Overview: Understanding Risks, Impacts, and Responses

Fifth National Climate Assessment

U.S. Global Change Research Program

Chapter 1. Overview: Understanding Risks, Impacts, and Responses

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Tammy West

The Fifth National Climate Assessment documents observed and projected vulnerabilities, risks, and impacts associated with climate change across the United States and provides examples of response actions underway in many communities. This Overview presents highlights from the Assessment, providing summary findings and a synthesis of material from the underlying chapters. Curly brackets indicate cross-references to full chapters (e.g., {Ch. 2}), Key Messages (e.g., {2.1}), figures (e.g., {Figure 32.8}), and other text elements.

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Margaret Plumley

How the United States Is Addressing Climate Change

The effects of human-caused climate change are already far-reaching and worsening across every region of the United States. Rapidly reducing greenhouse gas emissions can limit future warming and associated increases in many risks. Across the country, efforts to adapt to climate change and reduce emissions have expanded since 2018, and US emissions have fallen since peaking in 2007. However, without deeper cuts in global net greenhouse gas emissions and accelerated adaptation efforts, severe climate risks to the United States will continue to grow.

Future climate change impacts depend on choices made today

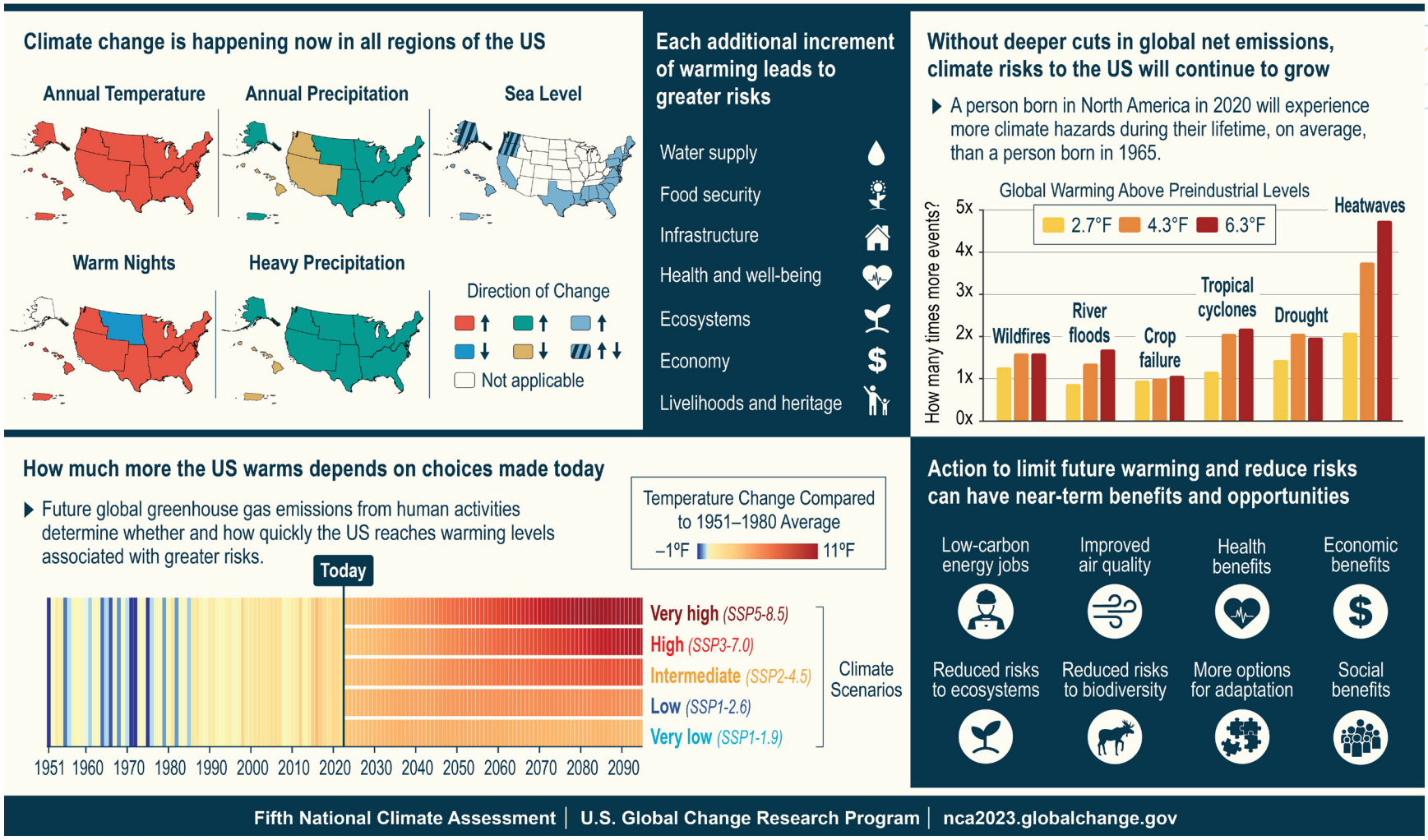
The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases. {2.3, 19.1}

However, this also means that each increment of warming that the world avoids—through actions that cut emissions or remove carbon dioxide (CO_2) from the atmosphere—reduces the risks and harmful impacts of climate change. While there are still uncertainties about how the planet will react to rapid warming, the degree to which climate change will continue to worsen is largely in human hands. {2.3, 3.4}

In addition to reducing risks to future generations, rapid emissions cuts are expected to have immediate health and economic benefits (Figure 1.1). At the national scale, the benefits of deep emissions cuts for current and future generations are expected to far outweigh the costs. {2.1, 2.3, 13.3, 14.5, 15.3, 32.4; Ch. 2, Introduction}

Taelyn B.

Climate Change Risks and Opportunities in the US



Climate change presents risks while action to limit warming and reduce risks presents opportunities for the US.

Figure 1.1. (**top left**) Changes in multiple aspects of climate are apparent in every US region. The five maps present observed changes for five temperature, precipitation, and sea level rise metrics: 1) warming is apparent in every region (based on changes in annual average temperature in 2002–2021 compared to the 1901–1960 average for the contiguous United States, Hawai'i, and Puerto Rico and to 1925–1960 for Alaska); 2) the number of warm nights per year (days with minimum temperatures at or above 70°F in 2002–2021 compared to 1901–1960) is increasing everywhere except the Northern Great Plains, where they have decreased, and in Alaska, where nights above 70°F are not common; 3) average annual precipitation is increasing in most regions, except in the Northwest, Southwest, and Hawai'i, where precipitation has decreased (same time periods as annual average temperature); 4) heavy precipitation events are increasing everywhere except Hawai'i and the US Caribbean, where there has been a decrease (trends over the period 1958–2021); and 5) relative sea levels are increasing along much of the US coast except in Oregon, Washington, and Alaska, where there is a mix of both increases and decreases (trends over 1990–2020). {2.2, 9.1; Figures 2.4, 2.5, 2.7, 2.8}

(**top center**) Every fraction of a degree of additional warming will lead to increasing risks across multiple sectors in the US (see Table 1.2 and "Current and Future Climate Risks to the United States" below). Without rapid, substantial reductions in the greenhouse gases that cause global warming, these climate risks in the US are expected to increase.

(**top right**) People born in North America in 2020, on average, will be exposed to more climate-related hazards compared to people born in 1965. How many more extreme climate events current generations experience compared to previous generations will depend on the level of future warming. {Figure 15.4}

(**bottom left**) This climate stripes chart shows the observed changes in US annual average surface temperature for 1951–2022 and projected changes in temperature for 2023–2095 for five climate scenarios, ranging from a very high scenario, where greenhouse gas emissions continue to increase through most of the century, to a very low scenario, where emissions decline rapidly, reaching net zero by around midcentury (see Figure 1.4 and Table 3 in the Guide to the Report). Each vertical stripe represents the observed or projected change in temperature for a given year compared to the 1951–1980 average; changes are averaged over all 50 states and Puerto Rico but do not include data for the US-Affiliated Pacific Islands and the US Virgin Islands (see also Figure 1.13).

(**bottom right**) Although climate benefits from even the most aggressive emissions cuts may not be detectable before the middle of the century, there are many other potential near-term benefits and opportunities from actions that reduce greenhouse gas emissions. {2.3, 8.3, 10.3, 13.3, 14.5, 15.3, 19.1, 31.3, 32.4}

Figure credits: (top left, top center, top right, bottom right) USGCRP, USGCRP/ICF, NOAA NCEI, and CISESS NC; (bottom left) adapted from panel (c) of Figure SPM.1 in IPCC 2023.

Box 1.1. Mitigation, Adaptation, and Resilience

Throughout this report, three important terms are used to describe the primary options for reducing the risks of climate change:

- **Mitigation**: Measures to reduce the amount and rate of future climate change by reducing emissions of heat-trapping gases (primarily carbon dioxide) or removing greenhouse gases from the atmosphere.
- **Adaptation**: The process of adjusting to an actual or expected environmental change and its effects in a way that seeks to moderate harm or exploit beneficial opportunities.
- **Resilience**: The ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover rapidly from adverse conditions and disruptions.

James Keul

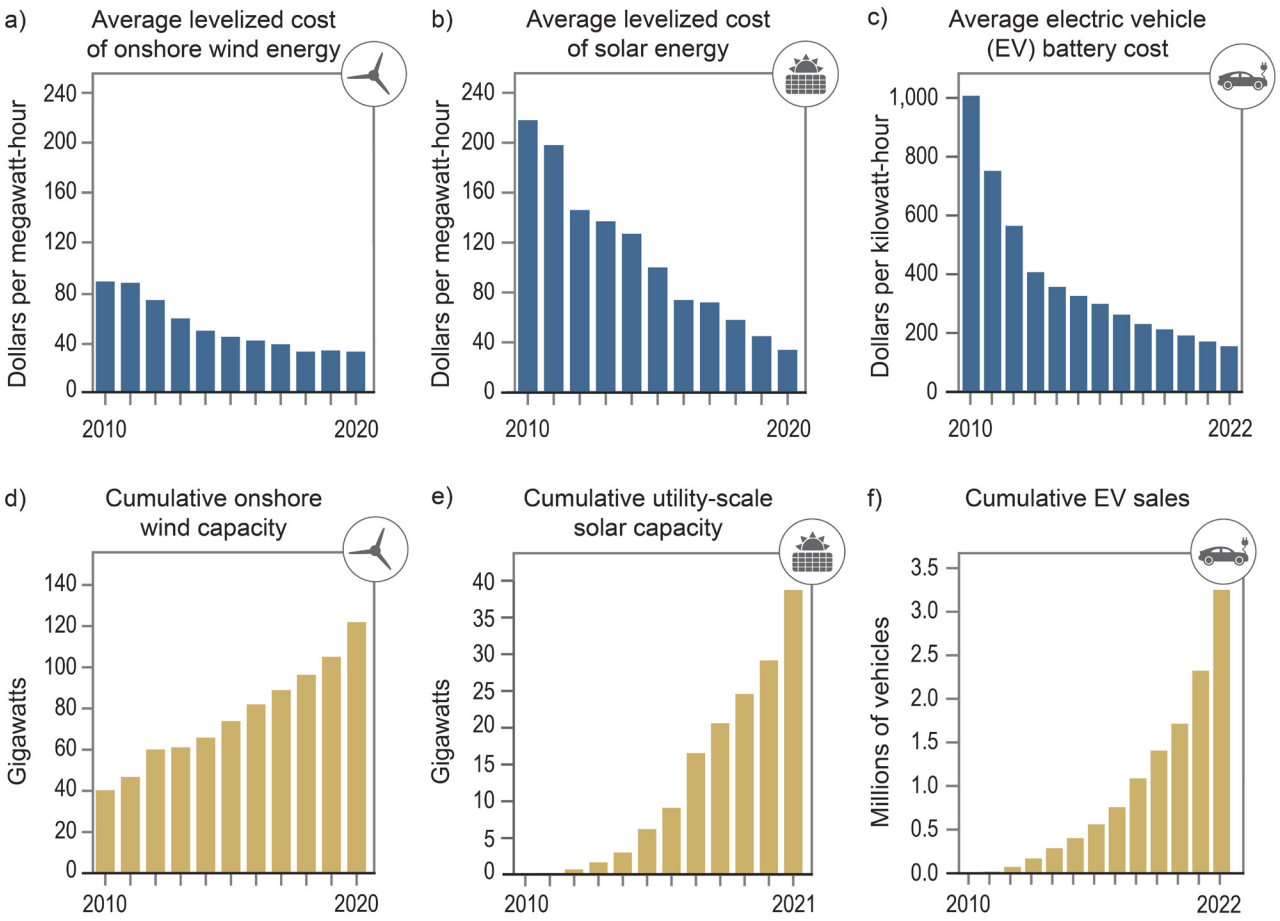
US emissions have decreased, while the economy and population have grown

Annual US greenhouse gas emissions fell 12% between 2005 and 2019. This trend was largely driven by changes in electricity generation: coal use has declined, while the use of natural gas and renewable technologies has increased, leading to a 40% drop in emissions from the electricity sector. Since 2017, the transportation sector has overtaken electricity generation as the largest emitter. {11.1, 13.1, 32.1; Figures 32.1, 32.3}

As US emissions have declined from their peak in 2007, the country has also seen sustained reductions in the amount of energy required for a given quantity of economic activity and the emissions produced per unit of energy consumed. Meanwhile, both population and per capita GDP have continued to grow. {32.1; Figures 32.1, 32.2}

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources (Figures 1.2, 1.3). {5.3, 12.3, 32.1, 32.2; Figure A4.17}

Across all sectors, innovation is expanding options for reducing energy demand and increasing energy efficiency, moving to zero- and low-carbon electricity and fuels, electrifying energy use in buildings and transportation, and adopting practices that protect and improve natural carbon sinks that remove and store CO_2 from the atmosphere, such as sustainable agricultural and land-management practices. {11.1, 32.2, 32.3; Boxes 32.1, 32.2; Focus on Blue Carbon}



Historical Trends in Unit Costs and Deployment of Low-Carbon Energy Technologies in the United States

Increasing capacities and decreasing costs of low-carbon energy technologies are supporting efforts to further reduce emissions.

Figure 1.2. Costs of onshore wind (**a**), solar photovoltaics (**b**), and electric vehicle (EV) batteries (**c**) have decreased sharply since 2000 (data shown here start in 2010), as the cumulative capacities of wind and solar generation (**d** and **e**) and the cumulative number of EVs sold (**f**) have increased. {Figure 32.8} Figure credit: Electric Power Research Institute, National Renewable Energy Laboratory, NOAA NCEI, and CISESS NC.

