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PAS REPORT 601

# PLANNING FOR CLIMATE MITIGATION AND ADAPTATION

Matt Bucchin, AICP, and Aaron Tuley, AICP

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## ON THE COVER

Boston's Clippership Wharf was designed in accordance with the guidelines of Climate Ready Boston, a city initiative to adapt to the effects of climate change. Rather than building seawalls, the intertidal area allows the tides to move in and out of the site naturally, creating amenity space that allows for the living shoreline to evolve and adapt to rising sea levels. Photo courtesy Ed Wonsek/The Architectural Team.

## ABOUT THE AUTHORS

**Matt Bucchin, AICP, LEED Green Associate**, is regional practice leader over planning at Halff Associates, Inc. He has over 25 years of public- and private-sector experience at the city, state, and special district levels of government. Over the past decade, he has worked as a consultant on planning, design, and code projects focused on how people live and use the built and natural environments. Beyond his primary job duties, he has also taken on leadership roles for several APA initiatives, including past chair of APA's Sustainable Communities Division and contributing author to APA's Climate Change Policy Guide. As part of his involvement with APA's Texas Chapter, he leads its Environment and Healthy Communities advocacy subcommittee. He holds a master of environmental planning degree from Arizona State University, a bachelor of liberal arts degree from Pennsylvania State University, and an associate's degree in fire science technology from Colorado Mountain College.

**Aaron Tuley, AICP,** is planning technical leader with Halff Associates, Inc. He has over 30 years of experience specializing in urban and regional design and planning, natural and cultural resources management, and place-based spatial and policy planning initiatives. He has worked on several forward-thinking and innovative projects, including drafting the state enabling legislation and regional design program for Louisiana's Atchafalaya National Heritage Area; administering the preparation of the Buffalo Bayou and Beyond Master Plan; and preparing environmental assessments for the siting of more than 1,500 megawatts of wind energy projects. As southwest district manager with the Climate Reality Project (2006–2012), he oversaw the delivery of hundreds of presentations on climate change by a team of over 90 people. He routinely makes presentations and conducts workshops on planning for climate change, environmental and urban corridor planning, and the interpretation and management of cultural landscapes. He received his bachelor of arts degree in landscape architecture from the University of Kentucky and his master of science degree in architecture from Louisiana State University.

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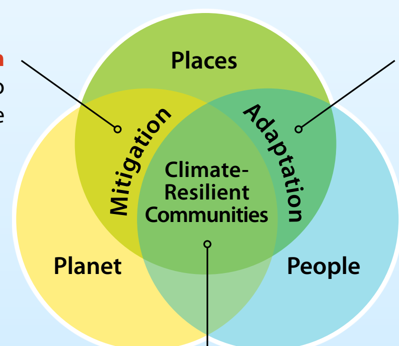
**"Global commitments, national policies, and local planning must all work together confronting and combating climate change and its impacts on people, places, and our planet."**
***APA President Leo Asuncion, Jr., AICP***

# A Climate Crisis

## The Earth is warming at an unprecedented and accelerating rate —

a climate emergency caused by human activities. Get a comprehensive foundation to take on this global challenge and help lead your community towards a more climate-resilient future with *Planning for Climate Mitigation and Adaptation*.

**Climate mitigation**
Reducing greenhouse gas emissions to keep climate change from getting worse




**Climate adaptation**
Anticipating the impacts of climate change on communities and taking action to reduce risk and vulnerability

**Climate resilience**
Surviving and thriving in the face of climate-related stresses and shocks

**Action is needed across all sectors. Planners can lead the way.**

## EXECUTIVE SUMMARY

Climate change is a global challenge that demands global solutions combined with local action. This includes mitigating future climate change through the reduction of greenhouse gas (GHG) emissions and adapting the built and natural environments to the changes already taking place or anticipated to take place in the future.

Effective responses will require a fundamental and systemic shift in how people manage the resources and ecosystems required to sustain life on this planet. Aggressive climate policies and projects in communities from rural towns to major metropolitan areas must be adopted and implemented within this country and aligned with actions around the world.

Success can only be achieved through a comprehensive, interdisciplinary approach, which starts with planning for sustainable and resilient outcomes that meet the needs of today while anticipating the requirements of future generations. Planners in all sectors will be required to not only be a part of the solution, but to lead it.

