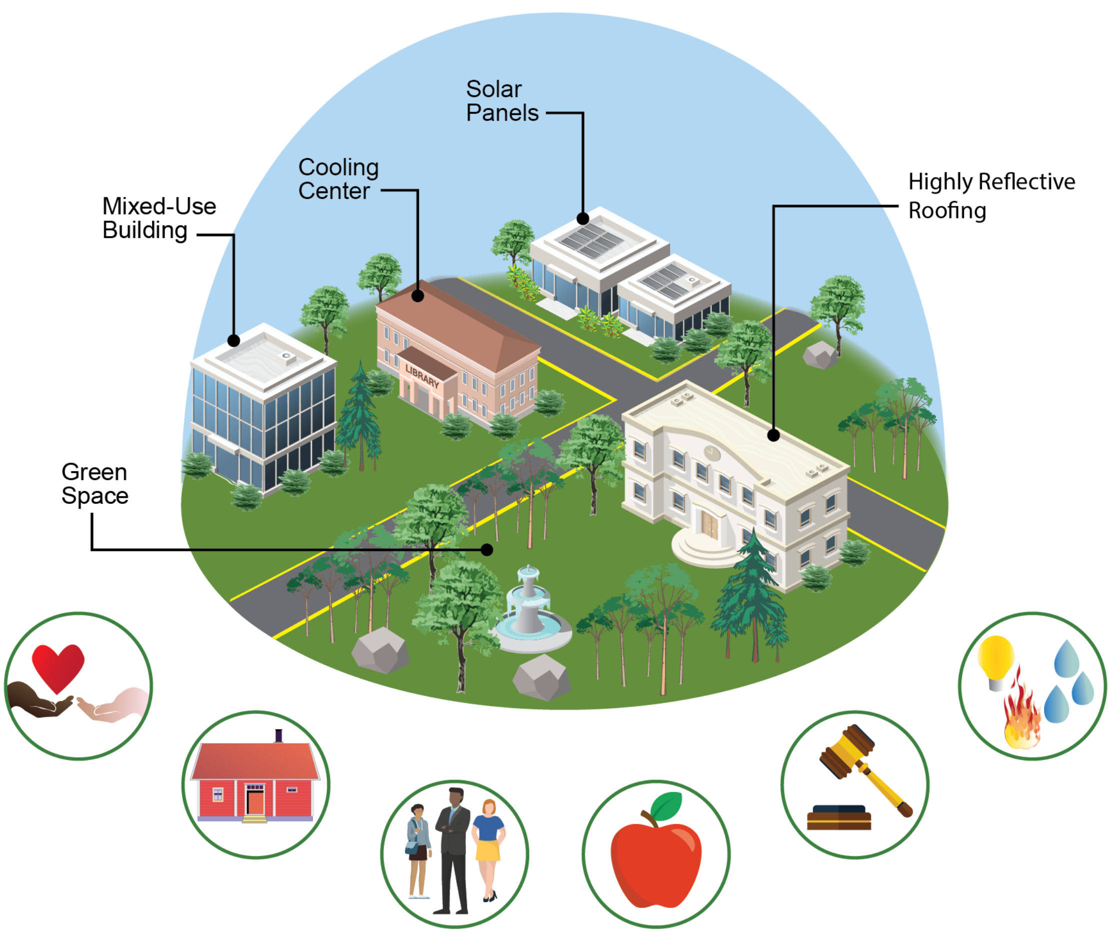


Figure 11.7: Protecting vulnerable people and places from the impacts of climate change involves infrastructure design (for example, green space and highly reflective roofing), along with social and institutional change (such as designating cooling centers). Social equity is supported by widespread participation in adaptation decision-making by non-profit organizations, local businesses, vulnerable populations, school districts, city governments, utility providers, and others. Source: EPA.

decisions about where to prioritize physical protections, install green infrastructure, locate cooling centers, or route public transportation have differential impacts on urban residents.[60,123,124,125] If urban responses do not address social inequities and listen to the voices of vulnerable populations, they can inadvertently harm low-income and minority residents.[60,123,124]

Urban actions can reduce climate change impacts on cities.[12,126,127,128,129,130] Urban adaptation plans often begin with small steps, such as improving emergency planning or requiring that development be set back from waterways (Ch. 28: Adaptation).[59,131] Not all plans address weightier concerns, tradeoffs, behaviors, and values. For example, coastal cities at risk from sea level rise may be constructing storm surge protections, but not discussing the possibility of eventual relocation or retreat (Ch. 8: Coastal, KM 3).[59,131] Increasing tree canopy and planting vegetation to manage storm water and provide cooling can increase water use, which may present difficulties for water-strapped cities.[132,133]

Urban adaptation and mitigation actions can provide near-term benefits to cities, including co-benefits to the local economy and quality of life (Ch. 29: Mitigation, KM 4).[3,19,113,134,135,136,137] Tree canopies and greenways increase thermal comfort and improve storm water management. They also enhance air quality, recreational opportunities, and property values (Figure 11.8). Wetlands serve to buffer flooding and are also a source of biodiversity and ecosystem regulation.

Urban climate change responses are often constrained by funding, technical resources,

Greenway in Dubuque, Iowa

Figure 11.8: In response to a history of flooding, Dubuque, Iowa, installed the Bee Branch Creek Greenway to control flooding and provide recreational space.[138] Photo credit: City of Dubuque, Iowa.

existing social inequities, authority, and competing priorities.[19,114,119,139,140,141] Coordinating among multiple jurisdictions and agencies is a challenge. Using scarce resources to address future risks is often a lower priority than tackling current problem areas. The absence of locally specific climate data and a standard methodology for estimating urban GHG emissions poses additional obstacles to urban responses.[19,72,114] Cities are dependent on state and national policies to modify statewide building codes, manage across landscapes and watersheds, incentivize energy efficiency, and discourage development that puts people and property in harm's way. Strong leadership and political will are central to addressing these challenges.[59,131,142] Many U.S. cities participate in networks such as the U.S. Conference of Mayors, ICLEI, the C40 Cities Climate Leadership Group (C40), and 100 Resilient Cities. Others participate in regional coalitions such as the Southeast Florida Regional Climate Change Compact. Multicity networks support development of urban climate policies and peer-to-peer learning (Ch. 28: Adaptation).[59,110,113,117,120,143] Effective urban planning to respond to climate change addresses social inequities and quality of life, uses participatory processes and risk management approaches, builds on local knowledge and values, encourages forward-looking investment, and coordinates across sectors and jurisdictions (Ch. 8: Coastal, KM 3).[59,60,115,120,124,140,142,144]

Acknowledgments

Technical Contributors

Julie Blue
Eastern Research Group, Inc.

Kevin Bush
U.S. Department of Housing and Urban Development (through August 2017)

USGCRP Coordinators

Natalie Bennett
Adaptation and Assessment Analyst

Fredric Lipschultz
Senior Scientist and Regional Coordinator

Opening Image Credit

Cleveland, Ohio: © Erik Drost/Flickr (CC BY 2.0). Adaptation: cropped top and bottom to conform to the size needed for publication.

Traceable Accounts

Process Description

Report authors developed this chapter through technical discussions of relevant evidence and expert deliberation and through regular teleconferences, meetings, and email exchanges. (For additional information on the overall report process, see App. 1: Process.) The author team evaluated scientific evidence from peer-reviewed literature, technical reports, and consultations with professional experts and the public via webinar and teleconferences. The scope of this chapter is urban climate change impacts, vulnerability, and response. It covers the built environment and infrastructure systems in the socioeconomic context of urban areas. This chapter updates findings from the Third National Climate Assessment and advances the understanding of previously identified urban impacts by including emerging literature on urban adaptation and emphasizing how urban social and ecological systems are related to the built environment and infrastructure. The five case-study cities were selected because they represent a geographic diversity of urban impacts from wildfire, sea level rise, heat, and inland flooding. The author team was selected based on their experiences and expertise in the urban sector. They bring a diversity of disciplinary perspectives and have a strong knowledge base for analyzing the complex ways that climate change affects the built environment, infrastructure, and urban systems.

Key Message 1

Impacts on Urban Quality of Life

The opportunities and resources in urban areas are critically important to the health and well-being of people who work, live, and visit there (*very high confidence*). Climate change can exacerbate existing challenges to urban quality of life, including social inequality, aging and deteriorating infrastructure, and stressed ecosystems (*high confidence*). Many cities are engaging in creative problem solving to improve quality of life while simultaneously addressing climate change impacts (*medium confidence*).

Description of evidence base

Urban areas provide resources and opportunities for residents' quality of life.[145,146] However, many cities face challenges to prosperity, including aging and deteriorating infrastructure,[13] social inequalities,[9,46] and lack of economic growth.[147,148] These challenges play out differently depending on a city's geographic location, economic history, urban development pattern, and governance. Studies link urban development with lower air,[15] water,[16] and soil[17] quality; altered microclimates (for example, urban heat islands);[149,150] increased risk of certain vector-borne diseases;[151] and adverse effects on biodiversity and ecosystem functioning.[152,153,154] Exposure to temperature extremes,[155] allergens,[156] and toxic substances[157] and limited access to healthy food[10,158,159] and green space[11,160,161] create environmental and social vulnerabilities for urban populations. Vulnerabilities are distributed unevenly within cities and reflect social inequalities related to differences in race, class, ethnicity, gender, health, and disability.[1] These populations of concern are at a greater risk of exposure to climate change and its impacts.[3,46,123]

Climate change combines with other trends to increase stress on the health and well-being of urban residents.[10,46,155,158] Research demonstrates that climate change can exacerbate many of the vulnerabilities described above. It raises temperatures, alters weather patterns, and increases the frequency and severity of extreme weather events, creating risks to urban ecosystems (such as urban tree cover),[162,163,164] infrastructure both above and below grade,[165,166,167] historic and cultural sites,[51,52,164,168,169,170] and residents' physical and mental health.[171,172,173,174] Coupled with climate change, urban expansion increases the risk of infectious disease[175,176] and air quality problems from wildfires.[55,177]

Metropolitan areas often have more resources than rural ones, as reflected in income per capita, employment rates, and workforce education.[178,179] Innovative urban problem solving that builds on these resources can take the form of policies and institutional collaborations,[58,180] technologies,[145,181] eco- and nature-based solutions,[182,183] public–private partnerships,[59] social network and climate justice initiatives,[60,184] "smart" cities,[106,145,181] or a combination of approaches. However, cities vary greatly in their capacity to innovate for reasons related to size, staffing, and existing resources.

Major uncertainties

It is difficult to predict future urban trends with certainty. Many factors influence the size and composition of urban populations, development patterns, social networks, cultural resources, and economic growth.[180] The degree to which climate change will exacerbate existing urban vulnerabilities depends in part on the frequency and intensity of extreme weather events,[145] which are projected with far less certainty than incremental changes in average conditions.[81] Moreover, projections are not often made at the city scale.[185] Climate change may accelerate urban tree growth, but overall effects on growing conditions depend on a variety of factors.[186] These uncertainties make it difficult to predict how climate change and other factors will intersect to affect urban quality of life. Furthermore, quality of life is difficult to measure, although some metrics are available.[187]

Urban climate vulnerability depends on local social, political, demographic, environmental, and economic characteristics.[59,110,145] Urban exposure to climate change depends on geographic factors (such as latitude, elevation, hydrology, distance from the coast).[145] Some places may be able to protect quality of life from minor climate stresses but not from extreme, though rare, events.[145] The speed and pace of innovative problem solving is difficult to predict, as is its effect on quality of life..[59]

Description of confidence and likelihood

There is *very high confidence* that the opportunities and resources available in a particular urban area influence the health and well-being of its residents. There is *high confidence* that climate change exacerbates challenges to aging and deteriorating infrastructure, degrading urban ecosystems, and urban residents' health and well-being. There is *medium confidence* that many cities are engaging in creative problem solving to address the challenges to quality of life posed by climate change. The effectiveness of this response depends on many factors (for example, intensity of extreme weather events, stakeholder collaboration, and internal and external resources available).