Accelerating advances in adaptation can help reduce rising climate risks

As more people face more severe climate impacts, individuals, organizations, companies, communities, and governments are taking advantage of adaptation opportunities that reduce risks. State climate assessments and online climate services portals are providing communities with location- and sector-specific information on climate hazards to support adaptation planning and implementation across the country. New tools, more data, advancements in social and behavioral sciences, and better consideration of practical experiences are facilitating a range of actions (Figure 1.3). {7.3, 12.3, 21.4, 25.4, 31.1, 31.5, 32.5; Table 31.1}

Actions include:

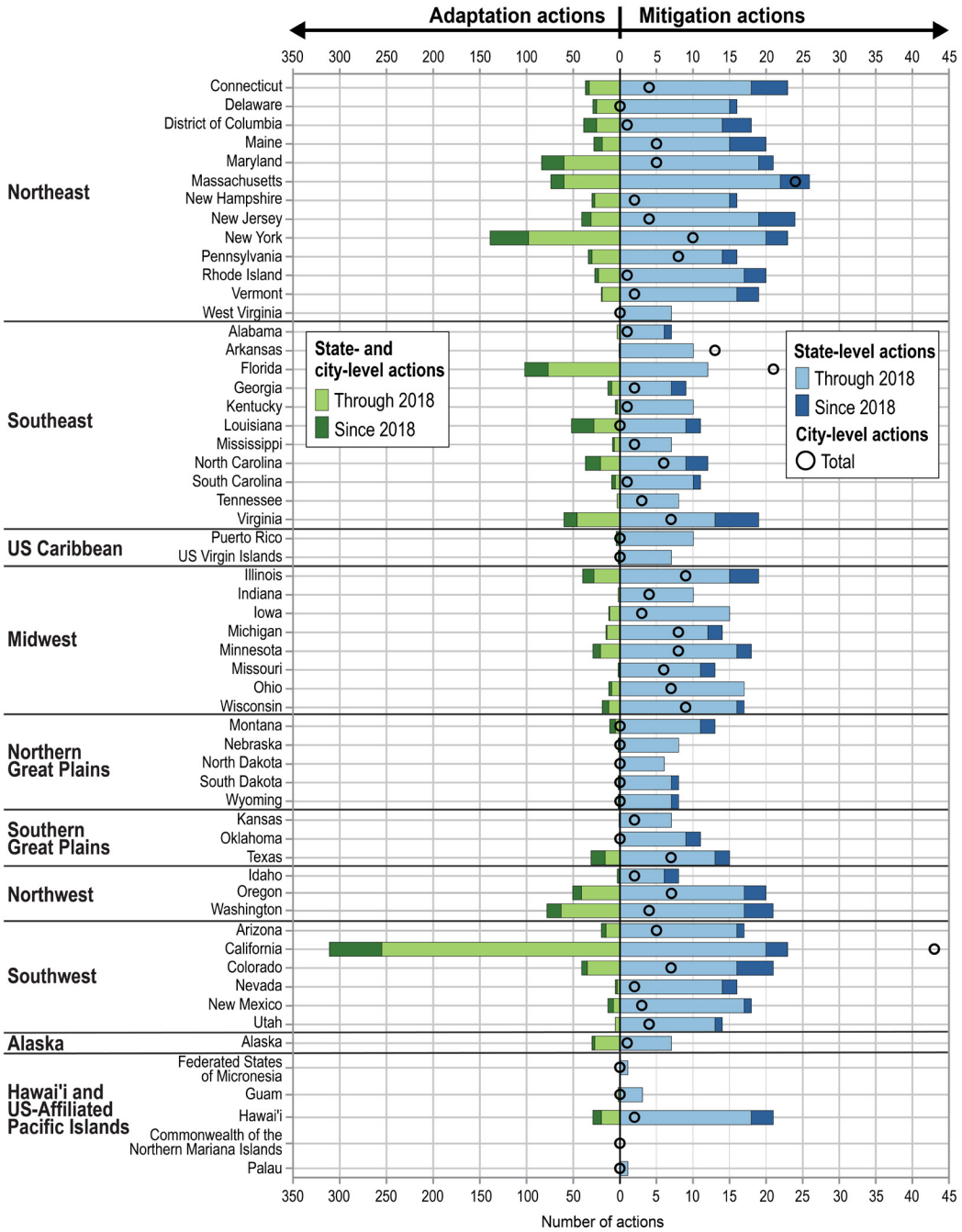
- Implementing nature-based solutions—such as restoring coastal wetlands or oyster reefs—to reduce shoreline erosion {8.3, 9.3, 21.2, 23.5}
- Upgrading stormwater infrastructure to account for heavier rainfall {4.2}
- Applying innovative agricultural practices to manage increasing drought risk {11.1, 22.4, 25.5}
- Assessing climate risks to roads and public transit {13.1}
- Managing vegetation to reduce wildfire risk {5.3}
- Developing urban heat plans to reduce health risks from extreme heat {12.3, 21.1, 28.4}
- Planning relocation from high-risk coastal areas {9.3}

Despite an increase in adaptation actions across the country, current adaptation efforts and investments are insufficient to reduce today's climate-related risks and keep pace with future changes in the climate. Accelerating current efforts and implementing new ones that involve more fundamental shifts in systems and practices can help address current risks and prepare for future impacts (see "Mitigation and adaptation actions can result in systemic, cascading benefits" below). {31.1, 31.3}

Pam DeChellis

Climate action has increased in every region of the US

Efforts to adapt to climate change and reduce net greenhouse gas emissions are underway in every US region and have expanded since 2018 (Figure 1.3; Table 1.1). Many actions can achieve both adaptation and mitigation goals. For example, improved forest- or land-management strategies can both increase carbon storage and protect ecosystems, and expanding renewable energy options can reduce emissions while also improving resilience. {31.1, 32.5}



US Adaptation and Mitigation Actions

Cities and states are acting on climate change, with a substantial increase in new activities underway since 2018.

Figure 1.3. Since 2018, city- and state-level adaptation plans and actions (**green bars**, left) increased by 32%, complemented by a 14% increase in the total number of new state-level mitigation activities (**blue bars**, right; 69% have updated their policies). In 2021 there were 271 city-level mitigation actions in place (**open circles**, right), according to the Global Climate Action Tracker. Renewable energy and energy efficiency projects on Tribal lands have also expanded (not shown). {31.1, 32.5; Figure 16.4; Table 1.1} Figure credit: US Army Corps of Engineers, EPA, Pennsylvania State University, NOAA NCEI, and CISESS-NC.

Climate adaptation and mitigation efforts involve trade-offs, as climate actions that benefit some or even most people can result in burdens to others. To date, some communities have prioritized equitable and inclusive planning processes that consider the social impacts of these trade-offs and help ensure that affected communities can participate in decision-making. As additional measures are implemented, more widespread consideration of their social impact can help inform decisions around how to distribute the outcomes of investments. {12.4, 13.4, 20.2, 21.3, 21.4, 26.4, 27.1, 31.2, 32.4, 32.5; Box 20.1}

Table 1.1. Climate Actions Are Taking Place Across All US Regions

Examples of recent local adaptation, resilience, and mitigation actions around the country follow.

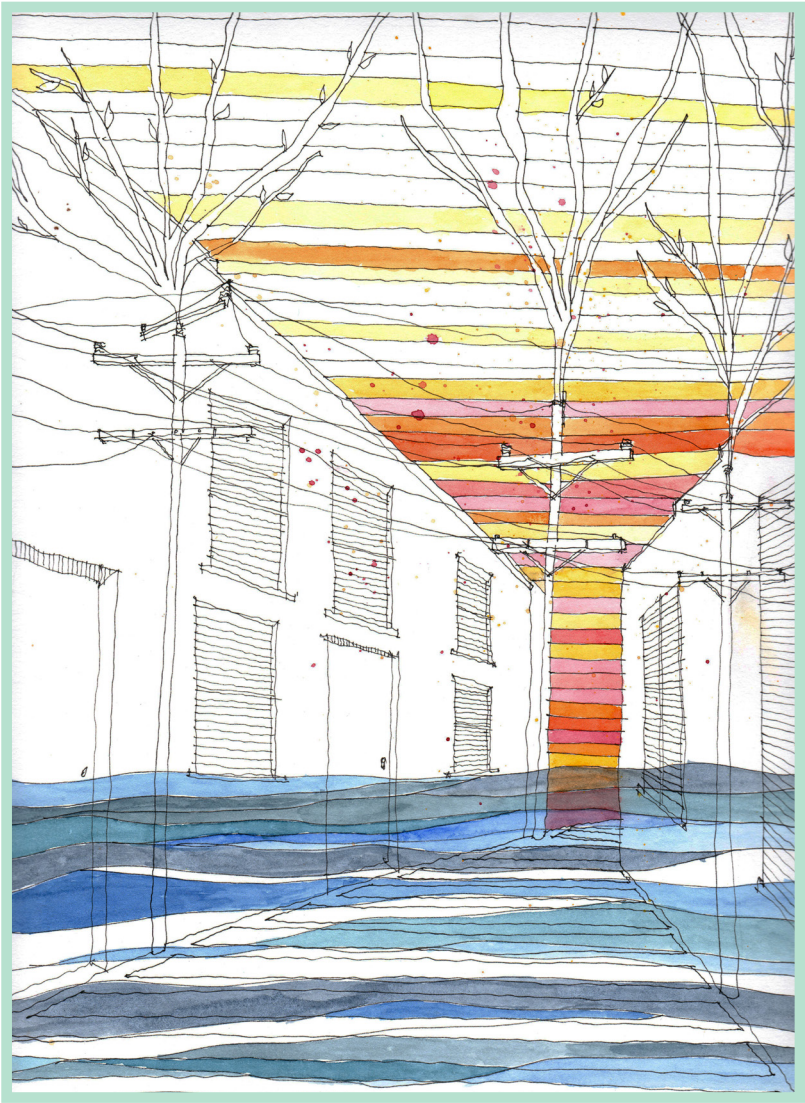
Region	Action
Northeast	The 2022 stormwater code in Pittsburgh, Pennsylvania, requires new developments to plan for projected increases in heavy rainfall under climate change rather than building to historical rainfall amounts. In 2021, the city also committed to achieve carbon neutrality by 2050. {Box 21.1}
Southeast	Following repeated flooding from multiple hurricanes, measures to reduce flood risk in Princeville, North Carolina, include buyouts, elevating homes, and building housing that meets local flood standards. In Orlando, Florida, the city and businesses are adopting commercial building energy-efficiency requirements and electric vehicle readiness policies and have used wastewater and food scraps from parks and resorts to generate renewable biogas. {Boxes 22.1, 32.3}
US Caribbean	Many community-based organizations in Puerto Rico have undertaken actions to advance adaptation, social transformation, and sustainable development. These organizations work to expand renewable energy and equitable access to energy resources, prepare for disasters, restore ecosystems, strengthen agriculture and food security, and protect public health. {23.5}
Midwest	A wetland creation project in Ashtabula, Ohio, restored habitat displaced by shoreline development, improving coastal protection for the port on Lake Erie. In Michigan, some state forestlands are being managed to bolster carbon storage and to support recreation and wildlife habitat. {24.2, 24.4; Figure 24.9}
Northern Great Plains	The Nebraska Natural Resources Conservation Service supported farmers in testing soil health and evaluating soil management practices that promote climate adaptation. Across the region, wind electricity generation tripled between 2011 and 2021, with a growing number of Tribes leading the Nation's renewable energy transition by installing wind, solar, and hydropower. {25.3, 25.5; Box 25.3}
Southern Great Plains	Texas- and Kansas-based groups are supporting soil and land management practices that increase carbon storage while protecting important ecosystems. Wind and solar energy generation and battery storage capacities have also grown, with the region accounting for 42% of national wind-generated electricity in 2022. {26.2}
Northwest	The Confederated Tribes of the Colville Reservation are prioritizing carbon capture in their forest and timber management efforts, leading to improved air and water quality and wildlife habitat as well as preservation of cultural areas and practices. {27.3}
Southwest	In response to severe drought, seven Colorado River basin states, the US and Mexican governments, and Indigenous Peoples are collaborating to improve water conservation and develop adaptation solutions. Dozens of cities are committed to emissions reductions; for instance, Phoenix is on track to meet a 2030 goal of 50% reduction in greenhouse gas emissions from 2018 levels. {Ch. 28, Introduction; Box 28.1}
Alaska	To address climate threats to traditional foods, the Chugach Regional Resources Commission is integrating Indigenous Knowledge and Western scientific methods in its adaptation efforts, including weekly water sampling for harmful algal blooms and restoring clam populations. Kelp farming is also being developed to reduce the effects of ocean acidification, serve as a carbon sink, and generate income. {29.7; Box 29.7}
Hawai'i and US-Affiliated Pacific Islands	The Kaua'i Island Utility Cooperative achieved a 69.5% renewable portfolio standard in 2021, and the island is occasionally 100% renewably powered during midday hours; it is projected to achieve a 90% renewable portfolio by 2026. Guam, the Republic of the Marshall Islands, the Federated States of Micronesia, and Palau plan to use blue carbon ecosystems to offset emissions while also protecting coastal infrastructure. {30.3; Box 30.3}

Meeting US mitigation targets means reaching net-zero emissions

The global warming observed over the industrial era is unequivocally caused by greenhouse gas emissions from human activities—primarily burning fossil fuels. Atmospheric concentrations of carbon dioxide (CO_2)—the primary greenhouse gas produced by human activities—and other greenhouse gases continue to rise due to ongoing global emissions. Stopping global warming would require both reducing emissions of CO_2 to net zero and rapid and deep reductions in other greenhouse gases. Net-zero CO_2 emissions means that CO_2 emissions decline to zero or that any residual emissions are balanced by removal from the atmosphere. {2.3, 3.1; Ch. 32}

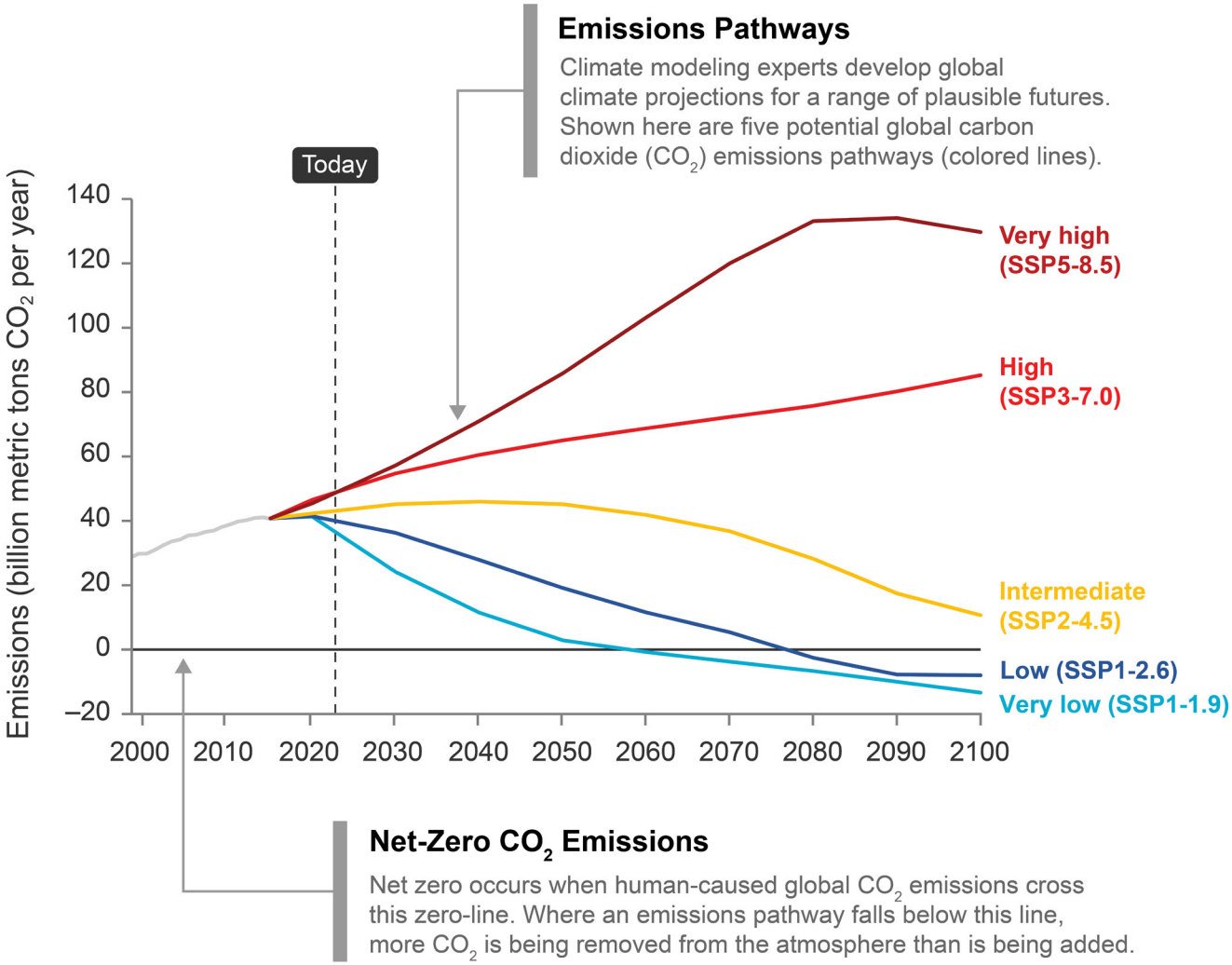
Once CO_2 emissions reach net zero, the global warming driven by CO_2 is expected to stop: additional warming over the next few centuries is not necessarily "locked in" after net CO_2 emissions fall to zero. However, global average temperatures are not expected to fall for centuries unless CO_2 emissions become net negative, which is when CO_2 removal from the atmosphere exceeds CO_2 emissions from human activities. Regardless of when or if further warming is avoided, some long-term responses to the temperature changes that have already occurred will continue. These responses include sea level rise, ice sheet losses, and associated disruptions to human health, social systems, and ecosystems. In addition, the ocean will continue to acidify after the world reaches net-zero CO_2 emissions, as it continues to gradually absorb CO_2 in the atmosphere from past emissions. {2.1, 2.3, 3.1; Ch. 2, Introduction}

National and international commitments seek to limit global warming to well below 2°C (3.6°F), and preferably to 1.5°C (2.7°F), compared to preindustrial temperature conditions (defined as the 1850–1900 average). To achieve this, global CO_2 emissions would have to reach net zero by around 2050 (Figure 1.4); global emissions of all greenhouse gases would then have to reach net zero within the following few decades. {2.3, 32.1}



Andrea Ruedy Trimble

Future Global Carbon Dioxide Emissions Pathways



Different scenarios of future carbon dioxide emissions are used to explore the range of possible climate futures.