PAS Report 601, *Planning for Climate Mitigation and Adaptation*, provides an overview of the necessary information and tools needed by planners to take leadership roles in helping our communities respond to climate change. It summarizes essential historical and scientific background information so that planners can be informed participants in future collaborative discussions about climate change, and it offers comprehensive guidance on climate mitigation and adaptation so that planners are better prepared to advance climate resilience in our communities.

### A CLIMATE EMERGENCY

In August 2021, the International Panel on Climate Change (IPCC) issued its Sixth Assessment Report (AR6) on climate change, calling it a "code red for humanity." The planet is warming at an unprecedented and intensifying rate—a climate emergency that is unequivocally caused by anthropogenic, or human, activities. Unless rapid and deep reductions in carbon dioxide ($CO_2$) and other GHG emissions are achieved in the coming decades, there will be little chance of meeting the commitments set out in the 2016 Paris Agreement, the United Nations' legally binding international treaty on climate change. It calls for limiting global warming to well below 2°C (3.6°F), and preferably to 1.5°C (2.7°F), compared to pre-industrial levels.

*Climate change* refers to changes in long-term temperature, precipitation, and wind patterns resulting from higher levels of $CO_2$ and other GHGs in the atmosphere. GHGs are a natural and critical component of regulating the conditions required to sustain life on this planet. However, the burning of fossil fuels, deforestation, and intensive agriculture production since the Industrial Revolution has caused levels of $CO_2$, methane, and other GHGs to increase, accelerating global warming.

This warming of the planet has caused unprecedented increases and variability in global temperatures, resulting in extreme heat; melting permafrost; warmer ocean temperatures, declining sea ice, and subsequent sea level rise; more frequent and intense storm events and inland flooding; acidification of the Earth's oceans; drought and threatened water supplies; increased fire activity; and declining biodiversity, among other climate-induced impacts to the natural and built environments. This PAS Report reviews the science behind climate change, explains the impacts of global warming on the earth's systems, and summarizes the coming changes planners and their communities can expect across the different U.S. regions.

### THE ROLE OF PLANNING

There is widespread recognition that patterns of development have significant implications regarding global emissions and resulting consequences. In particular, rethinking the spatial configuration and systems that enable cities to function (e.g., increasing densification; reducing sprawl and vehicle miles traveled; localizing production and distribution of renewable energy; taking full advantage of ecosystem services and green infrastructure solutions; and implementing life-cycle thinking regarding production, consumption, and reuse of resources) may prove to be some of the most effective and impactful opportunities to rapidly reduce GHG emissions and mitigate climate change.

Past GHG emissions have already changed global climate conditions and will continue to do, even if current and future emissions are mitigated. Communities are increasingly turning to climate adaptation actions and projects to reduce their vulnerability to climate impacts from climate variability and extreme weather events. However, these efforts may not be part of a comprehensive and far-sighted approach, instead only responding to a single climatic impact or addressing today's problems rather than anticipated future conditions. This needs to change. Successful climate adaptation requires the comprehensive, long-range, and interdisciplinary perspective that planners offer.

Addressing climate change will be the defining challenge for our generation and subsequent generations. And as climate impacts continue to worsen, a larger burden will be placed on those who are least able to adapt—those with the fewest resources, the least access to information, and the least likelihood of being heard. This requires planners to simultaneously advance both mitigation and adaptation actions while working within the framework of sustainable development, embracing and integrating factors of social equity and inclusion as part of all climate-related decision-making.

## THE ELEMENTS OF CLIMATE ACTION

To help their communities move towards a climate-resilient future, planners need to rapidly advance their knowledge regarding climate mitigation and adaptation planning and implementation.

*Climate mitigation* involves actions that reduce the levels of GHG emissions in the atmosphere or enhance systems that absorb more GHGs than are emitted (e.g., sequestration through afforestation and other nature-based solutions). Mitigation actions predominantly focus on keeping climate change from getting worse. This requires rapid emissions reductions across all sectors, including transportation, energy production and transmission, industrial operations, agriculture and food production systems, building construction and operations, and materials and waste management, while transitioning to a more circular and sustainable economy. This report identifies the principal sources of emissions that planners need to be aware of to advance climate mitigation, and it highlights strategies and recommended practices planners can use to reduce GHG emissions in their communities.