Key Message 2

Forward-Looking Design for Urban Infrastructure

Damages from extreme weather events demonstrate current urban infrastructure vulnerabilities (*very high confidence*). With its long service life, urban infrastructure must be able to endure a future climate that is different from the past (*very high confidence*). Forward-looking design informs investment in reliable infrastructure that can withstand ongoing and future climate risks (*high confidence*).

Description of evidence base

There is wide agreement that architects, engineers, and city planners need to consider a range of future climate conditions in urban infrastructure design to guarantee that assets perform for the duration of their expected service lives.[14,62,80,81,188,189,190,191,192] Many researchers and professionals from various industries—engineering,[80,81,193,194] water resources,[195,196] architecture, construction and building science,[62,190,197,198,199,200,201,202] transportation,[203,204,205] energy,[206] and insurance[207,208]—are actively developing or have proposed strategies to integrate climate change science and infrastructure design. The Government Accountability Office, the State of California, and a variety of professional organizations have recognized the importance of incorporating forward-looking climate information (planning for or anticipating possible future events and conditions) in design standards, building codes, zoning requirements, and professional education and training programs to protect and adapt built systems and structures. This includes the need to develop and adopt design methodologies using risk management principles for uncertainty (see Ch. 28: Adaptation, KM 3 for more discussion)[90] and the integration of climate projections, nonstationarity, and extreme value analysis to inform designs that can adapt to a range of future conditions.[8,14,80,81,90,188,190,209,210,211,212,213,214,215] Similarly, there is support for incorporating climate change risk considerations into the preparation of financial disclosures.[44,96,191,216,217] Reports from multiple sectors highlight the need for licensed design professionals, property industry professionals, and decision-makers to be aware of emerging legal liabilities linked to climate change risks.[80,95,208,218,219,220]

Numerous studies document substantial economic damages in urban areas following extreme weather events and predict an increase in damages through time as these events occur with greater frequency and intensity.[14,165,166,167,205,221] Due to underinvestment in urban infrastructure[13,222] and well-documented urban vulnerabilities to the effects of climate change and extreme weather,[80,81,223] forward-looking design strategies are critical to the future reliability of urban infrastructure.[14,80]

Major uncertainties

There are gaps in our understanding of the performance capacity of existing structures exposed to climate change stressors and of the available resources and commitment (at the state, local, tribe, and federal level) to implement forward-looking designs in investments.[192,224] The scale and speed with which climate security design principles will be integrated into infrastructure design, investments, and funding sources are difficult to predict, as are the implications for municipal bonds, solvency, and investment transparency.[77,83,96,97,98,192] There is also uncertainty regarding how the U.S. legal system will determine the limits of professional liability for climate-related risks for licensed design professionals, attorneys, and investors.[95,218,219,220,225]

The extent to which key climate stressors will change over the design life of urban systems and structures is uncertain. It depends on the rate of global climate change as well as regional and local factors.[150,185,192] Engineering and architectural design is largely concerned with weather extremes,[80,81,190,226] which are generally projected with far less certainty than changes in average conditions.[81] Action depends on how individual decision-makers weigh the costs and benefits of implementing designs that attempt to account for future climate change. The extent to which the U.S. market is able to innovate to provide these services to the global market is unknown.

Description of confidence and likelihood

There is *very high confidence* that the integrity of urban infrastructure is and will continue to be threatened by exposure to climate change stressors (for example, more frequent and extreme precipitation events, sea level rise, and heat) and that damages from weather events demonstrate infrastructure vulnerability. Many urban areas have endured high costs from such events, and many of those costs can be attributed to infrastructure failures or damages. There is *very high confidence* that urban infrastructure will need to endure a future climate that is different from the past in order to fulfill its long service life. There is *high confidence* that investment in forward-looking design provides a foundation for reliable infrastructure that can withstand ongoing and future climate risks. How much implementing forward-looking design will reduce risks is less clear, since much depends on other factors such as changes in urban population, social inequalities, the broader economy, and rates of climate change.

Key Message 3

Impacts on Urban Goods and Services

Interdependent networks of infrastructure, ecosystems, and social systems provide essential urban goods and services (*very high confidence*). Damage to such networks from current weather extremes and future climate will adversely affect urban life (*medium confidence*). Coordinated local, state, and federal efforts can address these interconnected vulnerabilities (*medium confidence*).

Description of evidence base

Research focusing on urban areas shows that climate change has or is anticipated to have a net negative effect on transportation,[43,205,223,227] food,[44,107,108] housing,[228] the economy,[44,228,229,230,231] ecology,[3,152] public health,[2,3,12,44,231,232] energy,[43,44,233,234] water,[43,122,228,235] and sports and recreation.[2,235,236]

Researchers have modeled and documented how negative effects on one system that provides urban goods and services cascade into others that rely on it.[3,43,44,109,122,229,231,233,234] Several draw on the example of Superstorm Sandy. These effects scale up to the national economy and across to other sectors, creating longer-term hazards and vulnerabilities.[44,99,109,227] The energy–water nexus, defined as the reliance of energy and water systems on each other for functionality, is a good example of documented system interdependency.[43,234] Research indicates that direct or high-level climate impacts on a variety of urban sectors (such as transportation, energy, drinking water, storm water) have cascading economic, socioeconomic, and public health consequences.[3,12,44,229,231]

The literature shows that coordinated resilience planning across sectors and jurisdictions to address interdependencies involves using models and plans,[3,43,108,111,227,237,238] finding effective intervention points,[109] creating system redundancy,[43,237] and motivating behavioral change. Recent reports discuss how interdependencies among energy, water, transportation, and communications services inform adaptation strategies that span sectors.[43,227]

Major uncertainties

Interconnections among urban systems have been studied less extensively than climate change effects on individual urban sectors, and there are still gaps to be filled.[239,240,241] The complexity of urban systems leads to uncertainty and modeling challenges. System models need to account for interconnections, feedback loops, and cascading effects from rural areas, among urban sectors, and within a sector. Creating a comprehensive framework to understand these connections is difficult.[239,242] There is a lack of forward-looking models of how projected climate changes will impact interdependent urban systems. Cities do not usually have the range of data needed to fully analyze system connections.[102,111] Mixed methods analysis, where professional experience and qualitative data supplement available datasets, may partially compensate for this problem.[241] Despite information gaps, urban stakeholders are beginning to address system interconnections in adaptation efforts.[59]

While it has been demonstrated that climate change affects urban systems, the extent to which climate change will affect a given urban system is difficult to predict. It depends on the unique strengths and vulnerabilities of that system as well as the regional and local climate conditions to which the system is exposed.[110,223,243] Modifying factors include spatial layout, age of infrastructure, available resources, and ongoing resilience efforts.[43,244] Similarly, critical points of intervention are unique to each urban area. Local-scale analysis of vulnerability and resilience has not been done for most U.S. cities.[102,241]

The severity of future climate impacts and cascading consequences for urban networks depends on the magnitude of global climate change.[223] Urban systems may be able to tolerate some levels of stress with only minor disruptions. Stresses of greater frequency, longer duration, or greater intensity may compromise a system's ability to function.[36,43,109,122,227] Models can reveal changes in the likelihood or frequency of occurrence for a particular type of extreme event (such as a 100-year flood), but they cannot predict when these events will occur or whether they will hit a particular city or town.[245]

Description of confidence and likelihood

There is *very high confidence* that urban areas rely on essential goods and services that are vulnerable to climate change because they are part of interdependent networks of infrastructure, ecosystems, and social systems. There is *high confidence* that extreme weather events have resulted in adverse cascading effects across urban sectors and systems, as there is documentation of a significant number of case studies of urban areas demonstrating these effects. It is projected with *medium confidence* that network damages from future climate change will disrupt many aspects of urban life, given that the complexity of urban life and the many factors affecting urban resilience to climate change make future disruptions difficult to predict. Similarly, there is *medium confidence* that addressing interconnected vulnerabilities via coordinated efforts can build urban resilience to climate change.

Key Message 4

Urban Response to Climate Change

Cities across the United States are leading efforts to respond to climate change (*high confidence*). Urban adaptation and mitigation actions can affect current and projected impacts of climate change and provide near-term benefits (*medium confidence*). Challenges to implementing these plans remain. Cities can build on local knowledge and risk management approaches, integrate social equity concerns, and join multicity networks to begin to address these challenges (*high confidence*).

Description of evidence base

Multiple review studies have documented that cities in all parts of the United States are undertaking adaptation and mitigation actions.[45,115,246] Municipal departments, including public works, water systems, and transportation, along with public, private, and civic actors, work to assess vulnerability and reduce risk. Actions include land-use planning, protecting critical infrastructure and ecosystems, installing green infrastructure, and improving emergency preparedness and response.[45,114,115,117,247] Many cities are part of multicity networks (for example, the Great Lakes Climate Adaptation Network, ICLEI, and C40 Cities Climate Leadership Group) that provide opportunities for peer-to-peer learning, sharing best practices, and technical assistance.[59,114,117,120] Researchers have recognized the benefits of shared motivation and resource pooling across cities[59] and of incorporating local knowledge, priorities, and values into adaptation planning.[45,248] The private sector, utilities, nongovernmental organizations, libraries, museums, and civic organizations are involved with urban adaptation and mitigation.[2,45,59,115,196,249,250] Studies are beginning to analyze the social, economic, and political factors that shape whether and how cities carry out climate change response.[114,115,116,131,142]

Numerous studies have examined the ways in which adaptation actions reduce the impacts of weather extremes in urban areas. Documented benefits include reductions in urban heat risk[48,126,127,128,130,251] and flooding impacts.[118,252,253] These actions can provide additional public health and economic benefits.[59,254,255,256,257] Studies have also noted that low-regret and incremental urban adaptation are not likely to significantly reduce the impacts of projected climate change.[59,131,258] In addition, several studies discuss how urban adaptation can cause adverse consequences related to existing socioeconomic and spatial inequalities and the uneven distribution of urban climate risks.[60,123,124,125]

Major uncertainties

While urban adaptation actions can reduce the effects of extreme weather, there is uncertainty regarding the effectiveness of these actions against future climate change.[115,246] Much of this uncertainty arises from the difficulties inherent in predicting the future impacts of climate change. This uncertainty is compounded by a lack of regional and local data for many cities, by the difficulty of evaluating the effects of climate change on local extremes,[150,251] and by the inability of knowing how climate changes intersect with other urban changes.[67,185] Moreover, there is a lack of forward-looking models and standardized monitoring strategies to test the costs, co-benefits, and effectiveness of urban response. Adaptation actions that focus solely on physical protection of urban assets are not likely to effectively address social vulnerability.[114,123] Urban adaptation effectiveness depends heavily on local characteristics. While cities do learn best practices through multicity networks, one city's strategy may not be as applicable to other cities.

Research on drivers of and challenges to urban response is in the incipient stage, with divergent results about social and political requirements for effective response.[114,116,142] Although cities are leading the way in adaptation and mitigation, many face significant barriers such as resource challenges, which will affect the rate of spread, extent, and duration of urban response.[45,145] There is little research on the effectiveness of different incentives for urban response or how to best support action in low-income communities.

Description of confidence and likelihood

There is *high confidence* that municipal governments and other institutions in many U.S. cities are planning and implementing climate change adaptation and mitigation actions. There is *high confidence* that urban adaptation and mitigation can provide additional near-term benefits, although the distribution of benefits and harms within cities is uneven. There is *medium confidence* in the effect these actions have and will have on current and future climate change impacts. If cities take only small actions, they are unlikely to fully protect urban residents from devastating impacts, particularly given projected levels of climate change. There is *high confidence* that cities face challenges in responding to climate change and that when cities build on local knowledge, use risk management approaches, explicitly address social vulnerability, and participate in multicity networks, their ability to respond to climate change is improved. The degree of improvement depends on other factors that affect urban response outcomes.

References

1. Cutter, S.L., W. Solecki, N. Bragado, J. Carmin, M. Fragkias, M. Ruth, and T. Wilbanks, 2014: Ch. 11: Urban systems, infrastructure, and vulnerability. *Climate Change Impacts in the United States: The Third National Climate Assessment*. Melillo, J.M., T.C. Richmond, and G.W. Yohe, Eds. U.S. Global Change Research Program, Washington, DC, 282-296. http://dx.doi.org/10.7930/J0F769GR

2. Revi, A., D.E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, D.C. Roberts, and W. Solecki, 2014: Urban areas. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change*. Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, Eds. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 535-612.