Figure 1.4. The five scenarios shown (colored lines) demonstrate potential global carbon dioxide (CO_2) emissions pathways modeled from 2015 through 2100, with the solid light gray line showing observed global CO_2 emissions from 2000 to 2015. See Table 3 in the Guide to the Report for scenario definitions. Many projected impacts described in this report are based on a potential climate future defined by one or more of these scenarios for future CO_2 emissions from human activities, the largest long-term driver of climate change. The vertical dashed line, labeled "Today," marks the year 2023; the solid horizontal black line marks net-zero CO_2 emissions. Adapted with permission from Figure TS.4 in Arias et al. 2021.

While US greenhouse gas emissions are falling, the current rate of decline is not sufficient to meet national and international climate commitments and goals. US net greenhouse gas emissions remain substantial and would have to decline by more than 6% per year on average, reaching net-zero emissions around midcentury, to meet current national mitigation targets and international temperature goals; by comparison, US greenhouse gas emissions decreased by less than 1% per year on average between 2005 and 2019. {32.1}

Many cost-effective options that are feasible now have the potential to substantially reduce emissions over the next decade. Faster and more widespread deployment of renewable energy and other zero- and low-carbon energy options can accelerate the transition to a decarbonized economy and increase the chances of meeting a 2050 national net-zero greenhouse gas emissions target for the US. However, to reach the US net-zero emissions target, additional mitigation options need to be explored and advanced (see "Available mitigation strategies can deliver substantial emissions reductions, but additional options are needed to reach net zero" below). {5.3, 6.3, 32.2, 32.3}

David Zeiset

How the United States Is Experiencing Climate Change

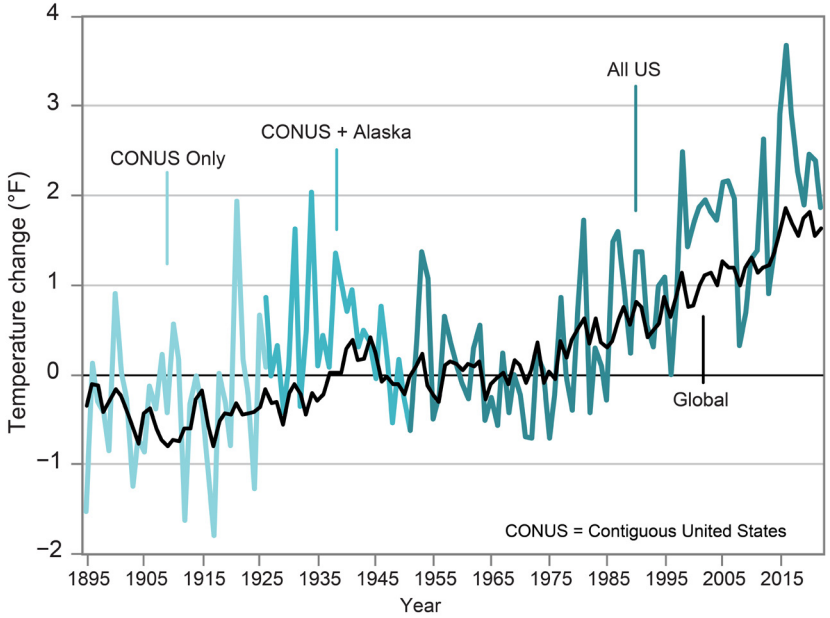
As extreme events and other climate hazards intensify, harmful impacts on people across the United States are increasing. Climate impacts—combined with other stressors—are leading to ripple effects across sectors and regions that multiply harms, with disproportionate effects on underserved and overburdened communities.

Current climate changes are unprecedented over thousands of years

Global greenhouse gas emissions from human activities continue to increase, resulting in rapid warming (Figure 1.5) and other large-scale changes, including rising sea levels, melting ice, ocean warming and acidification, changing rainfall patterns, and shifts in timing of seasonal events. Many of the climate conditions and impacts people are experiencing today are unprecedented for thousands of years (Figure 1.6). {2.1, 3.1; Figures A4.6, A4.7, A4.10, A4.13}

As the world's climate has shifted toward warmer conditions, the frequency and intensity of extreme cold events have declined over much of the US, while the frequency, intensity, and duration of extreme heat have increased. Across all regions of the US, people are experiencing warming temperatures and longer-lasting heatwaves. Over much of the country, nighttime temperatures and winter temperatures have warmed more rapidly than daytime and summer temperatures. Many other extremes, including heavy precipitation, drought, flooding, wildfire, and hurricanes, are becoming more frequent and/or severe, with a cascade of effects in every part of the country. {2.1, 2.2, 3.4, 4.1, 4.2, 7.1, 9.1; Ch. 2, Introduction; App. 4; Focus on Compound Events}

US and Global Changes in Average Surface Temperature



The US has warmed rapidly since the 1970s.

Figure 1.5. The graph shows the change in US annual average surface temperature during 1895–2022 compared to the 1951–1980 average. The temperature trend changes color as data become available for more regions of the US, with Alaska data added to the average temperature for the contiguous US (CONUS) beginning in 1926 (medium blue line) and Hawai'i, Puerto Rico, and US-Affiliated Pacific Islands data added beginning in 1951 (dark blue line). Global average surface temperature is shown by the black line. Figure credit: NOAA NCEI and CISESS NC.

Rapid and Unprecedented Changes

800k years — Present-day levels of greenhouse gases in the atmosphere are higher than at any time in at least the past 800,000 years, with most of these emissions occurring since 1970.

3,000 years — The rate of sea level rise in the 20th century was faster than in any other century in at least the last 3,000 years.

2,000 years — Global temperature has increased faster in the past 50 years than at any time in at least the past 2,000 years.

1,200 years — The current drought in the western US is now the most severe drought in at least 1,200 years and has persisted for decades.

Current climate conditions are unprecedented for thousands of years.

Figure 1.6. Human activities since industrialization have led to increases in atmospheric greenhouse gas concentrations that are unprecedented in records spanning hundreds of thousands of years. These are examples of some of the large and rapid changes in the climate system that are occurring as the planet warms. (Greenhouse gas concentrations {2.1}; sea level rise {3.4}; global temperature {2.1}; drought {2.2, 3.5}) Figure credit: USGCRP and ICF.

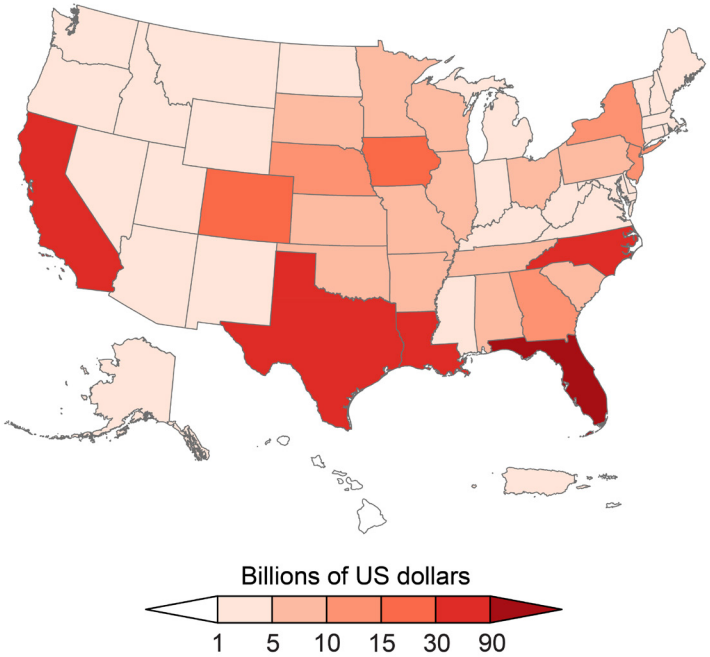
Risks from extreme events are increasing

One of the most direct ways that people experience climate change is through changes in extreme events. Harmful impacts from more frequent and severe extremes are increasing across the country—including increases in heat-related illnesses and death, costlier storm damages, longer droughts that reduce agricultural productivity and strain water systems, and larger, more severe wildfires that threaten homes and degrade air quality. {2.2, 4.2, 12.2, 14.2, 15.1, 19.2; Focus on Western Wildfires}

Extreme weather events cause direct economic losses through infrastructure damage, disruptions in labor and public services, and losses in property values. The number and cost of weather-related disasters have increased dramatically over the past four decades, in part due to the increasing frequency and intensity of extreme events and in part due to increases in assets at risk (through population growth, rising property values, and continued development in hazard-prone areas). Low-income communities, communities of color, and Tribes and Indigenous Peoples experience high exposure and vulnerability to extreme events due to both their proximity to hazard-prone areas and lack of adequate infrastructure or disaster management resources. {2.2, 4.2, 17.3, 19.1; Focus on Compound Events}

In the 1980s, the country experienced, on average, one (inflation-adjusted) billion-dollar disaster every four months. Now, there is one every three weeks, on average. Between 2018 and 2022, the US experienced 89 billion-dollar events (Figure 1.7). Extreme events cost the US close to $150 billion each year—a conservative estimate that does not account for loss of life, healthcare-related costs, or damages to ecosystem services. {2.2, 19.1; Ch. 2, Introduction; Figures 4.1, A4.5}

Damages by State from Billion-Dollar Disasters (2018–2022)



The US now experiences, on average, a billion-dollar weather or climate disaster every three weeks.

Figure 1.7. Billion-dollar weather and climate disasters are events where damages/costs reach or exceed $1 billion, including adjustments for inflation. Between 2018 and 2022, 89 such events affected the US, including 4 droughts, 6 floods, 52 severe storms, 18 tropical cyclones, 5 wildfires, and 4 winter storm events (see Figure A4.5 for the number of billion-dollar disasters per year). During this period, Texas had the highest total damages ($375 billion); Florida experienced the highest damages from a single event—Hurricane Ian ($113 billion). While similar data are not available for the US-Affiliated Pacific Islands, Super Typhoon Yutu caused $500 million in property damage alone in Saipan and the northern Marianas in 2018 (NCEI 2019). Increasing costs over time are driven by changes in the assets at risk and the increase in frequency or intensity of extreme events caused by climate change. Adapted from NCEI 2023.

Cascading and compounding impacts increase risks

The impacts and risks of climate change unfold across interacting sectors and regions. For example, wildfire in one region can affect air quality and human health in other regions, depending on where winds transport smoke. Further, climate change impacts interact with other stressors, such as the COVID-19 pandemic, environmental degradation, or socioeconomic stressors like poverty and lack of adequate housing that disproportionately impact overburdened communities. These interactions and interdependencies can lead to cascading impacts and sudden failures. For example, climate-related shocks to the food supply chain have led to local to global impacts on food security and human migration patterns that affect US economic and national security interests. {11.3, 17.1, 17.2, 17.3, 18.1, 22.3, 23.4, 31.3; Introductions in Chs. 2, 17, 18; Focus on Compound Events; Focus on Risks to Supply Chains; Focus on COVID-19 and Climate Change}

The risk of two or more extreme events occurring simultaneously or in quick succession in the same region—known as compound events—is increasing. Climate change is also increasing the risk of multiple extremes occurring simultaneously in different locations that are connected by complex human and natural systems. For instance, simultaneous megafires across multiple western states and record back-to-back Atlantic hurricanes in 2020 caused unprecedented demand on federal emergency response resources. {2.2, 3.2, 15.1, 22.2, 26.4; Focus on Compound Events; Ch. 4, Introduction}

Compound events often have cascading impacts that cause greater harm than individual events. For example, in 2020, record-breaking heat and widespread drought contributed to concurrent destructive wildfires across California, Oregon, and Washington, exposing millions to health hazards and straining firefighting resources. Ongoing drought amplified the record-breaking Pacific Northwest heatwave of June 2021, which was made 2° to 4°F hotter by climate change. The heatwave led

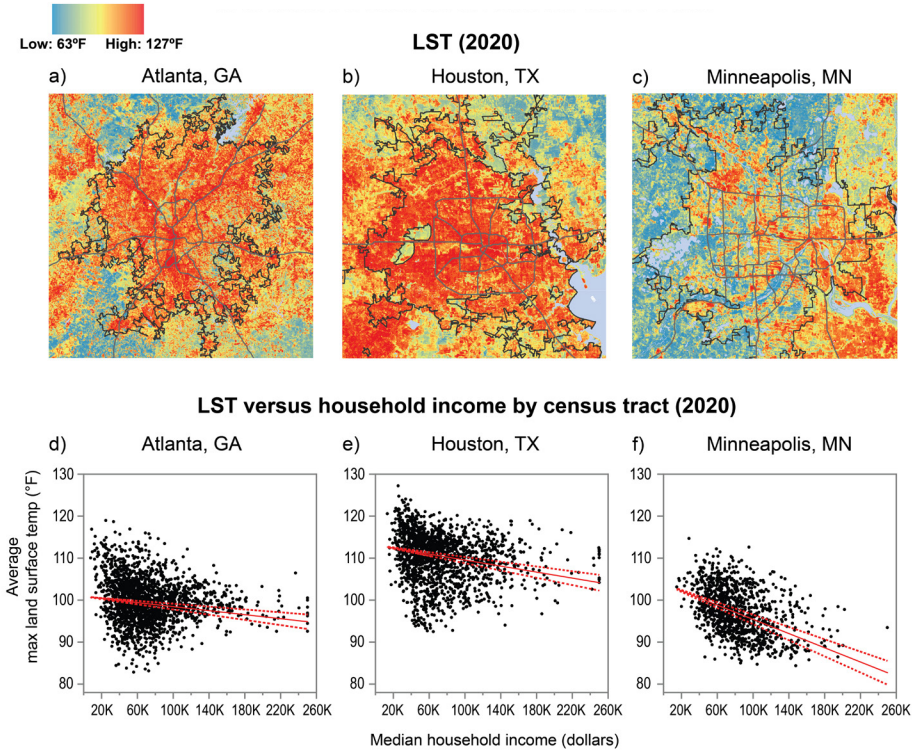
to more than 1,400 heat-related deaths, another severe wildfire season, mass die-offs of fishery species important to the region's economy and Indigenous communities, and total damages exceeding $38.5 billion (in 2022 dollars). {27.3; Ch. 2, Introduction; Focus on Compound Events, Focus on Western Wildfires}