*Climate adaptation* involves the anticipatory process of adjusting natural and built systems to accommodate and withstand actual or expected climate impacts. Adaptation actions stem from the need to reduce risk and vulnerability with regard to human health and well-being and the assets, resources, and ecosystems that sustain community viability. While climate adaptation actions will always be implemented locally, the extent to which adaptation actions are required will largely depend on the extent and speed with which mitigation policies are implemented globally. To better equip planners to advance climate adaptation action, this report reviews the impacts that climate change will have across key urban sectors—energy, transportation, land use, housing, waste management, the natural environment, and food systems—and the responses available to communities to manage and adapt to those impacts.

As planners, it is critical to become educated on the likely consequences of climate change. A greater understanding of climate vulnerability and communities' adaptive capacity to withstand the most severe impacts is imperative. To mobilize our communities to respond to a growing and intensifying list of climate impacts, planners must work on an interdisciplinary basis with allied professions (e.g., architects, landscape architects, and engineers) to advance strategies both structural (i.e., physical projects) and nonstructural (i.e., policies and regulations). Climate action has already begun in many communities across the country; this report offers case studies highlighting a range of climate mitigation and adaptation actions at the state and local levels.

## THE TIME IS NOW

The climate is changing rapidly and the rate of change is accelerating. Getting to action fast must be a planner's imperative. Cities are major population centers and economic hubs. They are responsible for generating much of the world's GHG emissions, and they are also the most vulnerable to increasing natural disasters and extreme weather events. This places urban areas at the forefront of climate response.

Unlike traditional planning and development actions that can be easily implemented as part of siloed responses, implementation for climate mitigation and adaptation action will require fundamental shifts in governance, community growth and redevelopment, and essential services. Because planning is the only profession working at the nexus of transportation, development, and land use—the sectors most critical to climate mitigation and adaptation—planners need to rise to the challenge to help guide their communities to a climate-resilient future.

This transformation necessitates actions that will fundamentally change the built environment, local and regional economies, and social norms. To ensure sustainable, resilient, and equitable outcomes, planning for climate mitigation and adaptation will require a comprehensive, visionary, and systems-oriented response based on robust and informed community engagement and facilitation, consensus building, and prioritization—placing planners as uniquely qualified to take a leadership role in this process.

This PAS Report offers planners a comprehensive overview and approach to the complexity and interconnectedness of climate mitigation and adaptation. It sets the stage for an ongoing journey that planners will need to embrace for the rest of their careers and weave into everything that they do. Additional research, tools, and strategies are still needed to advance every component of climate response—from mitigating future GHG emissions to adapting to its impacts. But the time for action is now.

CHAPTER 1

# A WARMING PLANET

*Now is an essential moment where global commitments, national policies, and local planning must all work together to meet the demands of confronting and combating climate change and its impacts on people, places, and our planet.*

APA President Leo Asuncion, Jr., AICP
Statement on UN Climate Change Conference, November 3, 2021

Today, the United States is facing several concurrent existential threats—climate change, systemic racism, economic inequality, a global pandemic, and challenges to democracy itself. All these issues are of major importance and present unprecedented obstacles, but the unchecked impacts of only one—climate change—has the potential to destroy human livability of the entire planet.

Climate change is a global challenge that demands global solutions combined with local action. An effective response will require fundamental and systemic changes to our built environment and inevitably must be addressed policy by policy and project by project in our local communities. This includes integrating climate considerations into all local decision-making, including policy, programs, plans, regulations, and projects. It also necessitates alignment with all regional, state, federal, and international climate goals.

Success can only be achieved through a comprehensive, interdisciplinary response that starts with planning and ends with a sustainable built environment, one that truly meets today's needs and those of future generations. Planners in all sectors and at all scales will be required to not only be a part of the solution, but to lead it.

## THE CLIMATE EMERGENCY

Despite decades of efforts from around the world to combat climate change, these efforts have been largely ineffective and woefully inadequate. Global warming and the rate of climate change has been exponentially getting worse (IPCC 2021).

In August 2021, the International Panel on Climate Change (IPCC) issued its Sixth Assessment Report (AR6) on climate change, calling it a "code red for humanity" (IPCC 2021). It indicated that climate change was widespread, rapid, and intensifying and that it was "unequivocal that human influence has warmed the atmosphere, ocean, and land." Some of the report's key takeaways include:

- The scale of recent changes across the climate system has been unprecedented over many thousands of years.
- Human-induced climate changes are already causing many weather and climate extreme events, from heat waves to heavy precipitation to droughts, and have likely increased the chance of compound extreme events.
- Global warming of 1.5°C and 2.0°C will be exceeded during the 21st century unless deep reductions in $CO_2$ and other greenhouse gas (GHG) emissions occur in the coming decades.
- Global surface temperature will continue to increase until at least midcentury under all emission scenarios.
- Changes in the climate system become larger in direct correlation to the increase in global warming.
- Many changes due to past and future GHG emissions are irreversible for centuries to millennia, especially changes in the oceans, ice sheets, and global sea levels.