3. Urban Climate Change Research Network, 2015: Climate Change and Cities. Second Assessment Report of the Urban Climate Change Research Network. Summary for City Leaders. Columbia University, New York, NY. http://uccrn.org/arc3-2/

4. U.S. Census Bureau American FactFinder, 2017: Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2016. U.S. Census Bureau, Population Division, Washington, DC. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2016_PEPANNRES&src=pt

5. Baumgardner, F.T., J.R. Hinson, and S.D. Panek, 2016: Annual Revision of Gross Domestic Product by Metropolitan Area: Advance Statistics for 2015 and Revised Statistics for 2001–2014 U.S. Dept. of Commerce, Bureau of Economic Analysis, 37 pp. https://bea.gov/scb/pdf/2016/10%20October/1016_gdp_by_metropolitan_area.pdf

6. Albouy, D., G. Ehrlich, and M. Shin, 2017: Metropolitan land values. *The Review of Economics and Statistics*, **100** (3), 454-466. http://dx.doi.org/10.1162/REST_a_00710

7. U.S. EPA, 2017: Updates to the Demographic and Spatial Allocation Models to Produce Integrated Climate and Land Use Scenarios (ICLUS) Version 2. EPA/600/R-16/366F. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Washington, DC, various pp. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=322479

8. Hayhoe, K., J. Edmonds, R.E. Kopp, A.N. LeGrande, B.M. Sanderson, M.F. Wehner, and D.J. Wuebbles, 2017: Climate models, scenarios, and projections. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 133-160. http://dx.doi.org/10.7930/J0WH2N54

9. Cunningham, J.C., 2015: Measuring wage inequality within and across US metropolitan areas, 2003-2013. *Monthly Labor Review*. U.S. Bureau of Labor Statistics, 15. http://dx.doi.org/10.21916/mlr.2015.35

10. Walker, R.E., C.R. Keane, and J.G. Burke, 2010: Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & Place*, **16**, 876-884. http://dx.doi.org/10.1016/j.healthplace.2010.04.013

11. Wolch, J.R., J. Byrne, and J.P. Newell, 2014: Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*, **125**, 234-244. http://dx.doi.org/10.1016/j.landurbplan.2014.01.017

12. USGCRP, 2016: *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program, Washington, DC, 312 pp. http://dx.doi.org/10.7930/J0R49NQX

13. American Society of Civil Engineers (ASCE), 2017: 2017 Infrastructure Report Card: A Comprehensive Assessment of America's Infrastructure. American Society of Civil Engineers, Washington, DC, 110 pp. https://www.infrastructurereportcard.org/

14. Gomez, J.A., 2016: Climate Change: Improved Federal Coordination Could Facilitate Use of Forward-Looking Climate Information in Design Standards, Building Codes, and Certifications. GAO-17-3. Government Accountability Office, Washington, DC, 40 pp. https://www.gao.gov/products/GAO-17-3

15. McCarty, J. and N. Kaza, 2015: Urban form and air quality in the United States. *Landscape and Urban Planning*, **139**, 168-179. http://dx.doi.org/10.1016/j.landurbplan.2015.03.008

16. McGrane, S.J., 2016: Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: A review. *Hydrological Sciences Journal*, **61** (13), 2295-2311. http://dx.doi.org/10.1080/02626667.2015.1128084

17. Pavao-Zuckerman, M.A., 2008: The nature of urban soils and their role in ecological restoration in cities. *Restoration Ecology*, **16**, 642-649. http://dx.doi.org/10.1111/j.1526-100X.2008.00486.x

18. Grimm, N.B., S.H. Faeth, N.E. Golubiewski, C.L. Redman, J. Wu, X. Bai, and J.M. Briggs, 2008: Global change and the ecology of cities. *Science*, **319** (5864), 756-760. http://dx.doi.org/10.1126/science.1150195

19. USGCRP, 2018: Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report. Cavallaro, N., G. Shrestha, R. Birdsey, M. Mayes, R. Najjar, S. Reed, P. Romero-Lankao, and Z. Zhu, Eds. U.S. Global Change Research Program, Washington, DC, 877 pp. http://dx.doi.org/10.7930/SOCCR2.2018

20. Seto, K.C., W.D. Solecki, and C.A. Griffith, Eds., 2016: *Routledge Handbook on Urbanization and Global Environmental Change*. Routledge, London, 582 pp.

21. USGCRP, 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, 470 pp. http://dx.doi.org/10.7930/J0J964J6

22. Serna, J., 2017: "La Tuna Fire, city's biggest by acreage, now 80% contained, officials say." *Los Angeles Times*. http://www.latimes.com/local/lanow/la-me-ln-verdugo-fire-containment-20170905-story.html

23. City of Pittsburgh, 2016: Resilient Pittsburgh. 100 Resilient Cities and Rockefeller Foundation, Pittsburgh, PA, 59 pp. http://apps.pittsburghpa.gov/cis/PRA2016_Final_version.pdf

24. City of Pittsburgh, 2017: ONE PGH: Pittsburgh's Resilience Strategy. Department of City Planning, Pittsburgh, PA, 117 pp. http://pittsburghpa.gov/onepgh/documents/pgh_resilience_strategy.pdf

25. Vose, R.S., D.R. Easterling, K.E. Kunkel, A.N. LeGrande, and M.F. Wehner, 2017: Temperature changes in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 185-206. http://dx.doi.org/10.7930/J0N29V45

26. Easterling, D.R., K.E. Kunkel, J.R. Arnold, T. Knutson, A.N. LeGrande, L.R. Leung, R.S. Vose, D.E. Waliser, and M.F. Wehner, 2017: Precipitation change in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 207-230. http://dx.doi.org/10.7930/J0H993CC

27. Kossin, J.P., T. Hall, T. Knutson, K.E. Kunkel, R.J. Trapp, D.E. Waliser, and M.F. Wehner, 2017: Extreme storms. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 257-276. http://dx.doi.org/10.7930/J07S7KXX

28. Adger, W.N., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D.R. Nelson, L.O. Naess, J. Wolf, and A. Wreford, 2009: Are there social limits to adaptation to climate change? *Climatic Change*, **93** (3-4), 335-354. http://dx.doi.org/10.1007/s10584-008-9520-z

29. Hibbard, K.A., F.M. Hoffman, D. Huntzinger, and T.O. West, 2017: Changes in land cover and terrestrial biogeochemistry. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 277-302. http://dx.doi.org/10.7930/J0416V6X

30. Solecki, W., C. Rosenzweig, V. Gornitz, R. Horton, D.C. Major, L. Partrick, and R. Zimmerman, 2014: Climate change and infrastructure adaptation in coastal New York City. *Climate Change and the Coast: Building Resilient Communities*. CRC Press, Boca Raton, FL, 125-146.

31. NOAA NWS, 2015: Historic Flooding—October 1–5, 2015 [story map]. NOAA National Weather Service, North Charleston, SC, accessed 17 April. https://www.weather.gov/chs/HistoricFlooding-Oct2015

32. NWS, 2016: The Historic South Carolina Floods of October 1–5, 2015. Service Assessment. NOAA National Weather Service (NWS), Silver Spring, MD, various pp. https://www.weather.gov/media/publications/assessments/SCFlooding_072216_Signed_Final.pdf

33. Venkateswaran, K., K. MacClune, S. Gladfelter, and M. Szönyi, 2015: Risk Nexus: What Can Be Learned from the Columbia and Charleston Floods 2015? Zurich Insurance Group, Zurich, Switzerland, 45 pp. https://www.zurich.com/_/media/dbe/corporate/docs/corporate-responsibility/risk-nexus-south-carolina-floods-2015.pdf

34. City of Fort Collins, 2015: 2015 Climate Action Plan Framework. Fort Collins, CO, 51 pp. https://www.fcgov.com/environmentalservices/pdf/cap-framework-2015.pdf

35. Vogel, J.M., M. O'Grady, and S. Renfrow, 2015: A Climate Change Vulnerability Assessment Report for the National Renewable Energy Laboratory: May 23, 2014–June 5, 2015. NREL/SR-3500-64174. National Renewal Energy Laboratory, Golden, CO, 42 pp. https://www.nrel.gov/docs/fy16osti/64174.pdf

36. Hanak, E., J. Mount, C. Chappelle, J. Lund, J. Medellín-Azuara, P. Myoyle, and N.E. Seavy, 2015: What If California's Drought Continues? Public Policy Institute of California, San Francisco, CA, 20 pp. http://www.ppic.org/publication/what-if-californias-drought-continues/

37. NOAA, 2015: Storm Events Database: Drought in San Joaquin Valley, California. National Oceanic and Atmospheric Administration (NOAA), National Centers for Environmental Information, Asheville, NC, accessed 17 April 17. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=605750

38. Gleick, P.H., 2016: Impacts of California's Ongoing Drought: Hydroelectricity Generation 2015 Update. Pacific Institute, Oakland, CA, 9 pp. http://pacinst.org/wp-content/uploads/2016/02/Impacts-Californias-Ongoing-Drought-Hydroelectricity-Generation-2015-Update.pdf

39. Little, R.G., 2002: Controlling cascading failure: Understanding the vulnerabilities of interconnected infrastructures. *Journal of Urban Technology*, **9** (1), 109-123. http://dx.doi.org/10.1080/106307302317379855

40. Kirshen, P., M. Ruth, and W. Anderson, 2008: Interdependencies of urban climate change impacts and adaptation strategies: A case study of Metropolitan Boston USA. *Climatic Change*, **86** (1), 105-122. http://dx.doi.org/10.1007/s10584-007-9252-5

41. Rosenzweig, C., N.W. Arnell, K.L. Ebi, H. Lotze-Campen, F. Raes, C. Rapley, M.S. Smith, W. Cramer, K. Frieler, C.P.O. Reyer, J. Schewe, D. van Vuuren, and L. Warszawski, 2017: Assessing inter-sectoral climate change risks: The role of ISIMIP. *Environmental Research Letters*, **12** (1), 010301. http://dx.doi.org/10.1088/1748-9326/12/1/010301

42. Brown, M.E., J.M. Antle, P. Backlund, E.R. Carr, W.E. Easterling, M.K. Walsh, C. Ammann, W. Attavanich, C.B. Barrett, M.F. Bellemare, V. Dancheck, C. Funk, K. Grace, J.S.I. Ingram, H. Jiang, H. Maletta, T. Mata, A. Murray, M. Ngugi, D. Ojima, B. O'Neill, and C. Tebaldi, 2015: Climate Change, Global Food Security, and the U.S. Food System. U.S. Global Change Research Program, Washington, DC, 146 pp. http://dx.doi.org/10.7930/J0862DC7

43. Wilbanks, T.J. and S. Fernandez, Eds., 2014: *Climate Change and Infrastructure, Urban Systems, and Vulnerabilities*. Technical Report to the U.S. Department of Energy in Support of the National Climate Assessment. Island Press, Washington, DC, 108 pp. https://islandpress.org/book/climate-change-and-infrastructure-urban-systems-and-vulnerabilities

44. Houser, T., S. Hsiang, R. Kopp, K. Larsen, M. Delgado, A. Jina, M. Mastrandrea, S. Mohan, R. Muir-Wood, D.J. Rasmussen, J. Rising, and P. Wilson, 2015: *Economic Risks of Climate Change: An American Prospectus*. Columbia University Press, New York, 384 pp.