Climate change exacerbates inequities

Some communities are at higher risk of negative impacts from climate change due to social and economic inequities caused by ongoing systemic discrimination, exclusion, and under- or disinvestment. Many such communities are also already overburdened by the cumulative effects of adverse environmental, health, economic, or social conditions. Climate change worsens these long-standing inequities, contributing to persistent disparities in the resources needed to prepare for, respond to, and recover from climate impacts. {4.2, 9.2, 12.2, 14.3, 15.2, 16.1, 16.2, 18.2, 19.1, 20.1, 20.3, 21.3, 22.1, 23.1, 26.4, 27.1, 31.2}

For example, low-income communities and communities of color often lack access to adequate flood infrastructure, green spaces, safe housing, and other resources that help protect people from climate impacts. In some areas, patterns of urban growth have led to the displacement of under-resourced communities to suburban and rural areas with less access to climate-ready housing and infrastructure. Extreme heat can lead to higher rates of illness and death in low-income neighborhoods, which are hotter on average (Figure 1.8). Neighborhoods that are home to racial minorities and low-income people have the highest inland (riverine) flood exposures in the South, and Black communities nationwide are expected to bear a disproportionate share of future flood damages—both coastal and inland (Figure 1.9). {4.2, 11.3, 12.2, 15.1, 22.1, 22.2, 26.4, 27.1; Ch. 2, Introduction}

Land Surface Temperature and Its Relationship to Median Household Income for Three Cities

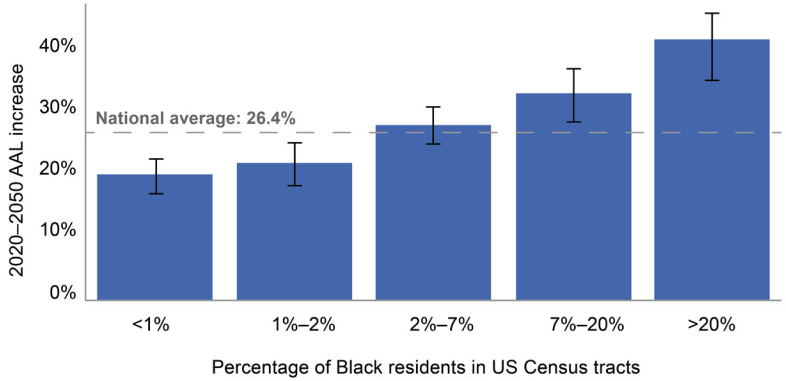


Lower-income urban neighborhoods experience higher surface temperatures.

Figure 1.8. The figure shows the spatial distribution of maximum land surface temperature (LST) in 2020 for Atlanta (**a**), Houston (**b**), and Minneapolis (**c**). Graphs (**d**), (**e**), and (**f**) depict the relationship between maximum LST and median household income across census tracts in each city (see also Figure A4.4). A statistical trend analysis (the Theil-Sen estimator) returns negative values for all three cities, indicating that LST decreases as income increases (solid red line). Dashed red lines indicate the 95% confidence interval, meaning that the true slope of the trend is expected to fall within this range. Note that LST is measured at ground level and may differ from surface air temperature, which is measured at a height of 2 meters. {Figure 12.6} Portions of this figure include intellectual property of Esri and its licensors and are used under license. Copyright © 2020 Esri and its licensors. All rights reserved. Figure credit: University of California, Davis; University of Texas at El Paso; Massachusetts Institute of Technology; City of Phoenix, Arizona; and USGS.

These disproportionate impacts are partly due to exclusionary housing practices—both past and ongoing—that leave underserved communities with less access to heat and flood risk-reduction strategies and other economic, health, and social resources. For example, areas that were historically redlined—a practice in which lenders avoided providing services to communities, often based on their racial or ethnic makeup—continue to be deprived of equitable access to environmental amenities like urban green spaces that reduce exposure to climate impacts. These neighborhoods can be as much as 12°F hotter during a heatwave than nearby wealthier neighborhoods. {8.3, 9.2, 12.2, 15.2, 20.3, 21.3, 22.1, 26.4, 27.1, 32.4; Ch. 2, Introduction}

Projected Increases in Average Annual Losses (AALs) from Floods by 2050



Losses due to floods are projected to increase disproportionately in US Census tracts with higher percentages of Black residents.

Figure 1.9. The bars show that the average annual losses—or the economic damage in a typical year—due to floods in census tracts with a Black population of at least 20% are projected to increase at roughly twice the rate of that in tracts where Black populations make up less than 1% of population. {Figure 4.14} Adapted from Wing et al. 2022 [CC BY 4.0].

Harmful impacts will increase in the near term

Even if greenhouse gas emissions fall substantially, the impacts of climate change will continue to intensify over the next decade (see "Meeting US mitigation targets means reaching net-zero emissions" above; Box 1.4), and all US regions are already experiencing increasingly harmful impacts. Although a few US regions or sectors may experience limited or short-term benefits from climate change, adverse impacts already far outweigh any positive effects and will increasingly eclipse benefits with additional warming. {2.3, 19.1; Ch. 2, Introduction; Chs. 21–30}

Table 1.2 shows examples of critical impacts expected to affect people in each region between now and 2030, with disproportionate effects on overburdened communities. While these examples affect particular regions in the near term, impacts often cascade through social and ecological systems and across borders and may lead to longer-term losses. {15.2, 18.2, 20.1; Figure 15.5; Ch. 20, Introduction}

Table 1.2. Climate Change Is Already Affecting All US Regions and Will Continue to Have Impacts in the Near Term

The table shows three climate impacts of significant concern to each US region between now and 2030. Icons indicate general categories of impacts: infrastructure, water supply, health and well-being, food security, economy, livelihoods and heritage, and ecosystems. More information can be found in the regional chapters (Chs. 21–30).

Infrastructure | Water Supply | Health and Well-Being | Food Security | Economy | Livelihoods and Heritage | Ecosystems

Northeast

- Extreme weather events damage critical infrastructure. {21.1}
- Warming temperatures shift distributions of coastal and marine species and habitats. {21.2}
- Extreme heat and flooding disproportionately impact overburdened communities. {21.3}

Southeast

- Sea level rise and coastal flooding harm rapidly growing communities. {22.1}
- Extreme heat threatens human health, especially stressing urban communities. {22.2}
- Heavy rain and longer dry spells reduce water supply and access. {22.4}

US Caribbean

- Agricultural losses, especially from tropical cyclones, threaten food security. {23.1}
- Severe drought leads to large agricultural and economic losses. {23.3}
- Rising temperatures increase mortality and power demand; hurricanes and storms stress power grids. {23.2, 23.4}

Midwest

- Rising temperatures and extreme events threaten livelihoods and trades. {24.2}
- Extreme weather events harm public health. {24.3}
- Rising temperatures and extreme rainfall damage buildings, homes, and businesses. {24.4}

Northern Great Plains

- Rising temperatures and decreasing snowpack reduce water supply. {25.1}
- Increases in extreme heat, wildfire, and flooding harm physical and mental health. {25.1, 25.2}
- Livelihoods are at greater risk, especially in agriculture, recreation, and energy sectors. {25.3}

Southern Great Plains

- Drier conditions threaten agriculture, ecosystems, and water supplies. {26.1, 26.2, 26.5}
- Extreme heat and high humidity harm human health and exacerbate inequities. {26.4}
- Multiple stressors and extreme events disrupt business, outdoor recreation, and leisure activities. {26.1, 26.2, 26.3}

Northwest

- Less water is available for hydropower, rural communities, and aquatic ecosystems. {27.1, 27.2, 27.4}
- Extreme heat and wildfire smoke endanger at-risk urban, rural, and Tribal communities. {27.1, 27.3, 27.5}
- Wildfire, extreme heat, and floods threaten livelihoods and heritage tied to natural resources. {27.1, 27.3, 27.6}

Alaska

- Landscape degradation increases damage to private and municipal infrastructure. {29.2, 29.4}
- Reduced fish stocks harm local economies, Tribal sovereignty, and overall well-being. {29.6, 29.7}
- Diminished access to mammals, seabirds, fish, and vegetation decreases local food security. {29.5}

Southwest

- Intensifying drought and decreases in groundwater recharge reduce water supply. {28.1}
- Economic losses to farmers and ranchers increase. {28.3}
- Extreme heat, drought, wildfire smoke, and coastal flooding harm physical and mental health. {28.3, 28.4}

Hawai‘i and US-Affiliated Pacific Islands

- Sea level rise and saltwater intrusion reduce irrigation and drinking water supply. {30.1}
- Damages to the coastal built environment, including traditional structures, increase. {30.3, 30.5}
- Risks to unique and biodiverse flora and fauna continue to grow. {30.4}

Current and Future Climate Risks to the United States

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities. Many of the extreme events and harmful impacts that people are already experiencing will worsen as warming increases and new risks emerge.

Safe, reliable water supplies are threatened by flooding, drought, and sea level rise

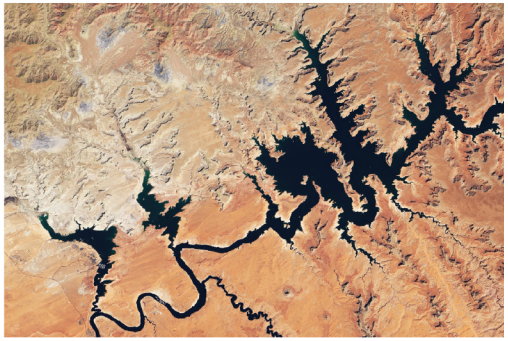
More frequent and intense heavy precipitation events are already evident, particularly in the Northeast and Midwest. Urban and agricultural environments are especially vulnerable to runoff and flooding. Between 1981 and 2016, US corn yield losses from flooding were comparable to those from extreme drought. Runoff and flooding also transport debris and contaminants that cause harmful algal blooms and pollute drinking water supplies. Communities of color and low-income communities face disproportionate flood risks. {2.2, 4.2, 6.1, 9.2, 21.3, 24.1, 24.5, 26.4; Figure A4.8}

Between 1980 and 2022, drought and related heatwaves caused approximately $328 billion in damages (in 2022 dollars). Recent droughts have strained surface water and groundwater supplies, reduced agricultural productivity, and lowered water levels in major reservoirs, threatening hydropower generation. As higher temperatures increase irrigation demand, increased pumping could endanger groundwater supplies, which are already declining in many major aquifers. {4.1, 4.2; Figure A4.9}

Droughts are projected to increase in intensity, duration, and frequency, especially in the Southwest, with implications for surface water and groundwater supplies. Human and natural systems are threatened by rapid shifts between wet and dry periods that make water resources difficult to predict and manage. {2.2, 2.3, 4.1, 4.2, 5.1, 28.1}

In coastal environments, dry conditions, sea level rise, and saltwater intrusion endanger groundwater aquifers and stress aquatic ecosystems. Inland, decreasing snowpack alters the volume and timing of streamflow and increases wildfire risk. Small rural water providers that often depend on a single water source or have limited capacity are especially vulnerable. {4.2, 7.2, 9.2, 21.2, 22.1, 23.1, 23.3, 25.1, 27.4, 28.1, 28.2, 28.5, 30.1; Figure A4.7}

Many options are available to protect water supplies, including reservoir optimization, nature-based solutions, and municipal management systems to conserve and reuse water. Collaboration on flood hazard management at regional scales is particularly important in areas where flood risk is increasing, as cooperation can provide solutions unavailable at local scales. {4.3, 9.3, 26.5; Focus on Blue Carbon}



(**left**; Toledo, Ohio) Rising temperatures are intensifying harmful algal blooms, negatively affecting human and animal health. (**top right**; Utah, Arizona) Water levels on Lake Powell have fallen to historic lows in recent years, affecting millions of people across the Southwest. (**bottom right**) Rain gardens, a form of green infrastructure, absorb excess stormwater. Photo credits: (left) Aerial Associates Photography Inc. by Zachary Haslick; (top right) NASA Earth Observatory images by Lauren Dauphin, using Landsat data from the USGS; (bottom right) Alisha Goldstein, EPA.

Disruptions to food systems are expected to increase

As the climate changes, increased instabilities in US and global food production and distribution systems are projected to make food less available and more expensive. These price increases and disruptions are expected to disproportionately affect the nutrition and health of women, children, older adults, and low-wealth communities. {11.2, 15.2}

Climate change also disproportionately harms the livelihoods and health of communities that depend on agriculture, fishing, and subsistence lifestyles, including Indigenous Peoples reliant on traditional food sources. Heat-related stress and death are significantly greater for farmworkers than for all US civilian workers. {11.2, 11.3, 15.1, 15.2, 16.1; Focus on Risks to Supply Chains}

While farmers, ranchers, and fishers have always faced unpredictable weather, climate change heightens risks in many ways:

- Increasing temperatures, along with changes in precipitation, reduce productivity, yield, and nutritional content of many crops. These changes can introduce disease, disrupt pollination, and result in crop failure, outweighing potential benefits of longer growing seasons and increased CO_2 fertilization. {11.1, 19.1, 21.1, 22.4, 23.3, 24.1, 26.2}
- Heavy rain and more frequent storms damage crops and property and contaminate water supplies. Longer-lasting droughts and larger wildfires reduce forage production and nutritional quality, diminish water supplies, and increase heat stress on livestock. {23.2, 25.3, 28.3}
- Increasing water temperatures, invasive aquatic species, harmful algal blooms, and ocean acidification and deoxygenation put fisheries at risk. Fishery collapses can result in large economic losses, as well as loss of cultural identity and ways of life. {11.3, 29.3}

In response, some farmers and ranchers are adopting innovations—such as agroecological practices, data-driven precision agriculture, and carbon monitoring—to improve resilience, enhance soil carbon storage, and reduce emissions. Across the Nation, Indigenous food security efforts are helping improve community resilience to climate change while also improving cultural resilience. Some types of aquaculture have the potential to increase climate-smart protein production, human nutrition, and food security, although some communities have raised concerns over issues such as conflict with traditional livelihoods and the introduction of disease or pollution. {10.2, 11.1, 29.6, 25.5; Boxes 22.3, 27.2}

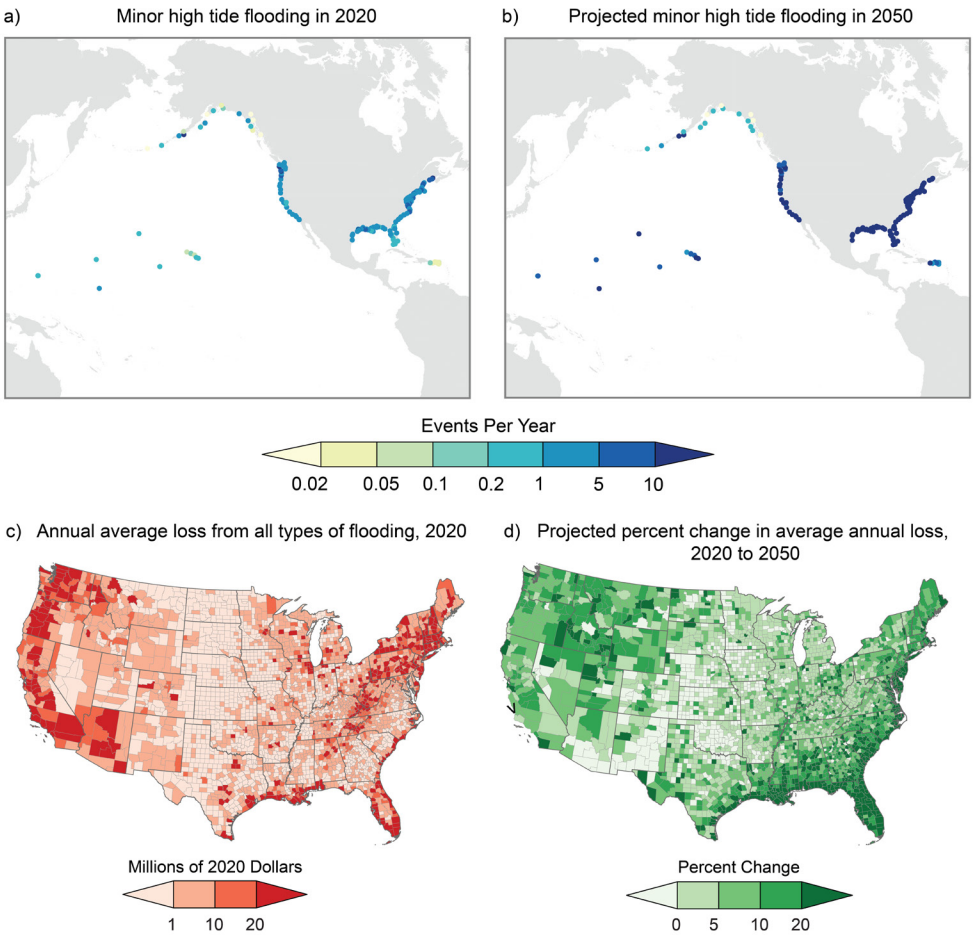
(**left**; Baltimore, Maryland) Urban farms offer the potential to reduce carbon emissions while helping to improve community food security. (**top right**; California) A Northern California vineyard is affected by wildfire. (**bottom right**; Kenai River, Alaska) Recent climate extremes have contributed to declines in many salmon populations. Photo credits: (left) Preston Keres, USDA/FPAC; (top right) Ordinary Mario/iStock via Getty Images; (bottom right) Eric Vance, EPA.