Today, global surface temperatures have increased by an estimated 1.07°C degrees above pre-industrial levels (Figure 1.1, p. 11) (IPCC 2021). This rate of increase is unprecedented in at least the last 2,000 years and can only be accounted for by factoring in emissions caused by human activities.

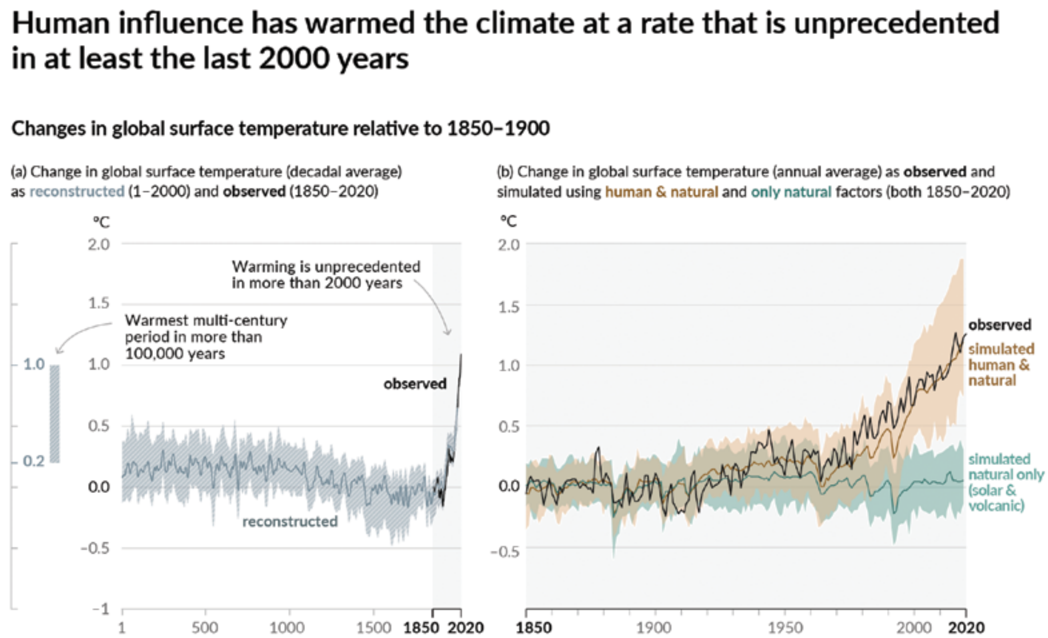



*Figure 1.1. Changes in global surface temperatures relative to 1850–1900 (Figure SPM.1, IPCC 2021)*

To minimize impacts, global $CO_2$ emissions must reach net zero by 2050 to limit global warming to 1.5°C, or by 2070 to limit global warming to 2.0°C (IPCC 2018). Because it is not possible to eliminate all GHG emissions, achieving net zero emissions will require removal of past emissions from the atmosphere (Levin et al. 2019) (Figure 1.2). This will require far-reaching transitions in energy, land use, infrastructure, transportation, buildings, and industrial systems (IPCC 2018).

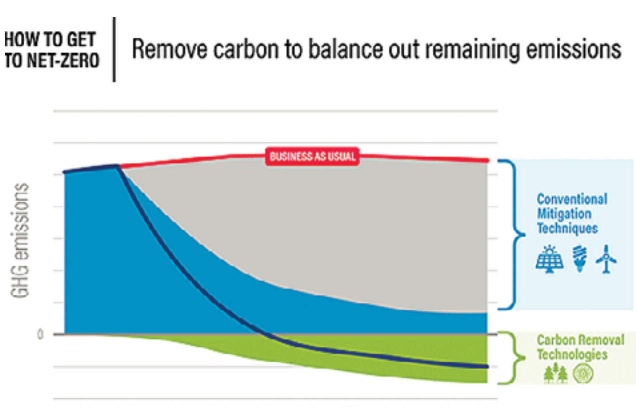



*Figure 1.2. Achieving net zero emissions requires both reduction of human-caused GHG emissions and removal of past emissions from the atmosphere (World Resources Institute/Levin et al. 2019)*

## A Changing Planet

Climate change has resulted in well-documented increases in global temperature, sea level rise, and reductions in Arctic sea ice and snowpack (USGCRP 2017; USGCRP 2018). Additional impacts include increased intensity and frequency of rainfall, with corresponding increases in flood damage and loss of life; increased frequency and intensity of coastal flooding outside of severe storm events; increased frequency and duration of droughts, heat waves, and wildfires; reductions in available water supply; biodiversity loss; and ocean warming and acidification (USGCRP 2017; USGCRP 2018).