45. Bierbaum, R., J.B. Smith, A. Lee, M. Blair, L. Carter, F.S. Chapin, P. Fleming, S. Ruffo, M. Stults, S. McNeeley, E. Wasley, and L. Verduzco, 2013: A comprehensive review of climate adaptation in the United States: More than before, but less than needed. *Mitigation and Adaptation Strategies for Global Change*, **18** (3), 361-406. http://dx.doi.org/10.1007/s11027-012-9423-1

46. Sampson, R.J., 2017: Urban sustainability in an age of enduring inequalities: Advancing theory and ecometrics for the 21st-century city. *Proceedings of the National Academy of Sciences of the United States of America*, **114** (34), 8957-8962. http://dx.doi.org/10.1073/pnas.1614433114

47. Pincetl, S., M. Chester, and D. Eisenman, 2016: Urban heat stress vulnerability in the US Southwest: The role of sociotechnical systems. *Sustainability*, **8** (9). http://dx.doi.org/10.3390/su8090842

48. Milan, B.F. and F. Creutzig, 2015: Reducing urban heat wave risk in the 21st century. *Current Opinion in Environmental Sustainability*, **14**, 221-231. http://dx.doi.org/10.1016/j.cosust.2015.08.002

49. Vanos, J.K., A. Middel, G.R. McKercher, E.R. Kuras, and B.L. Ruddell, 2016: Hot playgrounds and children's health: A multiscale analysis of surface temperatures in Arizona, USA. *Landscape and Urban Planning*, **146**, 29-42. http://dx.doi.org/10.1016/j.landurbplan.2015.10.007

50. Habeeb, D., J. Vargo, and B. Stone, 2015: Rising heat wave trends in large US cities. *Natural Hazards*, **76** (3), 1651-1665. http://dx.doi.org/10.1007/s11069-014-1563-z

51. Rockman, M., M. Morgan, S. Ziaja, G. Hambrecht, and A. Meadow, 2016: Cultural Resources Climate Change Strategy. Cultural Resources, Partnerships, and Science and Climate Change Response Program, National Park Service, Washington, DC. https://www.nps.gov/subjects/climatechange/upload/ClimateChange_01-05_DigitalPrelim.pdf

52. Merritt, E., 2012: A Rising Tide: The Changing Landscape of Risk. Center for the Future of Museums, Arlington, VA. http://futureofmuseums.blogspot.com/2012/05/rising-tide-changing-landscape-of-risk.html

53. Fatorić, S. and E. Seekamp, 2017: Are cultural heritage and resources threatened by climate change? A systematic literature review. *Climatic Change*, **142** (1), 227-254. http://dx.doi.org/10.1007/s10584-017-1929-9

54. Spanger-Siegfried, E., M. Fitzpatrick, and K. Dahl, 2014: 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, Cambridge, MA, 64 pp. http://www.ucsusa.org/global_warming/impacts/effects-of-tidal-flooding-and-sea-level-rise-east-coast-gulf-of-mexico

55. Kerns, B.K., J.B. Kim, J.D. Kline, and M.A. Day, 2016: US exposure to multiple landscape stressors and climate change. *Regional Environmental Change*, **16** (7), 2129-2140. http://dx.doi.org/10.1007/s10113-016-0934-2

56. Hauer, M.E., 2017: Migration induced by sea-level rise could reshape the US population landscape. *Nature Climate Change*, **7** (5), 321-325. http://dx.doi.org/10.1038/nclimate3271

57. Keenan, J.M., T. Hill, and A. Gumber, 2018: Climate gentrification: From theory to empiricism in Miami-Dade County, Florida. *Environmental Research Letters*, **13** (5), 054001. http://dx.doi.org/10.1088/1748-9326/aabb32

58. Mayors' Climate Protection Center, 2015: U.S. Mayors' Report on a Decade of Global Climate Leadership: Selected Mayor Profiles. The United States Conference of Mayors, Washington, DC, 42 pp. http://www.usmayors.org/wp-content/uploads/2017/06/1205-report-climateaction.pdf

59. Vogel, J., K.M. Carney, J.B. Smith, C. Herrick, M. Stults, M. O'Grady, A.S. Juliana, H. Hosterman, and L. Giangola, 2016: Climate Adaptation—The State of Practice in U.S. Communities. Kresge Foundation, Detroit. http://kresge.org/sites/default/files/library/climate-adaptation-the-state-of-practice-in-us-communities-full-report.pdf

60. Shi, L.D., E. Chu, I. Anguelovski, A. Aylett, J. Debats, K. Goh, T. Schenk, K.C. Seto, D. Dodman, D. Roberts, J.T. Roberts, and S.D. VanDeveer, 2016: Roadmap towards justice in urban climate adaptation research. *Nature Climate Change*, **6** (2), 131-137. http://dx.doi.org/10.1038/nclimate2841

61. NYC Parks, 2017: Why Plant Trees? New York City Parks, New York, accessed 15 September. http://www.nyc.gov/html/mancb3/downloads/resources/NYC%20Street%20Tree%20Overview.pdf

62. Gething, B. and K. Puckett, 2010: *Design for Climate Change*. RIBA Publishing, Newcastle Upon Tyne, UK, 192 pp. https://www.arcc-network.org.uk/wp-content/D4FC/01_Design-for-Future-Climate-Bill-Gething-report.pdf

63. Federal Accounting Standards Advisory Board, 2013: Accounting for Impairment of General Property, Plant, and Equipment Remaining in Use. Federal Financial Accounting Standards 44. Federal Accounting Standards Advisory Board, Washington, DC, 71 pp. http://www.fasab.gov/pdffiles/original_sffas_44.pdf

64. Ayyub, B.M., 2014: *Risk Analysis in Engineering and Economics*, 2nd ed. Chapman and Hall/CRC, Boca Raton, FL, 640 pp.

65. Holstege, S., C. McGlade, and E. Gately, 2014: "Pumping stations failed at some freeway stations." AZ *Central*. http://www.azcentral.com/story/news/local/phoenix/2014/09/09/pumping-stations-failed-freeway-stations/15319725/.

66. Wright, K., K. Whitehouse, and J. Curti, 2017: Voluntary Resilience Standards: An Assessment of the Emerging Market for Resilience in the Built Environment. Meister Consultants Group, Boston, MA, 31 pp. http://www.mc-group.com/voluntary-resilience-standards-an-assessment-of-the-emerging-market-for-resilience-in-the-built-environment/

67. National Academies of Sciences, Engineering, and Medicine, 2016: *Attribution of Extreme Weather Events in the Context of Climate Change*. National Academies Press, Washington, DC, 186 pp. http://dx.doi.org/10.17226/21852

68. Herring, S.C., N. Christidis, A. Hoell, J.P. Kossin, C.J. Schreck, III, and P.A. Stott, 2018: Explaining extreme events of 2016 from a climate perspective. *Bulletin of the American Meteorological Society*, **99** (1), S1-S157. http://dx.doi.org/10.1175/BAMS-ExplainingExtremeEvents2016.1

69. Wehner, M.F., J.R. Arnold, T. Knutson, K.E. Kunkel, and A.N. LeGrande, 2017: Droughts, floods, and wildfires. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA, 231-256. http://dx.doi.org/10.7930/J0CJ8BNN

70. Business Continuity Institute, 2016: Supply Chain Resilience Report 2016. Business Continuity Institute, Caversham, UK, 39 pp. https://www.riskmethods.net/resources/research/bci-supply-chain-resilience-2016.pdf

71. Fankhauser, S., 2017: Adaptation to climate change. *Annual Review of Resource Economics*, **9** (1), 209-230. http://dx.doi.org/10.1146/annurev-resource-100516-033554

72. EPA, 2017: Multi-model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. EPA 430-R-17-001. U.S. Environmental Protection Agency (EPA), Washington, DC, 271 pp. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=335095

73. Costa, H., G. Floater, H. Hooyberghs, S. Verbeke, and K. De Ridder, 2016: Climate Change, Heat Stress and Labour Productivity: A Cost Methodology for City Economies. Centre for Climate Change Economics and Policy Working Paper No. 278 and Grantham Research Institute on Climate Change and the Environment Working Paper No. 248. Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment, London, UK, 15 pp. http://www.lse.ac.uk/GranthamInstitute/publication/climate-change-heat-stress-and-labour-productivity-a-cost-methodology-for-city-economies/

74. Bartos, M., M. Chester, N. Johnson, B. Gorman, D. Eisenberg, I. Linkov, and M. Bates, 2016: Impacts of rising air temperatures on electric transmission ampacity and peak electricity load in the United States. *Environmental Research Letters*, **11** (11), 114008. http://dx.doi.org/10.1088/1748-9326/11/11/114008

75. DOE, 2015: An Assessment of Energy Technologies and Research Opportunities: Quadrennial Technology Review. U.S. Department of Energy (DOE), Washington, DC, 489 pp. https://energy.gov/sites/prod/files/2015/09/f26/Quadrennial-Technology-Review-2015_0.pdf

76. Reyna, J.L. and M.V. Chester, 2017: Energy efficiency to reduce residential electricity and natural gas use under climate change. *Nature Communications*, **8**, 14916. http://dx.doi.org/10.1038/ncomms14916

77. Okuji, K., M. Wertz, K. Kurtz, and L. Jones, 2017: Environmental Risks: Evaluating the Impact of Climate Change on US State and Local Issuers. Technical Report No. 1071949. Moody's Investor Service, New York, NY, 21 pp. http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2017/12/Evaluating-the-impact-of-climate-change-on-US-state-and-local-issuers-11-28-17.pdf

78. Knopman, D. and R.J. Lempert, 2016: Risk governance framework for decisionmaking. *Urban Responses to Climate Change: Framework for Decisionmaking and Supporting Indicators*. RAND Corporation, Santa Monica, CA, 11-26. http://dx.doi.org/10.7249/RR1144

79. Ayyub, B.M. and G.J. Klir, 2006: *Uncertainty Modeling and Analysis in Engineering and the Sciences*. Chapman Hall/CRC, Boca Raton, FL, 400 pp.

80. WFEO Committee on Engineering and the Environment, 2015: Model Code of Practice: Principles of Climate Change Adaptation for Engineers. World Federation of Engineering Organizations (WFEO), Paris, France, 36 pp. http://www.aaes.org/sites/default/files/WFEO%20Model%20Code%20of%20Practice%20-%20Climate%20Change%20Adaptation%20Principles%20-%20REVIEW%20DRAFT%20-%20July%202015.pdf

81. Olsen, J.R., Ed. 2015: *Adapting Infrastructure and Civil Engineering Practice to a Changing Climate*. American Society of Civil Engineers, Reston, VA, 93 pp. http://dx.doi.org/10.1061/9780784479193

82. Mazzacurati, E., D.V. Mallard, Joshua Turner, N. Steinberg, and C. Shaw, 2017: Physical Climate Risk in Equity Portfolios. Four Twenty Seven for Deutsche Asset Management, Berkeley, CA, 28 pp. http://427mt.com/2017/11/08/physical-climate-risk-in-equity-portfolios-white-paper/

83. Koh, J., E. Mazzacurati, and S. Swann, 2016: Bridging the Adaptation Gap: Approaches to Measurement of Physical Climate Risk and Examples of Investment in Climate Adaptation and Resilience. Global Adaptation & Resilience Investment Working Group, 65 pp. https://garigroup.com/discussion-paper

84. Ayyub, B.M. and R.N. Wright, 2016: Adaptive climate risk control of sustainability and resilience for infrastructure systems. *Journal of Geography & Natural Disasters*, **6** (2), e118. http://dx.doi.org/10.4172/2167-0587.1000e118

85. McLeod, R.S., C.J. Hopfe, and Y. Rezgui, 2012: A proposed method for generating high resolution current and future climate data for Passivhaus design. *Energy and Buildings*, **55**, 481-493. http://dx.doi.org/10.1016/j.enbuild.2012.08.045

86. Mann, B., U. Passe, S. Rabideau, and E.S. Takle, 2012: Future context for thermal comfort: Impact of a changing climate on energy demand and human thermal comfort. In *7th Windsor Conference: The changing context of comfort in an unpredictable world*, Windsor, UK, 12-15 April 2012. Network for Comfort and Energy Use in Buildings (NCEUB). http://nceub.org.uk//w2012/pdfs/session5/W1285%20Passe.pdf

87. Radbideau, S.L., U. Passe, and E.S. Takle, 2012: Exploring alternatives to the “typical meteorological year” for incorporating climate change into building design. *ASHRAE Transactions*, **118**, 384-391. https://bit.ly/2Sem22a

88. Simonovic, S.P., A. Schardong, D. Sandink, and R. Srivastav, 2016: A web-based tool for the development of Intensity Duration Frequency curves under changing climate. *Environmental Modelling & Software*, **81**, 136-153. http://dx.doi.org/10.1016/j.envsoft.2016.03.016

89. Department of Defense, 2017: Nonstationary Weather Patterns and Extreme Events: Workshop Report. Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP), Alexandria, VA, various pp. https://www.serdp-estcp.org/News-and-Events/Blog/Nonstationary-Weather-Patterns-and-Extreme-Events-Workshop-Report