Homes and property are at risk from sea level rise and more intense extreme events

Homes, property, and critical infrastructure are increasingly exposed to more frequent and intense extreme events, increasing the cost of maintaining a safe and healthy place to live. Development in fire-prone areas and increases in area burned by wildfires have heightened risks of loss of life and property damage in many areas across the US. Coastal communities across the country—home to 123 million people (40% of the total US population)—are exposed to sea level rise (Figure 1.10), with millions of people at risk of being displaced from their homes by the end of the century. {2.3, 9.1, 12.2, 22.1, 27.4, 30.3; Figures A4.10, A4.14; Focus on Western Wildfires}

People who regularly struggle to afford energy bills—such as rural, low-income, and older fixed-income households and communities of color—are especially vulnerable to more intense extreme heat events and associated health risks, particularly if they live in homes with poor insulation and inefficient cooling systems. For example, Black Americans are more likely to live in older, less energy efficient homes and face disproportionate heat-related health risks. {5.2, 15.2, 15.3, 22.2, 26.4, 32.4; Figure A4.4}

Accessible public cooling centers can help protect people who lack adequate air-conditioning on hot days. Strategic land-use planning in cities, urban greenery, climate-smart building codes, and early warning communication can also help neighborhoods adapt. However, other options at the household scale, such as hardening homes against weather extremes or relocation, may be out of reach for renters and low-income households without assistance. {12.3, 15.3, 19.3, 22.2}



US Flooding Risks in 2020 and 2050

Increasing flooding puts more people and assets at risk.

Figure 1.10. (**top row**) Maps show (**a**) the average number of minor high tide flooding events per year in 2020 (with historical sea level rise) and (**b**) the expected number of events per year in 2050 (when driven by extrapolated sea level rise). (**bottom row**) Maps show (**c**) average annual loss (AAL) from all types of flooding in millions of dollars in 2020 and (**d**) the projected changes in AAL in 2050 relative to 2020. AAL estimates were made only for the contiguous US. Over the next three decades, the number of flooding days along all coastlines of the US is expected to increase. These increases in the occurrence of flooding will drive greater AALs, especially in coastal areas of the US. (a, b) Adapted from Sweet et al. 2022; (c, d) adapted from Wing et al. 2022 [CC BY 4.0].

Box 1.2. Migration and Displacement

Extreme events, such as extended drought, wildfire, and major hurricanes, have contributed to human migration and displacement. For example, numerous extreme events over the last two decades drove migration of vulnerable communities in Puerto Rico and the US Virgin Islands to the mainland. {9.2, 15.1, 17.2, 19.2, 23.1, 23.5; Box 18.2}

In the future, the combination of climate change and other factors, such as housing affordability, is expected to increasingly affect migration patterns. More severe wildfires in California, increasing sea level rise in Florida, and more frequent flooding in Texas are expected to displace millions of people. Climate-driven economic changes abroad, including reductions in crop yields, are expected to increase the rate of emigration to the United States. {9.2, 17.2, 19.2, 30.3}

From Alaska to low-lying Pacific atolls, forced migrations and displacements driven by climate change disrupt social networks, decrease housing security, and exacerbate grief, anxiety, and negative mental health outcomes. Indigenous Peoples, who have long faced land dispossession due to settler colonialism, are again being confronted with displacement and loss of traditional resources and practices. {4.2, 15.1, 16.1, 19.1, 20.1, 20.3, 22.1, 22.2, 29.1, 30.3; Box 18.2}

(**left**; Cedar Rapids, Iowa) More frequent and intense heavy precipitation events are already evident, particularly in the Northeast and Midwest. (**right**; Arizona) The 2021 Telegraph Fire destroyed homes and property. Photo credits: (left) Don Becker, USGS; (right) Andrew Avitt, USDA Forest Service.

Infrastructure and services are increasingly damaged and disrupted by extreme weather and sea level rise

Climate change threatens vital infrastructure that moves people and goods, powers homes and businesses, and delivers public services. Many infrastructure systems across the country are at the end of their intended useful life and are not designed to cope with additional stress from climate change. For example, extreme heat causes railways to buckle, severe storms overload drainage systems, and wildfires result in roadway obstruction and debris flows. Risks to energy, water, healthcare, transportation, telecommunications, and waste management systems will continue to rise with further climate change, with many infrastructure systems at risk of failing. {12.2, 13.1, 15.2, 23.4, 26.5; Focus on Risks to Supply Chains}

In coastal areas, sea level rise threatens permanent inundation of infrastructure, including roadways, railways, ports, tunnels, and bridges; water treatment facilities and power plants; and hospitals, schools, and military bases. More intense storms also disrupt critical services like access to medical care, as seen after Hurricanes Irma and Maria in the US Virgin Islands and Puerto Rico. {9.2, 23.1, 28.2, 30.3}

At the same time, climate change is expected to place multiple demands on infrastructure and public services. For example, higher temperatures and other effects of climate change, such as greater exposure to stormwater or wastewater, will increase demand for healthcare. Continued increases in average temperatures and more intense heatwaves will heighten electricity and water demand, while wetter storms and intensified

hurricanes will strain wastewater and stormwater management systems. In the Midwest and other regions, aging energy grids are expected to be strained by disruptions and transmission efficiency losses from climate change. {23.4, 24.4, 30.2}

Forward-looking designs of infrastructure and services can help build resilience to climatechange, offset costs from future damage to transportation and electrical systems, and provide other benefits, including meeting evolving standards to protect public health, safety, and welfare. Mitigation and adaptation activities are advancing from planning stages to deployment in many areas, including improved grid design and workforce training for electrification, building upgrades, and land-use choices. Grid managers are gaining experience planning and operating electricity systems with growing shares of renewable generation and working toward understanding the best approaches for dealing with the natural variability of wind and solar sources alongside increases in electrification. {5.3, 12.3, 13.1, 13.2, 22.3, 24.4, 32.3; Figure 22.17}

Climate change exacerbates existing health challenges and creates new ones

Climate change is already harming human health across the US, and impacts are expected to worsen with continued warming. Climate change harms individuals and communities by exposing them to a range of compounding health hazards, including the following:

- More severe and frequent extreme events {2.2, 2.3, 15.1}
- Wider distribution of infectious and vector-borne pathogens {15.1, 26.1; Figure A4.16}
- Air quality worsened by smog, wildfire smoke, dust, and increased pollen {14.1, 14.2, 14.4, 23.1, 26.1}
- Threats to food and water security {11.2, 15.1}
- Mental and spiritual health stressors {15.1}

(**left**; Oregon) The Hooskanaden Landslide, triggered by heavy rainfall, caused substantial road damage. (**right**; Maunabo, Puerto Rico) Punta Tuna Wetlands Nature Reserve, which helps buffer the coastline from extreme events, was severely damaged during Hurricane Maria in 2017. Photo credits: (left) Oregon Department of Transportation [CC BY 2.0]; (right) Kenneth Wilsey, FEMA.

While climate change can harm everyone's health, its impacts exacerbate long-standing disparities that result in inequitable health outcomes for historically marginalized people, including people of color, Indigenous Peoples, low-income communities, and sexual and gender minorities, as well as older adults, people with disabilities or chronic diseases, outdoor workers, and children. {14.3, 15.2}

The disproportionate health impacts of climate change compound with similar disparities in other health contexts. For example, climate-related disasters during the COVID-19 pandemic, such as drought along the Colorado River basin, western wildfires, and Hurricane Laura, disproportionately magnified COVID-19 exposure, transmission, and disease severity and contributed to worsened health conditions for essential workers, older adults, farmworkers, low-wealth communities, and communities of color. {15.2; Focus on COVID-19 and Climate Change}

Large reductions in greenhouse gas emissions are expected to result in widespread health benefits and avoided death or illness that far outweigh the costs of mitigation actions. Improving early warning, surveillance, and communication of health threats; strengthening the resilience of healthcare systems; and supporting community-driven adaptation strategies can reduce inequities in the resources and capabilities needed to adapt as health threats from climate change continue to grow. {14.5, 15.3, 26.1, 30.2, 32.4}

(**left**; New York, New York) The Empire State Building is shrouded in a haze caused by smoke from the 2023 Canadian wildfires. (top right; Charleston, South Carolina) An ambulance drives through floodwaters. (bottom right; Atlanta, Georgia) Heatwaves in the Southeast are happening more frequently. Park amenities, such as trees and splash pads, help cool people on hot days. Photo credits: (left) Anthony Quintano [CC BY 2.0]; (top right) US Air National Guard photo by Tech. Sgt. Jorge Intriago; (bottom right) ucumari photography [CC BY-NC-ND 2.0]

Box 1.3. Indigenous Ways of Life and Spiritual Health

Indigenous communities, whose ways of life, cultures, intergenerational continuity, and spiritual health are tied to nature and the environment, are experiencing disproportionate health impacts of climate change. Rising temperatures and intensifying extreme events are reducing biodiversity and shifting the ranges of culturally important species like Pacific salmon, wild rice, and moose, making it more difficult for Indigenous Peoples to fish, hunt, and gather traditional and subsistence resources within Tribal jurisdictions. Heatwaves can prevent Tribal members from participating in traditional ceremonies, while flooding, erosion, landslides, and wildfires increasingly disrupt or damage burial grounds and ceremonial sites. {16.1, 15.2, 27.6}

Indigenous Peoples are leading numerous actions in response to climate change, including planning and policy initiatives, youth movements, cross-community collaborative efforts, and the expansion of renewable energy (Figure 1.11). Many of these efforts involve planning processes that start with place-based Indigenous Knowledge of local climate and ecosystems. {16.3}

Exemplifying Indigenous Resilience

Figure 1.11. For over 2,000 years, the Hopi People have farmed on land with only 6–10 inches of annual precipitation. Today, Hopi children learn both the practices and process of Hopi dryland farming and the values, customs, and identities that underpin them. Photo credit: ©Michael K. Johnson. {Panel from Figure 16.6}

Ecosystems are undergoing transformational changes

Together with other stressors, climate change is harming the health and resilience of ecosystems, leading to reductions in biodiversity and ecosystem services. Increasing temperatures continue to shift habitat ranges as species expand into new regions or disappear from unfavorable areas, altering where people can hunt, catch, or gather economically important and traditional food sources. Degradation and extinction of local flora and fauna in vulnerable ecosystems like coral reefs and montane rainforests are expected in the near term, especially where climate changes favor invasive species or increase susceptibility to pests and pathogens. Without significant emissions reductions, rapid shifts in environmental conditions are expected to lead to irreversible ecological transformations by mid- to late century. {2.3, 6.2, 7.1, 7.2, 8.1, 8.2, 10.1, 10.2, 21.1, 24.2, 27.2, 28.5, 29.3, 29.5, 30.4; Figure A4.12}

Changes in ocean conditions and extreme events are already transforming coastal, aquatic, and marine ecosystems. Coral reefs are being lost due to warming and ocean acidification, harming important fisheries; coastal forests are converting to ghost forests, shrublands, and marsh due to sea level rise, reducing coastal protection; lake and stream habitats are being degraded by warming, heavy rainfall, and invasive species, leading to declines in economically important species. {8.1. 10.1, 21.2, 23.2, 24.2, 27.2; Figures 8.7, A4.11}

Increased risks to ecosystems are expected with further climate change and other environmental changes, such as habitat fragmentation, pollution, and overfishing. For example, mass fish die-offs from extreme summertime heat are projected to double by midcentury in northern temperate lakes under a very high scenario (RCP8.5). Continued climate changes are projected to exacerbate runoff and erosion, promote harmful algal blooms, and expand the range of invasive species. {4.2, 7.1, 8.2, 10.1, 21.2, 23.2, 24.2, 27.2, 28.2, 30.4}

While adaptation options to protect fragile ecosystems may be limited, particularly under higher levels of warming, management and restoration measures can reduce stress on ecological systems and build resilience. These measures include migration assistance for vulnerable species and protection of essential habitats, such as establishing wildlife corridors or places where species can avoid heat. Opportunities for nature-based solutions that assist in mitigation exist across the US, particularly those focused on protecting existing carbon sinks and increasing carbon storage by natural ecosystems. {8.3, 10.3, 23.2, 27.2; Focus on Blue Carbon}

(**top left**; Nags Head Woods, North Carolina) Coastal ghost forests result when trees are killed by sea level rise and saltwater intrusion. (**top right**; Molokai Island, Hawai'i) High island ecosystems are at risk due to invasive species, habitat destruction, intensifying fire, and drought. (**bottom**; Florida) A diver works on coral reef restoration around Florida Keys National Marine Sanctuary. Photo credits: (top left) NC Wetlands [CC BY 2.0]; (top right) Lucas Fortini, USGS; (bottom) Mitchell Tartt, NOAA.