The United States Global Change Research Program (USGCRP) prepares a report on climate change every four years. Its Fourth National Climate Assessment (NCA4) found that the near- and longer-term impacts of climate change will be far reaching and will have profound implications to planners and our communities. The sidebar on p. 12 summarizes 12 high-level key messages highlighted in that report.

As is evident in the summary findings, climate change will affect every corner of the country and all aspects of the natural and built environments. The issues, impacts, and solutions are all interconnected, and they require a proactive and holistic response. This will place planners at the forefront of the climate response.

## NATIONAL CLIMATE ASSESSMENT 4: SUMMARY FINDINGS

The NCA4 contains more than 1,500 pages of pertinent technical information, including 16 national-level topic chapters (e.g., land cover and land-use change, built environment, urban systems, and cities), 10 chapters focused on regional variations, and two chapters focused on societal response strategies for mitigation and adaptation (USGCRP 2018). It highlights the following 12 key findings to inform the response to global climate change in the United States.

1. **Communities.** Climate change creates new risks and exacerbates existing vulnerabilities for communities across the United States. This presents new challenges to human health and safety, quality of life, and the rate of economic growth.
2. **Economy.** Climate change is expected to increasingly degrade infrastructure and cause property losses, which will impede the rate of economic growth during this century.
3. **Interconnected impacts.** Climate change affects and exacerbates issues with and between interconnected systems (i.e., natural, built, and social systems), and these systems will be increasingly vulnerable to cascading impacts that are often difficult to predict.
4. **Actions to reduce risks.** Climate action is not occurring quickly enough to keep climate change from getting worse. Despite substantial progress by public and private entities in mitigation and adaptation, these efforts do not yet approach the scale considered necessary to reduce risk and avoid significant damages to the economy, environment, and human health over the coming decades.
5. **Water.** Climate change has been impacting the quality and quantity of water available for use by people and to maintain ecosystems. This has resulted in increased risks and costs related to energy production, environmental protection, and economic sectors such as agriculture, industry, and recreation.
6. **Health.** Climate change is causing significant impacts to human health through extreme weather and climate-related events, degradation of air quality, and the transmission of disease through insects and pests, food, and water, particularly for more vulnerable populations.
7. **Indigenous peoples.** Climate change is increasingly disrupting and threatening the health, cultural identities, and economic livelihoods of indigenous people and cultures.
8. **Ecosystems and ecosystem services.** Climate change is rapidly altering ecosystems and the benefits provided by ecosystem services (e.g., coral reef degradation and species migration).
9. **Agriculture and food.** Climate change is increasingly impacting agricultural productivity, including degradation of livestock health and declines in crop yields and quality. This is affecting rural livelihoods, food security, and price stability.
10. **Infrastructure.** Climate change has and will continue to degrade our nation's infrastructure performance, longevity, and fiscal sustainability. Combined with aging infrastructure, this has the potential to cause cascading impacts to our economy, national security, essential services, and overall livability.
11. **Oceans and coasts.** Climate change is altering coastal communities and the ecosystems that support them. Without significant reductions in global greenhouse gas emissions and regional and local adaptation measures, these coastal regions will be transformed by the latter part of this century. This could have cascading impacts to coastal community livability, the economy, and national security. It could also result in significant migration of coastal populations to inland areas.
12. **Tourism and recreation.** Climate change is increasingly threatening the livelihoods and economies of tourist and recreation areas. This could include such areas as coastal tourist areas, public lands affected by drought and wildfires, and areas that rely on snowpack and winter recreation.