90. Canadian Engineering Qualifications Board, 2014: Principles of Climate Change Adaptation for Engineers. Engineers Canada, Ottawa, ON, 37 pp. https://engineerscanada.ca/sites/default/files/01_national_guideline_climate_change_adaptation.pdf

91. APEGBC, 2016: Developing Climate Change–Resilient Designs for Highway Infrastructure in British Columbia. APEGBC Professional Practice Guidelines V1.0. Association of Professional Engineers and Geoscientists of British Columbia, Burnaby, BC, 100 pp. https://www.egbc.ca/getmedia/1ac17fe9-8eaf-41d3-b095-afac3953b8f3/2017_MoTI-guidelines-06F-web_1.pdf.aspx

92. Wright, R.N., B.M. Ayyub, and F.T. Lombardo, 2013: Bridging the gap between climate change science and structural engineering practice. *Structure Magazine*, **September**, 29-32. http://www.structuremag.org/?p=656

93. Hsiang, S., R. Kopp, A. Jina, J. Rising, M. Delgado, S. Mohan, D.J. Rasmussen, R. Muir-Wood, P. Wilson, M. Oppenheimer, K. Larsen, and T. Houser, 2017: Estimating economic damage from climate change in the United States. *Science*, **356** (6345), 1362-1369. http://dx.doi.org/10.1126/science.aal4369

94. Staebler, P., 2017: The 50% FEMA rule appraisal. *The Appraisal Journal*, **Fall**, 261-273. http://www.myappraisalinstitute.org/webpac/pdf/TAJ2017/FEMA_Appraisal.pdf

95. Hutley, N. and S. Hartford-Davis, 2016: Climate Change and Director’s Duties. The Centre for Policy Development and the Future Business Council, Syndey, Australia, 22 pp. http://cpd.org.au/wp-content/uploads/2016/10/Legal-Opinion-on-Climate-Change-and-Directors-Duties.pdf

96. Koh, J., E. Mazzacurati, and C. Trabacchi, 2017: An Investor Guide to Physical Climate Risk & Resilience: An Introduction. Global Adaptation & Resilience Investment Working Group, 13 pp. https://garigroup.com/investor-guide

97. Caldecott, B. and L. Kruitwagen, 2016: Guest Opinion: How Asset Level Data Can Improve the Assessment of Environmental Risk In Credit Analysis. *S&P Global Credit Portal*, 3 October. Standard & Poor's. https://bit.ly/2LCRvqT

98. Investor Group on Climate Change, 2017: Transparency in Transition: A Guide to Investor Disclosure on Climate Change. Investor Group on Climate Change, New South Wales, Australia, 40 pp. https://igcc.org.au/transparency-transition-guide-investor-disclosure-climate-change/

99. City of New York, 2013: A Stronger, More Resilient New York. New York, NY, 438 pp. https://www.nycedc.com/resource/stronger-more-resilient-new-york

100. City of Boston, 2017: Climate Resiliency Guidance and Checklist. Boston Planning and Development Agency Boston, MA, 14 pp. http://www.bostonplans.org/getattachment/5d668310-ffd1-4104-98fa-eef30424a9b3

101. City of Chicago, 2008: Chicago Climate Action Plan: Our City. Our Future. 57 pp. http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINALv2.pdf

102. Aylett, A., 2015: Institutionalizing the urban governance of climate change adaptation: Results of an international survey. *Urban Climate*, **14, Part 1**, 4-16. http://dx.doi.org/10.1016/j.uclim.2015.06.005

103. Kenward, A., D. Adams-Smith, and U. Raja, 2013: Wildfires and Air Pollution: The Hidden Health Hazards of Climate Change. Climate Central, Princeton, NJ, 37 pp. http://assets.climatecentral.org/pdfs/WildfiresAndAirPollution.pdf

104. Warziniack, T. and M. Thompson, 2013: Wildfire risk and optimal investments in watershed protection. *Western Economics Forum*, **12** (2), 19-28. https://www.fs.usda.gov/treesearch/pubs/45753

105. Fischbach, J.R., K. Siler-Evans, D. Tierney, M.T. Wilson, L.M. Cook, and L.W. May, 2017: Robust Stormwater Management in the Pittsburgh Region: A Pilot Study. RR0-1673-MCF. RAND Corporation, Santa Monica, CA, 120 pp. http://dx.doi.org/10.7249/RR1673

106. Torres, D. and M. Maletjane, 2015: Information and Communication Technologies for Climate Change Adaptation in Cities. International Telecommunication Union (ITU), Focus Group on Smart Sustainable Cities—Working Group 2, 33 pp. https://www.itu.int/en/ITU-T/focusgroups/ssc/Documents/website/web-fg-ssc-0107-r7-ICTs-for-climate-change-adaptation.docx

107. Watson, A., A. Gaspard, and A. Lebreton, 2016: Food, Climate Change, and the City. FNH-IUFN-UNEP Policy Perspectives Paper. United Nations Environment Programme, Nairobi, Kenya, 20 pp. http://www.iufn.org/wp-content/uploads/2015/09/CCUF_Policy-Perspectives-Paper_VERSION_GB-2.pdf

108. Toth, A., S. Rendall, and F. Reitsma, 2016: Resilient food systems: A qualitative tool for measuring food resilience. *Urban Ecosystems*, **19** (1), 19-43. http://dx.doi.org/10.1007/s11252-015-0489-x

109. Department of the Interior Strategic Sciences Group, 2013: Operational Group Sandy Technical Progress Report. U.S. Department of the Interior, Strategic Sciences Group, Reston, VA, 75 pp. https://coastal.er.usgs.gov/hurricanes/sandy/sandy_tech_122413.pdf

110. C40 Cities and Arup, 2015: Climate Action in Megacities 3.0. C40 Cities-Arup Partnership, London, UK, 127 pp. http://www.cam3.c40.org/images/C40ClimateActionInMegacities3.pdf

111. Arup, Regional Plan Association, and Siemens, 2013: Toolkit for Resilient Cities: Infrastructure, Technology and Urban Planning. Arup, Regional Plan Association, and Siemens, New York, NY, 65 pp. http://www.acclimatise.uk.com/login/uploaded/resources/SiemensResilience_InteractPDF_2013-09-25.pdf

112. Charleston Resilience Network, 2016: Understanding the October 2015 Charleston Floods: A Symposium Report. Charleston Resilience Network, Charleston, SC, 53 pp. http://www.charlestonresilience.net/wp-content/uploads/2017/03/CRN_Flood_Symposium_Report-_FINAL.pdf

113. Rashidi, K. and A. Patt, 2018: Subsistence over symbolism: The role of transnational municipal networks on cities' climate policy innovation and adoption. *Mitigation and Adaptation Strategies for Global Change*, **23** (4), 507-523. http://dx.doi.org/10.1007/s11027-017-9747-y

114. Carlson, K. and S. McCormick, 2015: American adaptation: Social factors affecting new developments to address climate change. *Global Environmental Change*, **35**, 360-367. http://dx.doi.org/10.1016/j.gloenvcha.2015.09.015

115. Hughes, S., 2015: A meta-analysis of urban climate change adaptation planning in the U.S. *Urban Climate*, **14, Part 1**, 17-29. http://dx.doi.org/10.1016/j.uclim.2015.06.003

116. Koski, C. and A. Siulagi, 2016: Environmental harm or natural hazard? Problem identification and adaptation in U.S. municipal climate action plans. *Review of Policy Research*, **33** (3), 270-290. http://dx.doi.org/10.1111/ropr.12173

117. Rosenzweig, C., W. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal, T. Bowman, and S. Ali Ibrahim, 2015: ARC3.2 Summary for City Leaders. Urban Climate Change Research Network, Columbia University, New York. http://uccrn.org/arc3-2/

118. Aerts, J.C.J.H., W.J.W. Botzen, K. Emanuel, N. Lin, H. de Moel, and E.O. Michel-Kerjan, 2014: Evaluating flood resilience strategies for coastal megacities. *Science*, **344** (6183), 473-475. http://dx.doi.org/10.1126/science.1248222

119. EPA, 2017: Smart Growth Fixes for Climate Adaptation and Resilience. U.S. Environmental Protection Agency, Washington, DC, 84 pp. https://www.epa.gov/sites/production/files/2017-01/documents/smart_growth_fixes_climate_adaptation_resilience.pdf

120. Moser, S.C., J. Coffee, and A. Seville, 2017: Rising to the Challenge, Together: A Review and Critical Assessment of the State of the US Climate Adaptation Field. Kresge Foundation, Troy, MI, 105 pp. https://kresge.org/content/rising-challenge-together

121. Blue, J., R.A. Krop, N. Hiremath, C. Gillette, J. Rooke, C.L. Knutson, and K. Smith, 2015: Drought Management in a Changing Climate: Using Cost-Benefit Analyses to Assist Drinking Water Utilities. Web Report #4546. Water Research Foundation, Denver, CO, 167 pp. https://cadmusgroup.com/wp-content/uploads/2015/08/WaterRF_Drought-Management.pdf

122. EPA, 2015: Systems Measures of Water Distribution System Resilience. EPA/600/R-14/383. U.S. Environmental Protection Agency, Washington, DC, 52 pp. https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=521634&Lab=NHSRC

123. Anguelovski, I., L. Shi, E. Chu, D. Gallagher, K. Goh, Z. Lamb, K. Reeve, and H. Teicher, 2016: Equity impacts of urban land use planning for climate adaptation: Critical perspectives from the global north and south. *Journal of Planning Education and Research*, **36** (3), 333-348. http://dx.doi.org/10.1177/0739456x16645166

124. Kashem, S.B., B. Wilson, and S. Van Zandt, 2016: Planning for climate adaptation: Evaluating the changing patterns of social vulnerability and adaptation challenges in three coastal cities. *Journal of Planning Education and Research*, **36** (3), 304-318. http://dx.doi.org/10.1177/0739456x16645167

125. Chan, A.Y. and K.G. Hopkins, 2017: Associations between sociodemographics and green infrastructure placement in Portland, Oregon. *Journal of Sustainable Water in the Built Environment*, **3** (3), 05017002. http://dx.doi.org/10.1061/JSWBAY.0000827

126. Brown, R.D., J. Vanos, N. Kenny, and S. Lenzholzer, 2015: Designing urban parks that ameliorate the effects of climate change. *Landscape and Urban Planning*, **138**, 118-131. http://dx.doi.org/10.1016/j.landurbplan.2015.02.006

127. Estrada, F., W.J.W. Botzen, and R.S.J. Tol, 2017: A global economic assessment of city policies to reduce climate change impacts. *Nature Climate Change*, **7** (6), 403-406. http://dx.doi.org/10.1038/nclimate3301

128. Georgescu, M., P.E. Morefield, B.G. Bierwagen, and C.P. Weaver, 2014: Urban adaptation can roll back warming of emerging megapolitan regions. *Proceedings of the National Academy of Sciences of the United States of America*, **111** (8), 2909-2914. http://dx.doi.org/10.1073/pnas.1322280111

129. Moore, T.L., J.S. Gulliver, L. Stack, and M.H. Simpson, 2016: Stormwater management and climate change: Vulnerability and capacity for adaptation in urban and suburban contexts. *Climatic Change*, **138** (3-4), 491-504. http://dx.doi.org/10.1007/s10584-016-1766-2

130. Stone, B.J., J. Vargo, P. Liu, D. Habeeb, A. DeLucia, M. Trail, Y. Hu, and A. Russell, 2014: Avoided heat-related mortality through climate adaptation strategies in three US cities. *PLOS ONE*, **9** (6), e100852. http://dx.doi.org/10.1371/journal.pone.0100852

131. Butler, W.H., R.E. Deyle, and C. Mutnansky, 2016: Low-regrets incrementalism: Land use planning adaptation to accelerating sea level rise in Florida's coastal communities. *Journal of Planning Education and Research*, **36** (3), 319-332. http://dx.doi.org/10.1177/0739456X16647161

132. Gober, P., R. Quay, and K.L. Larson, 2016: Outdoor water use as an adaptation problem: Insights from North American cities. *Water Resources Management*, **30** (3), 899-912. http://dx.doi.org/10.1007/s11269-015-1205-6

133. Larson, K., D. White, P. Gober, and A. Wutich, 2015: Decision-making under uncertainty for water sustainability and urban climate change adaptation. *Sustainability*, **7** (11), 14761-14784. http://www.mdpi.com/2071-1050/7/11/14761

134. Demuzere, M., K. Orru, O. Heidrich, E. Olazabal, D. Geneletti, H. Orru, A.G. Bhave, N. Mittal, E. Feliu, and M. Faehnle, 2014: Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*, **146**, 107-115. http://dx.doi.org/10.1016/j.jenvman.2014.07.025

135. Iacob, O., J.S. Rowan, I. Brown, and C. Ellis, 2014: Evaluating wider benefits of natural flood management strategies: An ecosystem-based adaptation perspective. *Hydrology Research*, **45** (6), 774-787. http://dx.doi.org/10.2166/nh.2014.184

136. Kabisch, N., H. Korn, J. Stadler, and A. Bonn, 2017: Nature-based solutions to climate change adaptation in urban areas—Linkages between science, policy and practice. *Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice*. Kabisch, N., H. Korn, J. Stadler, and A. Bonn, Eds. Springer International Publishing, Cham, 1-11. http://dx.doi.org/10.1007/978-3-319-56091-5_1

137. Forest Service, 2018: Urban Nature for Human Health and Well-Being: A Research Summary for Communicating the Health Benefits of Urban Trees and Green Space. FS-1096. U.S. Department of Agriculture, Forest Service, Washington, DC, 24 pp.