Climate change slows economic growth, while climate action presents opportunities

With every additional increment of global warming, costly damages are expected to accelerate. For example, 2°F of warming is projected to cause more than twice the economic harm induced by 1°F of warming. Damages from additional warming pose significant risks to the US economy at multiple scales and can compound to dampen economic growth. {19.1}

- International impacts can disrupt trade, amplify costs along global supply chains, and affect domestic markets. {17.3, 19.2; Focus on Risks to Supply Chains}
- While some economic impacts of climate change are already being felt across the country, the impacts of future changes are projected to be more significant and apparent across the US economy. {19.1}
- States, cities, and municipalities confront climate-driven pressures on public budgets and borrowing costs amid spending increases on healthcare and disaster relief. {19.2}
- Household consumers face higher costs for goods and services, like groceries and health insurance premiums, as prices change to reflect both current and projected climate-related damages. {19.2}

Mitigation and adaptation actions present economic opportunities. Public and private measures—such as climate financial risk disclosures, carbon offset credit markets, and investments in green bonds—can avoid economic losses and improve property values, resilience, and equity. However, climate responses are not without risk. As innovation and trade open further investment opportunities in renewable energy and the country continues to transition away from fossil fuels, loss and disposal costs of stranded capital assets such as coal mines, oil and gas wells, and outdated power plants are expected. Climate solutions designed without input from affected communities can also result in increased vulnerability and cost burden. {17.3, 19.2, 19.3, 20.2, 20.3, 27.1, 31.6}

Many regional economies and livelihoods are threatened by damages to natural resources and intensifying extremes

Climate change is projected to reduce US economic output and labor productivity across many sectors, with effects differing based on local climate and the industries unique to each region. Climate-driven damages to local economies especially disrupt heritage industries (e.g., fishing traditions, trades passed down over generations, and cultural heritage–based tourism) and communities whose livelihoods depend on natural resources. {11.3, 19.1, 19.3}

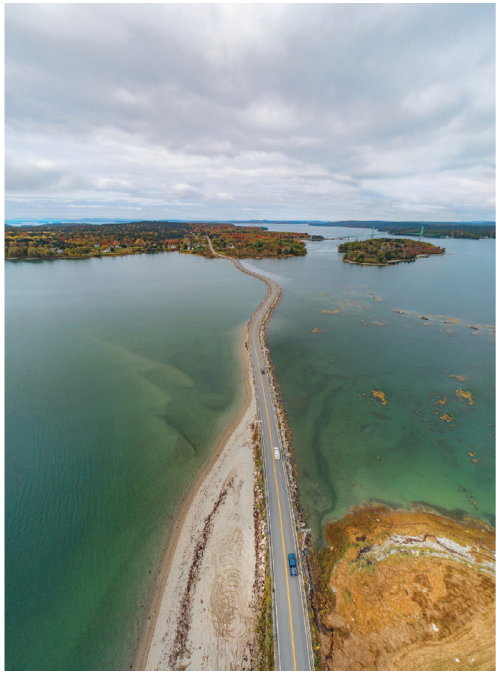
- As fish stocks in the Northeast move northward and to deeper waters in response to rapidly rising ocean temperatures, important fisheries like scallops, shrimp, and cod are at risk. In Alaska, climate change has already played a role in 18 major fishery disasters that were especially damaging for coastal Indigenous Peoples, subsistence fishers, and rural communities. {10.2, 21.2, 29.3}
- While the Southeast and US Caribbean face high costs from projected labor losses and heat health risks to outdoor workers, small businesses are already confronting higher costs of goods and services and potential closures as they struggle to recover from the effects of compounding extreme weather events. {22.3, 23.1}
- Agricultural losses in the Midwest, including lower corn yields and damages to specialty crops like apples, are linked to rapid shifts between wet and dry conditions and stresses from climate-induced increases in pests and pathogens. Extreme heat and more intense wildfire and drought in the Southwest are already threatening agricultural worker health, reducing cattle production, and damaging wineries. {24.1, 28.5}
- In the Northern Great Plains, agriculture and recreation are expected to see primarily negative effects related to changing temperature and rainfall patterns. By 2070, the

Southern Great Plains is expected to lose cropland acreage as lands transition to pasture or grassland. {25.3, 26.2}

- Outdoor-dependent industries, such as tourism in Hawai‘i and the US-Affiliated Pacific Islands and skiing in the Northwest, face significant economic loss from projected rises in park closures and reductions in workforce as continued warming leads to deterioration of coastal ecosystems and shorter winter seasons with less snowfall. {7.2, 8.3, 10.1, 10.3, 19.1, 27.3, 30.4}

Mitigation and adaptation actions taken by businesses and industries promote resilience and offer long-term benefits to employers, employees, and surrounding communities. For example, as commercial fisheries adapt, diversifying harvest and livelihoods can help stabilize income or buffer risk. In addition, regulators and investors are increasingly requiring businesses to disclose climate risks and management strategies. {10.2, 19.3, 26.2}

Scarlett W.



(**top left**; Fort Myers Beach, Florida) Shops and restaurants were severely damaged or completed destroyed by Hurricane Ian in 2022. (**bottom left**; Whatcom County, Washington) Snow-based recreational industries, such as skiing in the Pacific Northwest, are projected to lose revenue due to declining snowpack. (**right**; Maine) A causeway connecting Little Deer Isle to Deer Isle (the largest lobster port in the state) is threatened by sea level rise. Photo credits: (top left) Coast Guard Petty Officer 3rd Class Gabriel Wisdom; (bottom left) US Forest Service–Pacific Northwest Region; (right) ©Jack Sullivan, Island Institute.

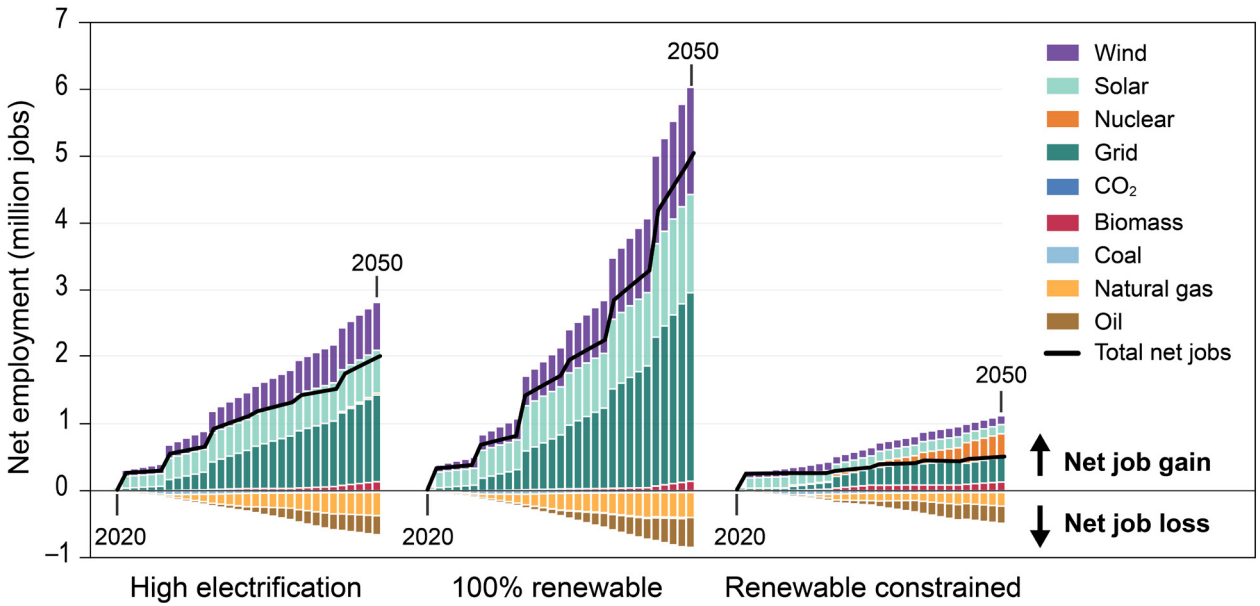
Job opportunities are shifting due to climate change and climate action

Many US households are already feeling the economic impacts of climate change. Climate change is projected to impose a variety of new or higher costs on most households as healthcare, food, insurance, building, and repair costs become more expensive. Compounding climate stressors can increase segregation, income inequality, and reliance on social safety net programs. Quality of life is also threatened by climate change

in ways that can be more difficult to quantify, such as increased crime and domestic violence, harm to mental health, reduced happiness, and fewer opportunities for outdoor recreation and play. {11.3, 19.1, 19.3}

Climate change, and how the country responds, is expected to alter demand for workers and shift where jobs are available. For example, energy-related livelihoods in the Northern and Southern Great Plains are expected to shift as the energy sector transforms toward more renewables, low-carbon technologies, and electrification of more sectors of the economy. Losses in fossil fuel–related jobs are projected to be completely offset by greater increases in mitigation-related jobs, as increased demand for renewable energy and low-carbon technologies is expected to lead to long-term expansion in most states' energy and decarbonization workforce (Figure 1.12). Grid expansion and energy efficiency efforts are already creating new jobs in places like Nevada, Vermont, and Alaska, and advancements in biofuels and agrivoltaics (combined renewable energy and agriculture) provide economic opportunities in rural communities. {10.2, 11.3, 19.3, 25.3, 26.2, 29.3, 32.4}

Additional opportunities include jobs in ecosystem restoration and construction of energy-efficient and climate-resilient housing and infrastructure. Workforce training and equitable access to clean energy jobs, which have tended to exclude women and people of color, are essential elements of a just transition to a decarbonized economy. {5.3, 19.3, 20.3, 22.3, 25.3, 26.2, 27.3, 32.4}



Energy Employment (2020–2050) for Alternative Net-Zero Pathways

Employment gains in electrification and renewable energy industries are projected to far outpace job losses in fossil fuel industries.

Figure 1.12. Despite decreases in the number of fossil fuel–related jobs, the overall number of energy jobs (specifically those involved in the supply of energy) relative to 2019 is generally projected to increase in net-zero-emissions energy scenarios between 2020 and 2050, although by much more in some scenarios than in others. {Figure 32.17} Adapted with permission from Jenkins et al. 2021.

(**top**; Golden, Colorado) Solar panels are pictured on the campus of the National Renewable Energy Laboratory. (**bottom left**; San Antonio, Texas) Participants in the 2022 Collegiate Wind Competition focus on offshore wind projects. (**bottom right**; Lexington, Virginia) Workers install fiber-optic cables. Rural broadband deployment is associated with higher incomes and lower unemployment rates. Photo credits: (top and bottom left) Werner Slocum/NREL [CC-BY-NC-ND 2.0]; (bottom right) Preston Keres, USDA

Climate change is disrupting cultures, heritages, and traditions

As climate change transforms US landscapes and ecosystems, many deeply rooted community ties, pastimes, Traditional Knowledges, and cultural or spiritual connections to place are at risk. Cultural heritage—including buildings, monuments, livelihoods, and practices—is threatened by impacts on natural ecosystems and the built environment. Damages to archaeological, cultural, and historical sites further reduce opportunities to transfer important knowledge and identity to future generations. {6.1, 7.2, 8.3, 9.2, 10.1, 12.2, 16.1, 22.1, 23.1, 26.1, 27.6, 28.2; Introductions in Chs. 10, 30}

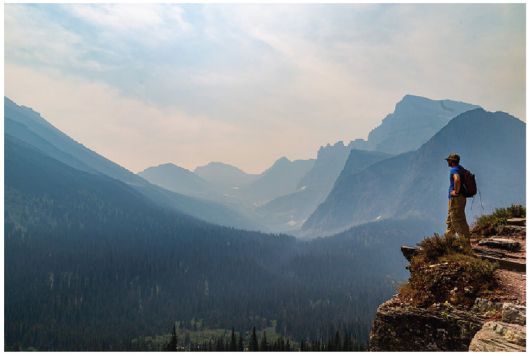
Many outdoor activities and traditions are already being affected by climate change, with overall impacts projected to further hinder recreation, cultural practices, and the ability of communities to maintain local heritage and a sense of place. {19.1}

For example:

- The prevalence of invasive species and harmful algal blooms is increasing as waters warm, threatening activities like swimming along Southeast beaches, boating and fishing for walleye in the Great Lakes, and viewing whooping cranes along the Gulf Coast. In the Northwest, water-based recreation demand is expected to increase in spring and summer months, but reduced water quality and harmful algal blooms are expected to restrict these opportunities. {24.2, 24.5, 26.3, 27.6}

- Ranges of culturally important species are shifting as temperatures warm, making them harder to find in areas where Indigenous Peoples have access (see Box 1.3). {11.2, 24.2, 26.1}
- Hikers, campers, athletes, and spectators face increasing threats from more severe heatwaves, wildfires, and floods and greater exposure to infectious disease. {15.1, 22.2, 26.3, 27.6}

Nature-based solutions and ecosystem restoration can preserve cultural heritage while also providing valuable local benefits, such as flood protection and new recreational opportunities. Cultural heritage can also play a key role in climate solutions, as incorporating local values, Indigenous Knowledge, and equity into design and planning can help reaffirm a community's connection to place, strengthen social networks, and build new traditions. {7.3, 26.1, 26.3, 30.5}



(**top left**; Glacier National Park, Montana) Wildfire smoke jeopardizes participation in outdoor sports and recreation. (**top right**; Boston Harbor, Massachusetts) Sea level rise threatens historical and archaeological sites on the Boston Harbor Islands. (**bottom**; Goose Island, Texas) Whooping cranes, which draw birdwatchers to the Gulf of Mexico, are at risk due to flooding, drought, and upstream water use. Photo credit: (top left) Andrew Parlette [CC BY 2.0]; (top right) cmh2315fl [CC BY-NC 2.0]; (bottom) Alan Schmierer [CC0 1.0].

The Choices That Will Determine the Future

With each additional increment of warming, the consequences of climate change increase. The faster and further the world cuts greenhouse gas emissions, the more future warming will be avoided, increasing the chances of limiting or avoiding harmful impacts to current and future generations.

Societal choices drive greenhouse gas emissions

The choices people make on a day-to-day basis—how to power homes and businesses, get around, and produce and use food and other goods—collectively determine the amount of greenhouse gases emitted. Human use of fossil fuels for transportation and energy generation, along with activities like manufacturing and agriculture, has increased atmospheric levels of carbon dioxide (CO_2) and other heat-trapping greenhouse gases. Since 1850, CO_2 concentrations have increased by almost 50%, methane by more than 156%, and nitrous oxide by 23%, resulting in long-term global warming. {2.1, 3.1; Ch. 2, Introduction}

The CO_2 not removed from the atmosphere by natural sinks lingers for thousands of years. This means that CO_2 emitted long ago continues to contribute to climate change today. Because of historical trends, cumulative CO_2 emissions from fossil fuels and industry in the US are higher than from any other country. To understand the total contributions of past actions to observed climate change, additional warming from CO_2 emissions from land use, land-use change, and forestry, as well as emissions of nitrous oxide and the shorter-lived greenhouse gas methane, should also be taken into account. Accounting for all of these factors and emissions from 1850–2021, emissions from the US are estimated to comprise approximately 17% of current global warming. {2.1}

Tami Phelps

Carbon dioxide, along with other greenhouse gases like methane and nitrous oxide, is well-mixed in the atmosphere. This means these gases warm the planet regardless of where they were emitted. For the first half of the 20th century, the vast majority of greenhouse gas emissions came from the US and Europe. But as US and European emissions have been falling (US emissions in 2021 were 17% lower than 2005 levels), emissions from the rest of the world, particularly Asia, have been rising rapidly. The choices the US and other countries make now will determine the trajectory of climate change and associated impacts for many generations to come (Figure 1.13). {2.1, 2.3; Ch. 32}