138. City of Dubuque, 2017: Upper Bee Branch Creek Restoration, Dubuque, IA, accessed August 1. http://www.cityofdubuque.org/1546/Upper-Bee-Branch-Creek-Restoration

139. Romero-Lankao, P., T. McPhearson, and D.J. Davidson, 2017: The food-energy-water nexus and urban complexity. *Nature Climate Change*, **7**, 233-235. http://dx.doi.org/10.1038/nclimate3260

140. Doherty, M., K. Klima, and J.J. Hellmann, 2016: Climate change in the urban environment: Advancing, measuring and achieving resiliency. *Environmental Science & Policy*, **66**, 310-313. http://dx.doi.org/10.1016/j.envsci.2016.09.001

141. Ekstrom, J.A. and S.C. Moser, 2014: Identifying and overcoming barriers in urban climate adaptation: Case study findings from the San Francisco Bay Area, California, USA. *Urban Climate*, **9**, 54-74. http://dx.doi.org/10.1016/j.uclim.2014.06.002

142. Shi, L., E. Chu, and J. Debats, 2015: Explaining progress in climate adaptation planning across 156 U.S. municipalities. *Journal of the American Planning Association*, **81** (3), 191-202. http://dx.doi.org/10.1080/01944363.2015.1074526

143. Clark, G. and G. Clark, 2014: Nations and the Wealth of Cities: A New Phase in Public Policy. Centre for London, London, UK, 66 pp. http://www.centreforlondon.org/wp-content/uploads/2016/08/CFLGCI_Nations_and_the_Wealth_of_Cities-optimised.pdf

144. Bulkeley, H., G.A.S. Edwards, and S. Fuller, 2014: Contesting climate justice in the city: Examining politics and practice in urban climate change experiments. *Global Environmental Change-Human and Policy Dimensions*, **25**, 31-40. http://dx.doi.org/10.1016/j.gloenvcha.2014.01.009

145. UN-Habitat, 2016: Urbanization and Development: Emerging Futures. World Cities report 2016. HS/038/16E. United Nations Human Settlements Programme (UN-Habitat) Nairobi, Kenya, 247 pp. http://wcr.unhabitat.org/wp-content/uploads/sites/16/2016/05/WCR-%20Full-Report-2016.pdf

146. Americans for the Arts, 2017: Arts and Economic Prosperity 5: Economic Impact of the Nonprofit Arts & Culture Industry. Americans for the Arts, New York, NY. https://www.americansforthearts.org/by-program/reports-and-data/research-studies-publications/arts-economic-prosperity-5

147. EIG, 2017: The 2017 Distressed Communities Index: An Analysis of Community Well-Being Across the United States. Economic Innovation Group (EIG), Washington, DC, 50 pp. http://eig.org/dci

148. Hartley, D., 2013: Urban Decline in Rust-Belt Cities. Economic Commentary 2013-06. Federal Reserve Bank of Cleveland, Cleveland, OH, 6 pp. https://www.clevelandfed.org/newsroom-and-events/publications/economic-commentary/2013-economic-commentaries/ec-201306-urban-decline-in-rust-belt-cities.aspx

149. Zhao, L., X. Lee, R.B. Smith, and K. Oleson, 2014: Strong contributions of local background climate to urban heat islands. *Nature*, **511** (7508), 216-219. http://dx.doi.org/10.1038/nature13462

150. Garuma, G.F., J.-P. Blanchet, É. Girard, and M. Leduc, 2018: Urban surface effects on current and future climate. *Urban Climate*, **24**, 121-138. http://dx.doi.org/10.1016/j.uclim.2018.02.003

151. Manore, C.A., R.S. Ostfeld, F.B. Agusto, H. Gaff, and S.L. LaDeau, 2017: Defining the risk of zika and chikungunya virus transmission in human population centers of the eastern United States. *PLOS Neglected Tropical Diseases*, **11** (1), e0005255. http://dx.doi.org/10.1371/journal.pntd.0005255

152. Elmqvist, T., M. Fragkias, J. Goodness, B. Güneralp, P.J. Marcotullio, R.I. McDonald, S. Parnell, M. Schewenius, M. Sendstad, K.C. Seto, and C. Wilkinson, 2013: *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities, A Global Assessment*. Springer Netherlands, 755 pp. http://dx.doi.org/10.1007/978-94-007-7088-1

153. Groffman, P.M., J. Cavender-Bares, N.D. Bettez, J.M. Grove, S.J. Hall, J.B. Heffernan, S.E. Hobbie, K.L. Larson, J.L. Morse, C. Neill, K. Nelson, J. O'Neil-Dunne, L. Ogden, D.E. Pataki, C. Polsky, R.R. Chowdhury, and M.K. Steele, 2014: Ecological homogenization of urban USA. *Frontiers in Ecology and the Environment*, **12** (1), 74-81. http://dx.doi.org/10.1890/120374

154. Szlavecz, K., P.S. Warren, and S.T.A. Pickett, 2011: Biodiversity in the urban landscape. *The Human Population: Its Influence on Biological Diversity*. Cincotta, R.P. and L.J. Gorenflo, Eds. Springer-Verlag, Berlin, 75-98.

155. Uejio, C.K., O.V. Wilhelmi, J.S. Golden, D.M. Mills, S.P. Gulino, and J.P. Samenow, 2011: Intra-urban societal vulnerability to extreme heat: The role of heat exposure and the built environment, socioeconomics, and neighborhood stability. *Health & Place*, **17** (2), 498-507. http://dx.doi.org/10.1016/j.healthplace.2010.12.005

156. Sheehan, W.J., P.A. Rangsithienchai, R.A. Wood, D. Rivard, S.P. Chinratanapisit, Matthew S. , G.L. Chew, J.M. Seltzer, E.C. Matsui, and W. Phipatanakul, 2010: Pest and allergen exposure and abatement in inner-city asthma: A Work Group Report of the American Academy of Allergy, Asthma & Immunology Indoor Allergy/Air Pollution Committee. *Journal of Allergy and Clinical Immunology*, **125** (3), 575-581. http://dx.doi.org/10.1016/j.jaci.2010.01.023

157. Dannenberg, A.L., H. Frumkin, and R.J. Jackson, 2011: *Making Healthy Places: Designing and Building for Health, Well-Being, and Sustainability*. Island Press, Washington, DC, 440 pp.

158. Ghosh-Dastidar, B., D. Cohen, G. Hunter, S.N. Zenk, C. Huang, R. Beckman, and T. Dubowitz, 2014: Distance to store, food prices, and obesity in urban food deserts. *American Journal of Preventive Medicine*, **47** (5), 587-595. http://dx.doi.org/10.1016/j.amepre.2014.07.005

159. Dubowitz, T., S.N. Zenk, B. Ghosh-Dastidar, D.A. Cohen, R. Beckman, G. Hunter, E.D. Steiner, and R.L. Collins, 2015: Healthy food access for urban food desert residents: Examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutrition*, **18** (12), 2220-2230. http://dx.doi.org/10.1017/S1368980014002742

160. Jennings, V. and C. Johnson Gaither, 2015: Approaching environmental health disparities and green spaces: An ecosystem services perspective. *International Journal of Environmental Research and Public Health*, **91** (04), 376-383. http://dx.doi.org/10.5558/tfc2015-067

161. Taylor, L. and D.F. Hochuli, 2015: Creating better cities: How biodiversity and ecosystem functioning enhance urban residents' wellbeing. *Urban Ecosystems*, **18** (3), 747-762. http://dx.doi.org/10.1007/s11252-014-0427-3

162. Johnston, M., 2004: Impacts and adaptation for climate change in urban forests. In *Fires, Storms and Pests—Crises in Our Urban Forests (6th Canadian Urban Forest Conference)*, Kelowna, B.C., Oct 20-21. Saskatchewan Research Council, 14 pp. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.388.6766&rep=rep1&type=pdf

163. Nowak, D.J. and E.J. Greenfield, 2012: Tree and impervious cover change in US cities. *Urban Forestry & Urban Greening*, **11** (1), 21-30. http://dx.doi.org/10.1016/j.ufug.2011.11.005

164. Beavers, R., A. Babson, and C. Schupp, 2016: Coastal Adaptation Strategies Handbook. NPS 999/134090. U.S. Department of the Interior, National Park Service, Washington, DC, 140 pp. https://www.nps.gov/subjects/climatechange/coastalhandbook.htm

165. Eddins, Q.W., 2015: Rising Vulnerability to Floods Risks Devastating Property Losses in U.S. Cities. CBRE Research, Los Angeles, CA. https://www.linkedin.com/pulse/rising-vulnerability-floods-risks-devastating-property-quinn-eddins

166. Ranson, M., T. Tarquinio, and A. Lew, 2016: Modeling the Impact of Climate Change on Extreme Weather Losses. National Center for Environmental Economics (NCEE), U.S. Environmental Protection Agency, Washington, DC.