George Lorio

Box 1.4. Global Warming Levels

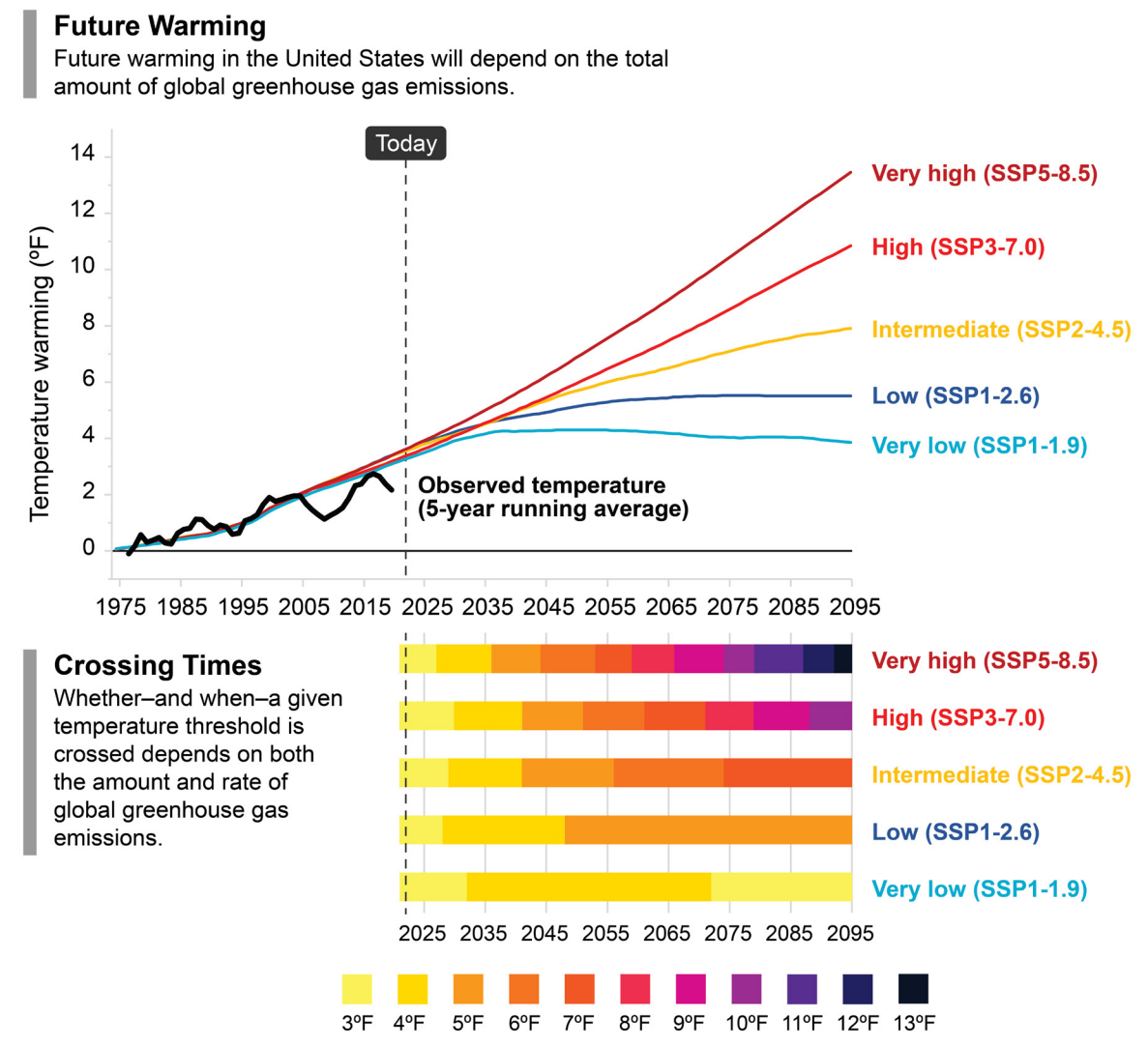
Because long-term societal actions are uncertain, climate modeling experts use different scenarios of plausible futures to represent a range of possible trajectories. These scenarios capture variables such as the relationship between human behavior, greenhouse gas emissions, Earth's responses to changes in the concentration of greenhouse gases in our atmosphere and ocean, and the resulting impacts, including temperature change and sea level rise. {3.3; Guide to the Report; App. 3}

Since there are uncertainties inherent in all of these factors—especially human behavior and the choices that determine emissions levels—the resulting range of projections are not predictions but instead reflect multiple potential future pathways. Future climate change under a given scenario is often expressed in one of two ways: as a range of potential outcomes in a future year (Figure 1.13a) or the time at which a specific outcome is expected (Figure 1.13b). {2.3, 3.3; App. 3}

Over the next decade, projected global warming is very similar across all scenarios. Updating energy infrastructure or making systemic economic and political changes takes time, thus temperature trajectories under different scenarios take time to diverge. {2.3}

By midcentury (2040–2070), differences between projected temperatures under higher and lower scenarios become apparent. By the end of the century, the global warming level—that is, how much the global average surface temperature increases above preindustrial levels—is expected to exceed 5.4°F (3°C) under high and very high scenarios (SSP3-7.0 and SSP5-8.5, respectively), and the world could see more than 7.2°F (4°C) of warming under a very high scenario (SSP5-8.5). Long-term global warming is expected to stay below 3.6°F (2°C) under a low scenario (SSP1-2.6) and can be limited to 2.7°F (1.5°C) only under a very low scenario (SSP1-1.9). {2.3}

The risk of exceeding a particular global warming level depends on future emissions. This means that projections are conditional: when or if the world reaches a particular level of warming is largely dependent on human choices. {2.3}



Potential Warming Pathways in the United States

When or if the US reaches a particular level of warming depends on global greenhouse gas emissions from human activities.

Figure 1.13. How much warming the US will experience—and when a given temperature threshold is crossed—depends on future global emissions. The **top graph** shows observed change in US surface temperature during 1975–2022 (black line, 5-year averaged) and modeled historical (1975–2014) and projected (2015–2095) change in surface temperature compared to 1951–1980, annually averaged over all 50 states and Puerto Rico under different climate scenarios (multicolored lines; see Table 3 in the Guide to the Report). The **bottom graph** shows the same projections in a different way, highlighting the year in which the US crosses temperature thresholds under each scenario. The vertical dashed line represents the year 2023. Data for the US-Affiliated Pacific Islands and the US Virgin Islands are not available. See Figure 1.5 for observed US and global temperature changes since 1895. Adapted with permission from Figure TS.1 in Arias et al. 2021.

Rising global emissions are driving global warming, with faster warming in the US

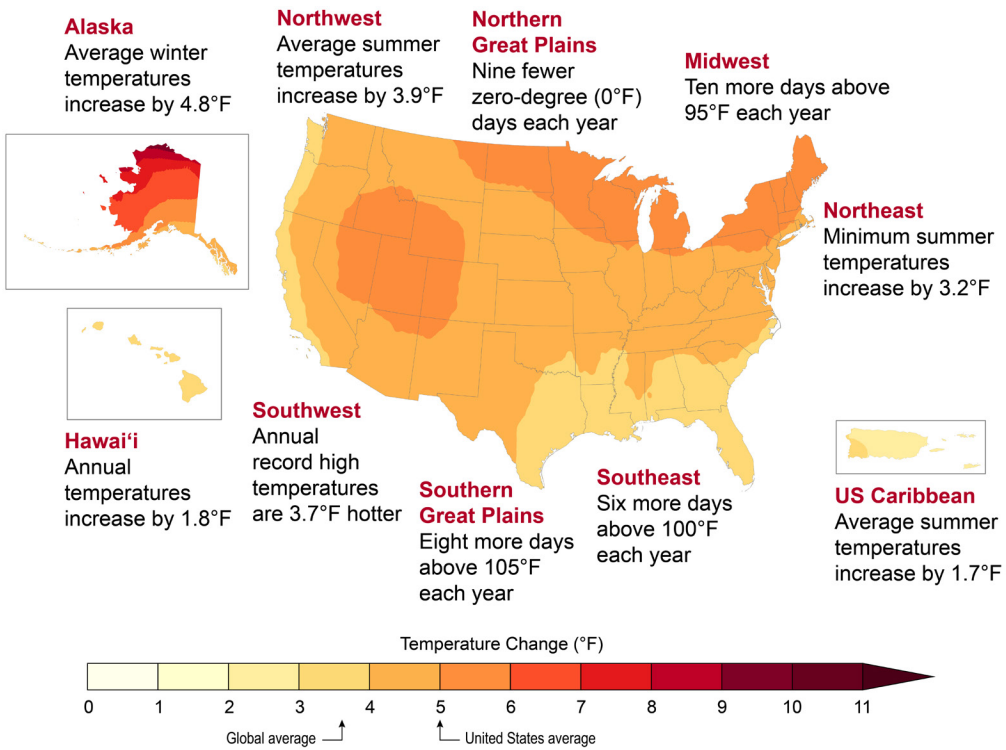
The observed global warming of about 2°F (1.1°C) over the industrial era is unequivocally caused by greenhouse gas emissions from human activities, with only very small effects from natural sources. About three-quarters of total emissions and warming (1.7°F [0.95°C]) have occurred since 1970. Warming would have been even greater without the land and ocean carbon sinks, which have absorbed more than half of the CO_2 emitted by humans. {2.1, 3.1, 7.2; Ch. 2, Introduction; Figures 3.1, 3.8}

The US is warming faster than the global average, reflecting a broader global pattern: land areas are warming faster than the ocean, and higher latitudes are warming faster than lower latitudes. Additional global warming is expected to lead to even greater warming in some US regions, particularly Alaska (Figure 1.14). {2.1, 3.4; Ch. 2, Introduction; App. 4}

Warming increases risks to the US

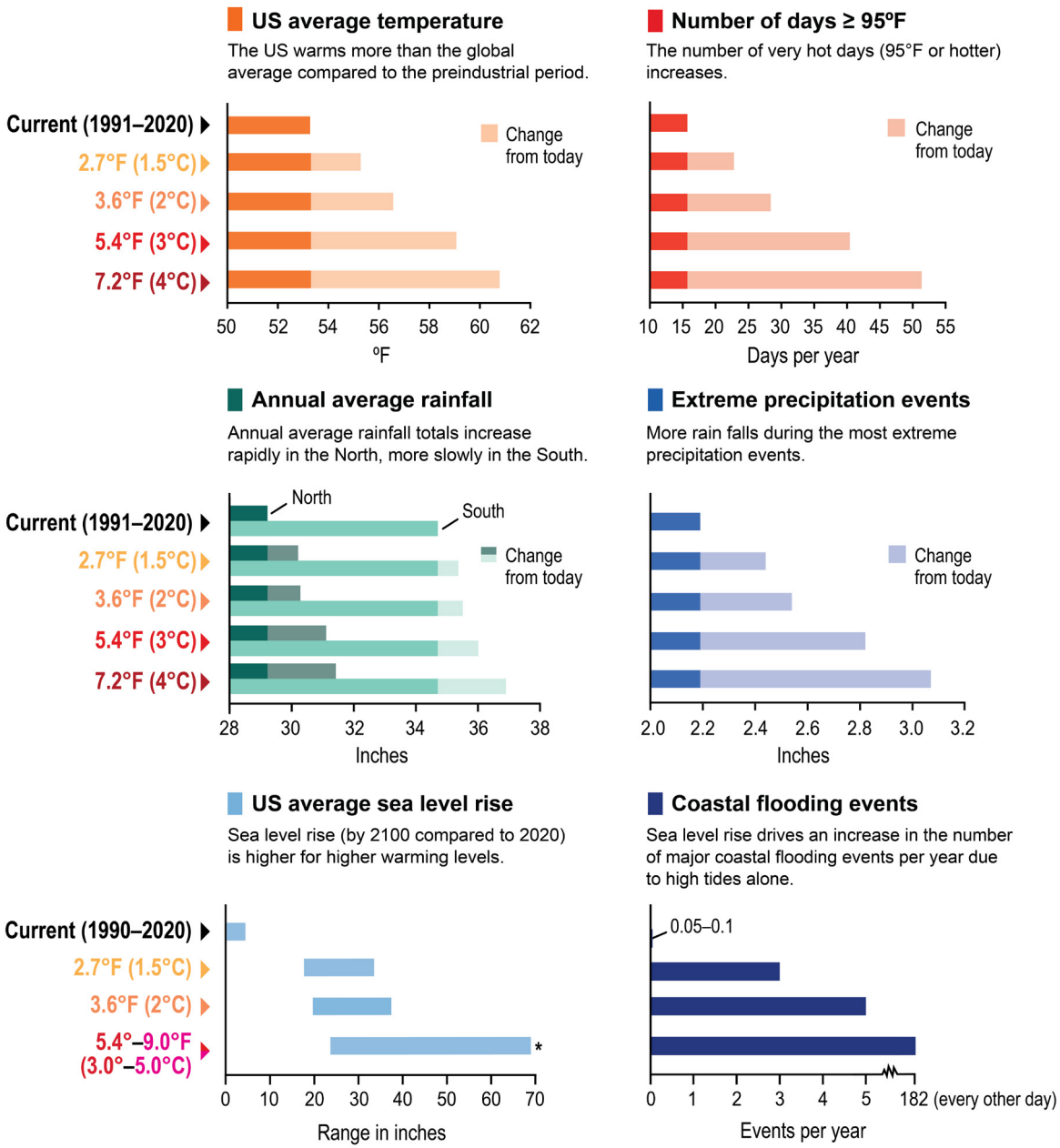
Rising temperatures lead to many large-scale changes in Earth's climate system, and the consequences increase with warming (Figure 1.15). Some of these changes can be further amplified through feedback processes at higher levels of warming, increasing the risk of potentially catastrophic outcomes. For example, uncertainty in the stability of ice sheets at high warming levels means that increases in sea level along the continental US of 3–7 feet by 2100 and 5–12 feet by 2150 are distinct possibilities that cannot be ruled out. The chance of reaching the upper end of these ranges increases as more warming occurs. In addition to warming more, the Earth warms faster in high and very high scenarios (SSP3-7.0 and SSP5-8.5, respectively), making adaptation more challenging. {2.3, 3.1, 3.4, 9.1}

Projected Changes at 3.6°F (2.0°C) of Global Warming



What would 3.6°F (2°C) of global warming feel like in the United States?

Figure 1.14. As the world warms, the United States warms more on average. The map shows projected changes in annual surface temperature compared to the present day (1991–2020) under a global warming level of 3.6°F (2°C) above preindustrial levels (see Figure 2.9). Regional examples show how different temperature impacts would be experienced across the country at this level of warming. Figure credit: USGCRP, NOAA NCEI, and CISESS NC.



*Rise at the upper end of this range cannot be ruled out due to the possibility of rapid ice sheet loss. The amount of warming required to trigger such loss is not currently known but is assessed to be above 3.6°F (2°C).

Consequences Are Greater at Higher Global Warming Levels

At higher global warming levels, the US will experience more severe climate impacts.

Figure 1.15. With each additional increment of global warming, climate impacts in the US are projected to be more severe: US average temperature warms more than the global average (**top left**), and the number of days per year at or above 95°F in the US increases (**top right**). Annual average US rainfall increases rapidly in the North and more slowly in the South (**center left**), and more rain falls during the most extreme precipitation events (**center right**). Sea level rise (range of projected increases by 2100 compared to 2020) is higher (**bottom left**), driving an increase in the number of major coastal flooding events per year due to high tides alone (**bottom right**). Temperature (averages and extremely hot days; top row) and extreme rainfall projections (center right) are averages for all 50 states and Puerto Rico. Average rainfall projections (center left) are shown for both the northern and southern US (above and below 37° latitude, respectively). Sea level rise (bottom left) and coastal flooding (bottom right) projections are averages for the contiguous United States. For sea level change estimates outside of the contiguous US, see Chapter 23 (for Puerto Rico and the US Virgin Islands), Chapter 30 (for Hawai'i and the US-Affiliated Pacific Islands), and Sweet et al. 2022 (for Alaska). Global warming levels refer to warming since preindustrial temperature conditions, defined as the 1851–1900 average. Figure credit: USGCRP, NOAA NOS, NASA, NOAA NCEI, and CISESS NC.

How Climate Action Can Create a More Resilient and Just Nation

Large near-term cuts in greenhouse gas emissions are achievable through many currently available and cost-effective mitigation options. However, reaching net-zero emissions by midcentury cannot be achieved without exploring additional mitigation options. Even if the world decarbonizes rapidly, the Nation will continue to face climate impacts and risks. Adequately and equitably addressing these risks involves longer-term inclusive planning, investments in transformative adaptation, and mitigation approaches that consider equity and justice.

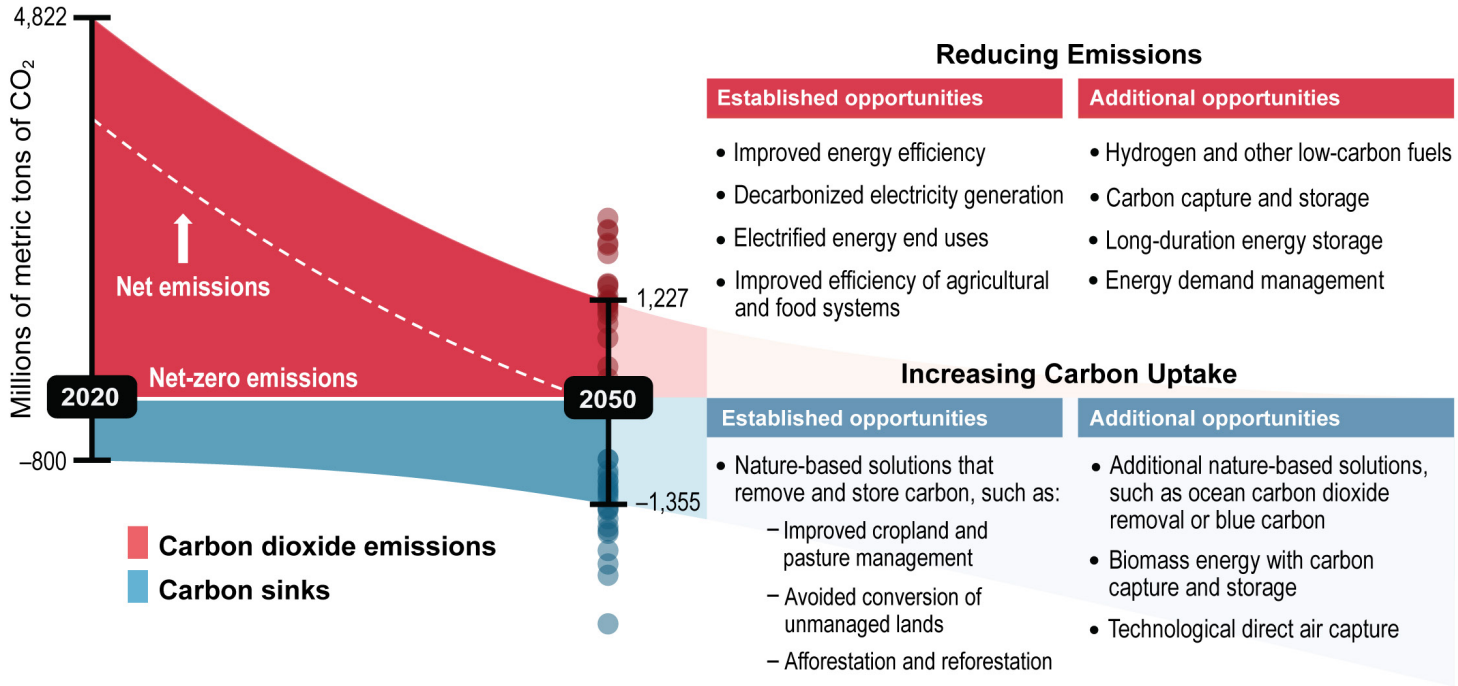
Available mitigation strategies can deliver substantial emissions reductions, but additional options are needed to reach net zero

Limiting global temperature change to well below 2°C (3.6°F) requires reaching net-zero CO_2 emissions globally by 2050 and net-zero emissions of all greenhouse gases from human activities within the following few decades (see "Meeting US mitigation targets means reaching net-zero emissions" above). Net-zero emissions pathways involve widespread implementation of currently available and cost-effective options for reducing emissions alongside rapid expansion of technologies and methods to remove carbon from the atmosphere to balance remaining emissions. However, to reach net-zero emissions, additional mitigation options need to be explored (Figure 1.16). Pathways to net zero involve large-scale technological, infrastructure, land-use, and behavioral changes and shifts in governance structures. {5.3, 6.3, 9.2, 9.3, 10.4, 13.2, 16.2, 18.4, 20.1, 24.1, 25.5, 30.5, 32.2, 32.3; Focus on Blue Carbon}

Scenarios that reach net-zero emissions include some of the following key options:

- Decarbonizing the electricity sector, primarily through expansion of wind and solar energy, supported by energy storage {32.2}
- Transitioning to transportation and heating systems that use zero-carbon electricity or low-carbon fuels, such as hydrogen {5.3, 13.1, 32.2, 32.3}
- Improving energy efficiency in buildings, appliances, and light- and heavy-duty vehicles and other transportation modes {5.3, 13.3, 32.2}
- Implementing urban planning and building design that reduces energy demands through more public transportation and active transportation and lower cooling demands for buildings {12.3, 13.1, 32.2}
- Increasing the efficiency and sustainability of food production, distribution, and consumption {11.1, 32.2}
- Improving land management to decrease greenhouse gas emissions and increase carbon removal and storage, with options ranging from afforestation, reforestation, and restoring coastal ecosystems to industrial processes that directly capture and store carbon from the air {5.3, 6.3, 8.3, 32.2, 32.3; Focus on Blue Carbon}

Portfolio of Mitigation Options for Achieving Net Zero by 2050



Reaching net zero by 2050 in the US will involve a mix of reductions in greenhouse gas emissions and increases in carbon dioxide removal.

Figure 1.16. Reaching net-zero emissions (horizontal white line) by midcentury in the US would mean deep reductions in emissions of carbon dioxide (CO_2) and other greenhouse gases (**top side of figure**; red), with residual emissions balanced by additional removal of CO_2 from the atmosphere (**bottom side of figure**; blue). The dashed white line shows net emissions to the atmosphere (the sum of carbon sources and carbon sinks). The dots at 2050 show ranges of emissions and uptake for energy model scenarios explored in detail in Chapter 32. Model scenarios that achieve these targets project a mix of established opportunities for reducing emissions and increasing carbon sinks. Among these, energy efficiency, decarbonized electricity (mainly renewables), and end-use electrification are critical for the energy sector. While not exhaustive, the list also includes additional opportunities, many of which are emerging technologies that will be integral to reaching net zero. These include options like use of hydrogen and low-carbon fuels to further reduce emissions in difficult-to-decarbonize sectors and greatly increasing CO_2 removal. Figure credit: EPA; University of California, Irvine; NOAA NCEI; and CISESS NC.

Due to large declines in technology and deployment costs over the last decade (Figure 1.2), decarbonizing the electricity sector is expected to be largely driven by rapid growth in renewable energy. Recent legislation is also expected to increase deployment rates of low- and zero-carbon technology. To reach net-zero targets, the US will need to add new electricity-generating capacity, mostly wind and solar, faster than ever before. This infrastructure expansion may drastically increase demand for products (batteries, solar photovoltaics) and resources, such as metals and critical minerals. Near-term shortages in minerals and metals due to increased demand can be addressed by increased recycling, for example, which can also reduce dependence on imported materials. {5.2, 5.3, 17.2, 25.3, 32.2, 32.4; Focus on Risks to Supply Chains}

Most US net-zero scenarios require CO_2 removal from the atmosphere to balance residual emissions, particularly from sectors where decarbonization is difficult. In these scenarios, nuclear and hydropower capacity are maintained but not greatly expanded; natural gas–fired generation declines, but more slowly if coupled with carbon capture and storage. {32.2}

Nature-based solutions that restore degraded ecosystems and preserve or enhance carbon storage in natural systems like forests, oceans, and wetlands, as well as agricultural lands, are cost-effective mitigation strategies. For example, with conservation and restoration, marine and coastal ecosystems could capture and store enough atmospheric carbon each year to offset about 3% of global emissions (based on 2019 and 2020 emissions). Many nature-based solutions can provide additional benefits, like improved ecosystem resilience, food production, improved water quality, and recreational opportunities. {8.3; Boxes 7.2, 32.2; Focus on Blue Carbon}

Adequately addressing climate risks involves transformative adaptation

While adaptation planning and implementation has advanced in the US, most adaptation actions to date have been incremental and small in scale (see Table 1.3). In many cases, more transformative adaptation will be necessary to adequately address the risks of current and future climate change. {31.1, 31.3}.

Table 1.3. Incremental Versus Transformative Adaptation Approaches

	Examples of incremental adaptation	Examples of transformative adaptation
	Using air-conditioning during heatwaves	Redesigning cities and buildings to address heat
	Reducing water consumption during droughts	Shifting water-intensive industry to match projected rainfall patterns
	Elevating homes above flood waters	Directing new housing development to less flood-prone areas

Transformative adaptation involves fundamental shifts in systems, values, and practices, including assessing potential trade-offs, intentionally integrating equity into adaptation processes, and making systemic changes to institutions and norms. While barriers to adaptation remain, many of these can be overcome with financial, cultural, technological, legislative, or institutional changes. {31.1, 31.2, 31.3}.

Adaptation planning can more effectively reduce climate risk when it identifies not only disparities in how people are affected by climate change but also the underlying causes of climate vulnerability. Transformative adaptation would involve consideration of both the physical and social drivers of vulnerability and how they interact to shape local experiences of vulnerability and disparities in risk. Examples include understanding how differing levels of access to disaster assistance constrain recovery outcomes or how disaster damage exacerbates long-term wealth inequality. Effective adaptation, both incremental and transformative, involves developing and investing in new monitoring and evaluation methods to understand the different values of, and impacts on, diverse individuals and communities. {9.3, 19.3, 31.2, 31.3, 31.5}

Transformative adaptation would require new and better-coordinated governance mechanisms and cooperation across all levels of government, the private sector, and society. A coordinated, systems-based approach can support consideration of risks that cut across multiple sectors and scales, as well as the development of context-specific adaptations. For example, California, Florida, and other states have used informal regional collaborations to develop adaptation strategies tailored to their area. Adaptation measures that are designed and implemented using inclusive, participatory planning approaches and leverage coordinated governance and financing have the greatest potential for long-term benefits, such as improved quality of life and increased economic productivity. {10.3, 18.4, 20.2, 31.4}

Ritika S.

Joan Hart

Mitigation and adaptation actions can result in systemic, cascading benefits

Actions taken now to accelerate net emissions reductions and adapt to ongoing changes can reduce risks to current and future generations. Mitigation and adaptation actions, from international to individual scales, can also result in a range of benefits beyond limiting harmful climate impacts, including some immediate benefits (Figure 1.1). The benefits of mitigation and proactive adaptation investments are expected to outweigh the costs. {2.3, 13.3, 14.5, 15.3, 17.4, 22.1, 31.6, 32.4; Introductions in Chs. 17, 31}

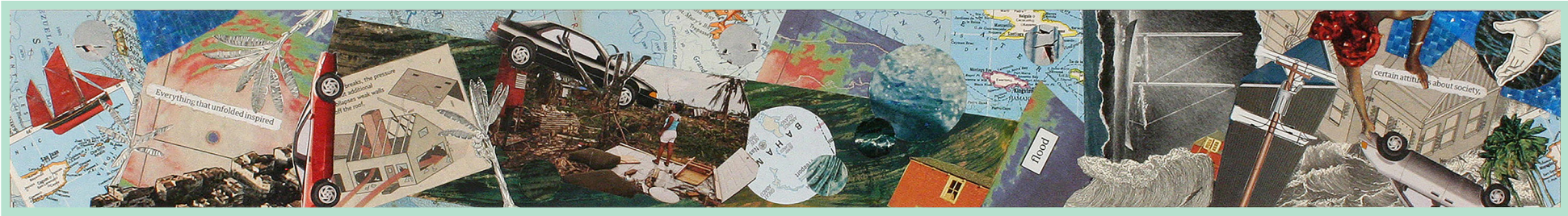
- Accelerating the deployment of low-carbon technologies, expanding renewable energy, and improving building efficiency can have significant near-term social and economic benefits like reducing energy costs and creating jobs. {32.4}
- Transitioning to a carbon-free, sustainable, and resilient transportation system can lead to improvements in air quality, fewer traffic fatalities, lower costs to travelers, improved mental and physical health, and healthier ecosystems. {13.3}
- Reducing emissions of short-lived climate pollutants like methane, black carbon, and ozone provides immediate air quality benefits that save lives and decrease the burden on healthcare systems while also slowing near-term warming. {11.1, 14.5, 15.3}
- Green infrastructure and nature-based solutions that accelerate pathways to net-zero emissions through restoration and protection of ecological resources can improve water quality, strengthen biodiversity, provide protection from climate hazards like heat extremes or flooding, preserve cultural heritage and traditions, and support more equitable access to environmental amenities. {8.3, 15.3, 20.3, 24.4, 30.4; Focus on Blue Carbon}
- Strategic planning and investment in resilience can reduce the economic impacts of climate change, including costs to households and businesses, risks to markets and supply chains, and potential negative impacts on employment and income, while also providing opportunities for economic gain. {9.2, 19.3, 26.2, 31.6; Focus on Risks to Supply Chains}
- Improving cropland management and climate-smart agricultural practices can strengthen the resilience and profitability of farms while also increasing soil carbon uptake and storage, reducing emissions of nitrous oxide and methane, and enhancing agricultural efficiency and yields. {11.1, 24.1, 32.2}

Climate actions that incorporate inclusive and sustained engagement with overburdened and underserved communities in the design, planning, and implementation of evidence-based strategies can also reduce existing disparities and address social injustices. {24.3, 31.2, 32.4}

Transformative climate actions can strengthen resilience and advance equity

Fossil fuel–based energy systems have resulted in disproportionate public health burdens on communities of color and/or low-income communities. These same communities are also disproportionately harmed by climate change impacts. {13.4, 15.2, 32.4}

A "just transition" is the process of responding to climate change with transformative actions that address the root causes of climate vulnerability while ensuring equitable access to jobs; affordable, low-carbon energy; environmental benefits such as reduced air pollution; and quality of life for all. This involves reducing impacts to overburdened communities, increasing resources to underserved communities, and integrating diverse worldviews, cultures, experiences, and capacities into mitigation and adaptation actions. As the country shifts to low-carbon energy industries, a just transition would include job creation and training for displaced fossil fuel workers and addressing



Melanie Mills

existing racial and gender disparities in energy workforces. For example, Colorado agencies are creating plans to guide the state's transition away from coal, with a focus on economic diversification, job creation, and workforce training for former coal workers. The state's plan also acknowledges a commitment to communities disproportionately impacted by coal power pollution. {5.3, 13.4, 14.3, 15.2, 16.2, 20.3, 31.2, 32.4; Figure 20.1}

A just transition would take into account key aspects of environmental justice:

- Recognizing that certain people have borne disparate burdens related to current and historical social injustices and, thus, may have different needs
- Ensuring that people interested in and affected by outcomes of decision-making processes are included in those procedures through fair and meaningful engagement
- Distributing resources and opportunities over time, including access to data and information, so that no single group or set of individuals receives disproportionate benefits or burdens

{20.3; Figure 20.1}

An equitable and sustainable US response to climate change has the potential to reduce climate impacts while improving well-being, strengthening resilience, benefiting the economy, and, in part, redressing legacies of racism and injustice. Transformative adaptation and the transition to a net-zero energy system come with challenges and trade-offs that would need to be considered to avoid exacerbating or creating new social injustices. For example, transforming car-centric transportation systems to emphasize public transit and walkability could increase accessibility for underserved communities and people with limited mobility—if user input and equity are intentionally considered. {13.4, 20.3, 31.3, 32.4; Ch. 31, Introduction}

Equitable responses that assess trade-offs strengthen community resilience and self-determination, often fostering innovative solutions. Engaging communities in identifying challenges and bringing together diverse voices to participate in decision-making allows for more inclusive, effective, and transparent planning processes that account for the structural factors contributing to inequitable climate vulnerability. {9.3, 12.4, 13.4, 20.2, 31.4}