167. Dinan, T., 2017: Projected increases in hurricane damage in the United States: The role of climate change and coastal development. *Ecological Economics*, **138**, 186-198. http://dx.doi.org/10.1016/j.ecolecon.2017.03.034

168. Holtz, D., A. Markham, K. Cell, and B. Ekwurzel, 2014: National Landmarks at Risk: How Rising Seas, Floods, and Wildfires Are Threatening the United States' Most Cherished Historic Sites. Union of Concerned Scientists, Cambridge, MA, 72 pp. http://www.ucsusa.org/landmarksatrisk

169. Markham, A., E. Osipova, K. Lafrenz Samuels, and A. Caldas, 2016: World Heritage and Tourism in a Changing Climate. UNESCO and UNEP, Nairobi, Kenya; Paris, France, 104 pp. http://whc.unesco.org/en/activities/883/

170. Newport Restoration Foundation, 2016: Keeping 74 Bridge Street Above Water: Lessons from the City of Newport and the Point Neighborhood on Protecting Historic Structures and Neighborhoods from the Impacts of Climate Change [exhibition booklet]. Newport, RI, 39 pp. http://historyabovewater.org/wp-content/uploads/2016/09/74-Bridge-Case-Study-Booklet.pdf

171. Lane, K., K. Charles-Guzman, K. Wheeler, Z. Abid, N. Graber, and T. Matte, 2013: Health effects of coastal storms and flooding in urban areas: A review and vulnerability assessment. *Journal of Environmental and Public Health*, **2013**, 913064. http://dx.doi.org/10.1155/2013/913064

172. Stanke, C., M. Kerac, C. Prudhomme, J. Medlock, and V. Murray, 2013: Health effects of drought: A systematic review of the evidence. *PLoS Currents: Disasters*. http://dx.doi.org/10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b004

173. Ahdoot, S. and S.E. Pacheco, 2015: Global climate change and children's health. *Pediatrics*, **136** (5), e1-e17. http://dx.doi.org/10.1542/peds.2015-3233

174. Clayton, S., C. Manning, K. Krygsman, and M. Speiser, 2017: Mental Health and Our Changing Climate: Impacts, Implications, and Guidance. American Psychological Association and ecoAmerica, Washington, DC, 69 pp. https://www.apa.org/news/press/releases/2017/03/mental-health-climate.pdf

175. Leisnham, P.T. and S.A. Juliano, 2012: Impacts of climate, land use, and biological invasion on the ecology of immature *Aedes* mosquitoes: Implications for La Crosse emergence. *EcoHealth*, **9** (2), 217-228. http://dx.doi.org/10.1007/s10393-012-0773-7

176. LaDeau, S.L., P.T. Leisnham, D. Biehler, and D. Bodner, 2013: Higher mosquito production in low-income neighborhoods of Baltimore and Washington, DC: Understanding ecological drivers and mosquito-borne disease risk in temperate cities. *International Journal of Environmental Research and Public Health*, **10** (4), 1505-1526. http://dx.doi.org/10.3390/ijerph10041505

177. Liu, Z., M.C. Wimberly, A. Lamsal, T.L. Sohl, and T.J. Hawbaker, 2015: Climate change and wildfire risk in an expanding wildland–urban interface: A case study from the Colorado Front Range Corridor. *Landscape Ecology*, **30** (10), 1943-1957. http://dx.doi.org/10.1007/s10980-015-0222-4

178. U.S. Census Bureau, 2016: Measuring America: Our Changing Landscape [Infographic]. U.S. Census Bureau, Washington, DC. https://www.census.gov/content/dam/Census/library/visualizations/2016/comm/acs-rural-urban.pdf

179. USDA ERS, 2017: Rural Employment and Unemployment. USDA, Economic Research Service (ERS), Washington, DC. https://www.ers.usda.gov/topics/rural-economy-population/employment-education/rural-employment-and-unemployment/

180. McCormick, K., S. Anderberg, L. Coenen, and L. Neij, 2013: Advancing sustainable urban transformation. *Journal of Cleaner Production*, **50**, 1-11. http://dx.doi.org/10.1016/j.jclepro.2013.01.003

181. IBM, 2017: Smarter Cities Challenge: The Challenge. IBM. https://www.smartercitieschallenge.org/about

182. U.S. Federal Government, 2016: U.S. Climate Resilience Toolkit: Environment and Natural Resources [web page]. U.S. Global Change Research Program, Washington, DC. https://toolkit.climate.gov/topics/built-environment/environment-and-natural-resources

183. Lovell, S.T. and J.R. Taylor, 2013: Supplying urban ecosystem services through multifunctional green infrastructure in the United States. *Landscape Ecology*, **28** (8), 1447-1463. http://dx.doi.org/10.1007/s10980-013-9912-y

184. Baldwin, C. and R. King, 2017: What About the People? The Socially Sustainable, Resilient Community and Urban Development. Oxford Brookes University, Oxford, UK, 103 pp. http://be.brookes.ac.uk/research/iag/resources/what-about-the-people.pdf

185. Mishra, V., A.R. Ganguly, B. Nijssen, and D.P. Lettenmaier, 2015: Changes in observed climate extremes in global urban areas. *Environmental Research Letters*, **10** (2), 024005. http://dx.doi.org/10.1088/1748-9326/10/2/024005

186. Pretzsch, H., P. Biber, E. Uhl, J. Dahlhausen, G. Schütze, D. Perkins, T. Rötzer, J. Caldentey, T. Koike, T.v. Con, A. Chavanne, B.d. Toit, K. Foster, and B. Lefer, 2017: Climate change accelerates growth of urban trees in metropolises worldwide. *Scientific Reports*, **7** (1), 15403. http://dx.doi.org/10.1038/s41598-017-14831-w

187. Albouy, D., W. Graf, R. Kellogg, and H. Wolff, 2016: Climate amenities, climate change, and American quality of life. *Journal of the Association of Environmental and Resource Economists*, **3** (1), 205-246. http://dx.doi.org/10.1086/684573

188. Lombardo, F.T. and B.M. Ayyub, 2015: Analysis of Washington, DC, wind and temperature extremes with examination of climate change for engineering applications. ASCE-ASME *Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, **1** (1), 04014005. http://dx.doi.org/10.1061/AJRUA6.0000812

189. Robert, A. and M. Kummert, 2012: Designing net-zero energy buildings for the future climate, not for the past. *Building and Environment*, **55**, 150-158. http://dx.doi.org/10.1016/j.buildenv.2011.12.014

190. American Institute of Architects and National Institute of Building Sciences, 2015: Industry Statement on Resilience: Preparing to Thrive: The Building Industry Statement on Resilience. Washington, DC, 24 pp. http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/Docs/WHRS_SignatoryReport_final.pdf

191. TCFD, 2017: Final Report: Recommendations of the Task Force on Climate-Related Financial Disclosures. Task Force on Climate-Related Financial Disclosures (TCFD), Basel, Switzerland, 66 pp. https://www.fsb-tcfd.org/publications/final-recommendations-report/

192. UNDP, 2011: Paving the Way for Climate-Resilient Infrastructure: Guidance for Practitioners and Planners. United Nations Development Programme (UNDP), New York, NY, 126 pp. https://www.uncclearn.org/sites/default/files/inventory/undp_paving_the_way.pdf

193. Cook, L.M., C.J. Anderson, and C. Samaras, 2017: Framework for incorporating downscaled climate output into existing engineering methods: Application to precipitation frequency curves. *Journal of Infrastructure Systems*, **23** (4), 04017027. http://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000382

194. Peng, L., M.G. Stewart, and R.E. Melchers, 2017: Corrosion and capacity prediction of marine steel infrastructure under a changing environment. *Structure and Infrastructure Engineering*, **13** (8), 988-1001. http://dx.doi.org/10.1080/15732479.2016.1229798

195. Ray, P.A. and C.M. Brown, 2015: Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework. World Bank Group, Washington, DC, 125 pp. http://dx.doi.org/10.1596/978-1-4648-0477-9

196. Stratus Consulting and Denver Water, 2015: Embracing Uncertainty: A Case Study Examination of How Climate Change Is Shifting Water Utility Planning. Prepared for the Water Utility Climate Alliance (WUCA), the American Water Works Association (AWWA), the Water Research Foundation (WRF), and the Association of Metropolitan Water Agencies (AMWA) by Stratus Consulting Inc., Boulder, CO (Karen Raucher and Robert Raucher) and Denver Water, Denver, CO (Laurna Kaatz). Stratus Consulting, Boulder, CO, various pp. https://www.wucaonline.org/assets/pdf/pubs-uncertainty.pdf

197. Conlon, K.C., N.B. Rajkovich, J.L. White-Newsome, L. Larsen, and M.S. O'Neill, 2011: Preventing cold-related morbidity and mortality in a changing climate. *Maturitas*, **69** (3), 197-202. http://dx.doi.org/10.1016/j.maturitas.2011.04.004

198. Kwok, A.G. and N.B. Rajkovich, 2010: Addressing climate change in comfort standards. *Building and Environment*, **45** (1), 18-22. http://dx.doi.org/10.1016/j.buildenv.2009.02.005

199. Holmes, S.H. and C.F. Reinhart, 2011: Climate change risks from a building owner's perspective: Assessing future climate and energy price scenarios. In *Building Simulation 2011: 12th Conference of IBPSA*, Sydney, Australia, 14-16 November. International Building Performance Simulation Association (IBPSA), 2522-2529. http://www.ibpsa.org/proceedings/BS2011/P_1788.pdf

200. Dirks, J.A., W.J. Gorrissen, J.H. Hathaway, D.C. Skorski, M.J. Scott, T.C. Pulsipher, M. Huang, Y. Liu, and J.S. Rice, 2015: Impacts of climate change on energy consumption and peak demand in buildings: A detailed regional approach. *Energy*, **79**, 20-32. http://dx.doi.org/10.1016/j.energy.2014.08.081

201. Jentsch, M.F., P.A.B. James, L. Bourikas, and A.S. Bahaj, 2013: Transforming existing weather data for worldwide locations to enable energy and building performance simulation under future climates. *Renewable Energy*, **55**, 514-524. http://dx.doi.org/10.1016/j.renene.2012.12.049

202. Girvetz, E.H., E.P. Maurer, P.B. Duffy, A. Ruesch, B. Thrasher, and C. Zganjar, 2013: Making Climate Data Relevant to Decision Making: The Important Details of Spatial and Temporal Downscaling. World Bank, Washington, DC, 43 pp. https://scholarcommons.scu.edu/cgi/viewcontent.cgi?article=1012&context=ceng

203. National Academies of Sciences, Engineering, and Medicine, 2012: *Airport Climate Adaptation and Resilience*. National Academies Press, Washington, DC, 87 pp. http://dx.doi.org/10.17226/22773

204. Meyer, M., M. Flood, J. Keller, J. Lennon, G. McVoy, C. Dorney, K. Leonard, R. Hyman, and J. Smith, 2014: *Strategic Issues Facing Transportation, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report*. National Academies Press, Washington, DC, 204 pp. http://dx.doi.org/10.17226/22473

205. National Academies of Sciences, Engineering, and Medicine, 2016: *Transportation Resilience: Adaptation to Climate Change*. National Academies Press, Washington, DC, 100 pp. http://dx.doi.org/10.17226/24648

206. DOE, 2015: Climate Change and the U.S. Energy Sector: Regional Vulnerabilities and Resilience Solutions DOE/EPSA-0005. U.S. Department of Energy (DOE), Washington, DC, 189 pp. https://energy.gov/sites/prod/files/2015/10/f27/Regional_Climate_Vulnerabilities_and_Resilience_Solutions_0.pdf

207. ClimateWise, 2016: Investing For Resilience. University of Cambridge Institute for Sustainability Leadership, Cambridge, UK, 37 pp.

208. Lloyd's of London, 2017: Stranded Assets: The Transition to a Low Carbon Economy. Overview for the Insurance Industry. Lloyd's, London, UK, 33 pp. https://www.lloyds.com/~/media/files/news-and-insight/risk-insight/2017/stranded-assets.pdf

209. Woodward, M., Z. Kapelan, and B. Gouldby, 2014: Adaptive flood risk management under climate change uncertainty using real options and optimization. *Risk Analysis*, **34** (1), 75-92. http://dx.doi.org/10.1111/risa.12088

210. Kotamarthi, R., L. Mearns, K. Hayhoe, C. Castro, and D. Wuebbles, 2016: Use of Climate Information for Decision-Making and Impact Research. U.S. Department of Defense, Strategic Environment Research and Development Program Report, 55 pp. http://dx.doi.org/10.13140/RG.2.1.1986.0085

211. ASLA, 2008: Statement on Climate Change. American Society of Landscape Architects (ASLA), Washington, DC. https://asla.org/uploadedFiles/CMS/Government_Affairs/Public_Policies/climatechange.pdf

212. California Assembly, 2016: Climate Change: Infrastructure Planning. Bill No. 2800. http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB2800

213. American Institute of Architects, n.d.: Where We Stand: Climate Change, accessed June 12. https://www.aia.org/resources/77541-where-we-stand-climate-change

214. APA Council of Representatives, n.d.: Resolution on Affirming Psychologists' Role in Addressing Global Climate Change. American Psychological Association (APA), Washington, DC. http://www.apa.org/about/policy/climate-change.aspx

215. Stults, M. and S. Meerow, 2017: Professional Societies and Climate Change. The Kresge Foundation, Troy, MI, 36 pp. https://kresge.org/sites/default/files/library/env1007-psreport-0117_revised_11917.pdf

216. Task Force on Climate-Related Financial Disclosures, 2016: Implementing the Recommendations of the Task Force on Climate-Related Financial Disclosures. Financial Stability Board, New York, NY, 82 pp. https://www.fsb-tcfd.org/wp-content/uploads/2017/12/FINAL-TCFD-Annex-Amended-121517.pdf

217. Sustainable Accounting Standards Board (SASB), 2017: SASB Conceptual Framework [web site]. https://www.sasb.org/standards-setting-process/conceptual-framework/

218. Carroll, C.M., J.R. Evans, L.E. Patton, and J.L. Zimolzak, 2012: *Climate Change and Insurance*. American Bar Association Book Publishing, Chicago, IL, 250 pp.

219. Burger, M. and J. Gundlach, 2017: The Status of Climate Change Litigation: A Global Review. U.N. Environment Programme, New York, NY, 40 pp. http://columbiaclimatelaw.com/files/2017/05/Burger-Gundlach-2017-05-UN-Envt-CC-Litigation.pdf

220. Marjanac, S., L. Patton, and J. Thornton, 2017: Acts of God, human influence and litigation. *Nature Geoscience*, **10**, 616-619. http://dx.doi.org/10.1038/ngeo3019

221. CBO, 2016: Potential Increases in Hurricane Damage in the United States: Implications for the Federal Budget. Congressional Budget Office (CBO), Washington, DC, 33 pp. https://www.cbo.gov/publication/51518

222. ASCE, 2016: Failure to Act: Closing the Infrastructure Investment Gap For America's Economic Future. 2017 Infrastructure Report Card. American Society of Civil Engineers, Reston, VA, 29 pp. https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/ASCE-Failure-to-Act-2016-FINAL.pdf

223. Neumann, J.E., J. Price, P. Chinowsky, L. Wright, L. Ludwig, R. Streeter, R. Jones, J.B. Smith, W. Perkins, L. Jantarasami, and J. Martinich, 2015: Climate change risks to US infrastructure: Impacts on roads, bridges, coastal development, and urban drainage. *Climatic Change*, **131** (1), 97-109. http://dx.doi.org/10.1007/s10584-013-1037-4

224. Melton, P., 2013: Designing for the next century's weather. *Environmental Building News*, **22** (10), 1-10.

225. Gerrard, M.B., 2016: Preparing clients for climate change. *GP Solo - American Bar Association*, **33** (3), 28-31. https://www.americanbar.org/groups/gpsolo/publications/gp_solo/2016/may-june/preparing_clients_climate_change/

226. Multihazard Mitigation Council, 2017: Natural Hazard Mitigation Saves: 2017 Interim Report—An Independent Study. National Institute of Building Sciences, Washington, DC, 340 pp. http://www.wbdg.org/files/pdfs/MS2_2017Interim%20Report.pdf

227. MTA, 2017: MTA Climate Adaptation Task Force Resiliency Report. Metropolitan Transit Authority (MTA), New York, NY, 33 pp. http://web.mta.info/sustainability/pdf/ResiliencyReport.pdf

228. HUD, 2014: Climate Change Adaptation Plan. U.S. Department of Housing and Urban Development (HUD), Washington, DC, 70 pp. https://www.hud.gov/sites/documents/HUD2014CCADAPTPLAN.PDF

229. Freddie Mac, 2016: Freddie Mac April 2016 Insight: Life's a Beach. http://freddiemac.mwnewsroom.com/press-releases/freddie-mac-april-2016-insight-otcqb-fmcc-1255648

230. Mills, E. and R.B. Jones, 2016: An insurance perspective on U.S. electric grid disruption costs. *The Geneva Papers on Risk and Insurance - Issues and Practice*, **41** (4), 555-586. http://dx.doi.org/10.1057/gpp.2016.9

231. Hunt, A. and P. Watkiss, 2011: Climate change impacts and adaptation in cities: A review of the literature. *Climatic Change*, **104** (1), 13-49. http://dx.doi.org/10.1007/s10584-010-9975-6

232. Kenney, W.L., D.H. Craighead, and L.M. Alexander, 2014: Heat waves, aging, and human cardiovascular health. *Medicine & Science in Sports & Exercise*, **46** (10), 1891-1899. http://dx.doi.org/10.1249/mss.0000000000000325

233. Willis, H.H. and K. Loa, 2015: Measuring the Resilience of Energy Distribution Systems. RR-883-DOE. RAND Corporation, Santa Monica, CA, 38pp. https://www.rand.org/pubs/research_reports/RR883.html

234. Zamuda, C., B. Mignone, D. Bilello, K. Hallett, C. Lee, J. Macknick, R. Newmark, and D. Steinberg, 2013: U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather. U.S. Department of Energy, Office of Policy and International Affairs, various pp. https://www.energy.gov/sites/prod/files/2013/07/f2/20130716-Energy%20Sector%20Vulnerabilities%20Report.pdf

235. Miller, K.A., A.F. Hamlet, D.S. Kenney, and K.T. Redmond, Eds., 2016: *Water Policy and Planning in a Variable and Changing Climate: Insights from the Western United States*. CRC Press, Boca Raton, FL, 434 pp.

236. Gilchrist, J., T. Haileyesus, M. Murphy, R.D. Comstock, C. Collins, N. McIlvain, and E. Yard, 2010: Heat illness among high school athletes—United States, 2005–2009. *MMWR. Morbidity and mortality weekly report*, **59** (32), 1009-1013. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5932a1.htm

237. Evans, P.C. and P. Fox-Penner, 2014: Resilient and sustainable infrastructure for urban energy systems. *Solutions Journal*, **5** (5), 48-54. https://www.thesolutionsjournal.com/article/resilient-and-sustainable-infrastructure-for-urban-energy-systems/

238. Ernst, K.M. and B.L. Preston, 2017: Adaptation opportunities and constraints in coupled systems: Evidence from the U.S. energy-water nexus. *Environmental Science & Policy*, **70**, 38-45. http://dx.doi.org/10.1016/j.envsci.2017.01.001

239. Jabareen, Y., 2013: Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. *Cities*, **31**, 220-229. http://dx.doi.org/10.1016/j.cities.2012.05.004

240. Cortekar, J., S. Bender, M. Brune, and M. Groth, 2016: Why climate change adaptation in cities needs customised and flexible climate services. *Climate Services*, **4**, 42-51. http://dx.doi.org/10.1016/j.cliser.2016.11.002

241. Blue, J., N. Hiremath, C. Gillette, and S. Julius, 2017: Evaluating Urban Resilience to Climate Change: A Multi-Sector Approach. EPA/600/R-16/365F, U.S. Environmental Protection Agency Office of Research and Development Ed. U.S. EPA, National Center for Environmental Assessment, Washington, DC, 674 pp. https://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=322482

242. Dawson, R.J., 2015: Handling interdependencies in climate change risk assessment. *Climate*, **3** (4), 1079-1096. http://dx.doi.org/10.3390/cli3041079

243. Grannis, J., V. Arroyo, S. Hoverter, and R. Stumberg, 2014: Preparing for Climate Impacts: Lessons from the Front Lines. Georgetown Climate Center, Washington, DC, 16 pp. https://www.issuelab.org/resource/preparing-for-climate-impacts-lessons-from-the-front-lines.html

244. Bulkeley, H. and R. Tuts, 2013: Understanding urban vulnerability, adaptation and resilience in the context of climate change. *Local Environment*, **18** (6), 646-662. http://dx.doi.org/10.1080/13549839.2013.788479

245. Field, C.B., V.R. Barros, K.J. Mach, M.D. Mastrandrea, M.v. Aalst, W.N. Adger, D.J. Arent, J. Barnett, R. Betts, T.E. Bilir, J. Birkmann, J. Carmin, D.D. Chadee, A.J. Challinor, M. Chatterjee, W. Cramer, D.J. Davidson, Y.O. Estrada, J.-P. Gattuso, Y. Hijioka, O. Hoegh-Guldberg, H.Q. Huang, G.E. Insarov, R.N. Jones, R.S. Kovats, P. Romero-Lankao, J.N. Larsen, I.J. Losada, J.A. Marengo, R.F. McLean, L.O. Mearns, R. Mechler, J.F. Morton, I. Niang, T. Oki, J.M. Olwoch, M. Opondo, E.S. Poloczanska, H.-O. Pörtner, M.H. Redsteer, A. Reisinger, A. Revi, D.N. Schmidt, M.R. Shaw, W. Solecki, D.A. Stone, J.M.R. Stone, K.M. Strzepek, A.G. Suarez, P. Tschakert, R. Valentini, S. Vicuña, A. Villamizar, K.E. Vincent, R. Warren, L.L. White, T.J. Wilbanks, P.P. Wong, and G.W. Yohe, 2014: Technical summary. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 35-94. http://www.ipcc.ch/report/ar5/wg2/

246. Romero-Lankao, P., K.R. Gurney, K.C. Seto, M. Chester, R.M. Duren, S. Hughes, L.R. Hutyra, P. Marcotullio, L. Baker, N.B. Grimm, C. Kennedy, E. Larson, S. Pincetl, D. Runfola, L. Sanchez, G. Shrestha, J. Feddema, A. Sarzynski, J. Sperling, and E. Stokes, 2014: A critical knowledge pathway to low-carbon, sustainable futures: Integrated understanding of urbanization, urban areas, and carbon. *Earth's Future*, **2** (10), 515-532. http://dx.doi.org/10.1002/2014ef000258

247. Gaffin, S.R., C. Rosenzweig, and A.Y.Y. Kong, 2012: Adapting to climate change through urban green infrastructure. *Nature Climate Change*, **2**, 704. http://dx.doi.org/10.1038/nclimate1685

248. Kettle, N.P., K. Dow, S. Tuler, T. Webler, J. Whitehead, and K.M. Miller, 2014: Integrating scientific and local knowledge to inform risk-based management approaches for climate adaptation. *Climate Risk Management*, **4–5**, 17-31. http://dx.doi.org/10.1016/j.crm.2014.07.001

249. ALA, 2015: Resolution on the Importance of Sustainable Libraries. American Library Association (ALA), Chicago, IL. http://www.ala.org/aboutala/sites/ala.org.aboutala/files/content/governance/council/council_documents/2015_annual_council_documents/cd_36_substainable_libraries_resol_final.pdf

250. Piacentini, R., 2017: When Leaders Won't Lead: Taking Action on Climate Change, accessed June 16, 2017. http://futureofmuseums.blogspot.com/2017/03/when-leaders-wont-lead-taking-action-on.html

251. Chui, A.C., A. Gittelson, E. Sebastian, N. Stamler, and S.R. Gaffin, 2018: Urban heat islands and cooler infrastructure—Measuring near-surface temperatures with hand-held infrared cameras. *Urban Climate*, **24**, 51-62. http://dx.doi.org/10.1016/j.uclim.2017.12.009

252. Pregnolato, M., A. Ford, C. Robson, V. Glenis, S. Barr, and R. Dawson, 2016: Assessing urban strategies for reducing the impacts of extreme weather on infrastructure networks. *Royal Society Open Science*, **3** (5). http://dx.doi.org/10.1098/rsos.160023

253. Derkzen, M.L., A.J.A. van Teeffelen, and P.H. Verburg, 2017: Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? *Landscape and Urban Planning*, **157**, 106-130. http://dx.doi.org/10.1016/j.landurbplan.2016.05.027

254. Donovan, G.H., 2017: Including public-health benefits of trees in urban-forestry decision making. *Urban Forestry & Urban Greening*, **22**, 120-123. http://dx.doi.org/10.1016/j.ufug.2017.02.010

255. Nowak, D.J., S. Hirabayashi, A. Bodine, and E. Greenfield, 2014: Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, **193**, 119-129. http://dx.doi.org/10.1016/j.envpol.2014.05.028

256. Nowak, D.J., N. Appleton, A. Ellis, and E. Greenfield, 2017: Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States. *Urban Forestry & Urban Greening*, **21**, 158-165. http://dx.doi.org/10.1016/j.ufug.2016.12.004

257. Younger, M., H.R. Morrow-Almeida, S.M. Vindigni, and A.L. Dannenberg, 2008: The built environment, climate change, and health: Opportunities for co-benefits. *American Journal of Preventive Medicine*, **35** (5), 517-526. http://dx.doi.org/10.1016/j.amepre.2008.08.017

258. Chen, C., M. Doherty, J. Coffee, T. Wong, and J. Hellmann, 2016: Measuring the adaptation gap: A framework for evaluating climate hazards and opportunities in urban areas. *Environmental Science & Policy*, **66**, 403-419. http://dx.doi.org/10.1016/j.envsci.2016.05.007