## THE NEED FOR ACTION

The global scientific consensus calls for major reductions in GHG emissions and proactive local adaptation efforts to protect our communities from the increasingly detrimental impacts of climate change. Key points for planners include the following:

- **Global climate change is getting worse at an increasing rate.** It is clear and unequivocal that our planet is facing a climate emergency. Data shows that Earth's climate is now changing faster than at any point in the history of modern civilization (IPCC 2021; USGCRP 2018). The severity of future impacts depends on the mitigation actions taken to reduce GHG emissions and local adaptation responses. Decisions made today will determine the risk exposure for both current and future generations.
- **Projected impacts of climate change are intensifying and not equal.** There is scientific consensus that the impacts of climate change are intensifying across the country and threats to Americans' physical, social, and economic well-being are rising. Because social, economic, and geographic factors shape the exposure of people and communities to climate-related impacts and their ability to respond, it is projected that climate change will exacerbate existing social and economic inequalities and more greatly impact those who are already vulnerable, including low-income communities, some communities of color, children, persons with physical and cognitive disabilities, and the elderly (USGCRP 2018).
- **Global responses to address climate change have not been enough.** Global efforts to combat climate change have been going on for decades but have been largely ineffective. At the same time, there has been rapid growth of carbon-intensive economies—the United States, China, the European Union, and other countries seeking to attain those same standards of living. Achieving the global target of keeping global average atmospheric temperatures to less than 1.5°C above pre-industrial levels will require a rapid decarbonization of the economies of developed countries and the development of carbon-neutral economies for developing countries. It will require fundamental and systemic changes to our built environment implemented through sustainable local action.
- **The United States will need to take a leadership role in solving climate change.** Currently, neither global nor U.S. efforts to address climate change and its associated impacts approach the scales needed to avoid substantial damage to the U.S. economy, environment, and human health and well-being over the coming decades (USGCRP 2018). Keeping the average global atmospheric temperatures to less than 1.5°C above pre-industrial levels is not achievable without the participation and leadership of the United States. Although state, regional, and local public-sector entities, as well as the private sector, have made initial strides in advancing a climate-resilient future, uncoordinated and often contradictory federal leadership has hampered U.S. efforts. Moving forward, a comprehensive and coordinated response will be required across all levels of government, the private sector, nongovernmental entities and coalitions, and members of the public.
- **Climate solutions across all sectors are needed.** A comprehensive combination of structural and nonstructural mitigation and adaptation climate solutions are needed across all sectors, including fundamental changes to the built environment, the generation and use of energy, transportation, and water usage and management. The United States requires new development (and preferably redevelopment) to accommodate our growing population, while at the same time we face a mounting need to replace our aging and failing infrastructure. If undertaken using a carbon-neutral and resilient approach, this will provide ample opportunity to maintain a high quality of life for current Americans while at the same time creating a climate-resilient future for generations to come.

Though the need for immediate action is clear, multiple challenges continue to hamper climate action efforts. Current practices for planning, designing, and maintaining our communities have been entrenched for decades—from design manuals to funding models—and change is often incremental and slow. Planners will have to overcome a whole host of interrelated issues, from lack of funding for implementation (including for staffing) and lack of awareness and understanding to competing priorities, entrenched inertia in both development design and processes, and difficult political environments, including negative political pushback and a focus on short-term political gain and outcomes.

These challenges are great and will require planners to change how we shape the growth and development, or redevelopment, of our cities. However, there are also potential opportunities to help planners implement more climate-positive outcomes. Current trends in development processes and built environments—from a shift to electrification, movement towards an online-based economy, and changes in workplace dynamics and patterns to transformational changes to our transportation modes and their impacts on the built environment—bring their own momentum and movement towards transformational change. And the technological changes driving the shift from the information age to the digital age are accelerating at an unprecedented rate. Infusing "smart city" concepts into the planning toolkit and adjusting planning processes to respond to the rapid digitalization of society provide planners with opportunities to build more climate-resilient communities.

## WHY PLANNERS MUST LEAD THE CLIMATE RESPONSE

This PAS Report describes the leadership role that planners need to take in addressing the climate emergency. Addressing climate change will be the defining challenge for our generation and subsequent generations. A successful response will require the comprehensive and interdisciplinary perspective that planners offer.

This does not mean that planners will do it by themselves. To the contrary, all disciplines across all sectors will be required to successfully implement the fundamental changes needed to our built environment—but planners can play a vital role in leading and coordinating these efforts. As first described in PAS Report 558, *Planning for a New Energy and Climate Future* (Shuford, Rynne, and Mueller 2010, excerpted and updated):

- **Planners have a comprehensive perspective.** This is particularly helpful in understanding how climate change relates to and affects other issues, such as land use, economic development, and transportation. Planners often work with and understand aspects of many different disciplines, allowing them to identify opportunities for synergy and interrelationships in plans and implementation.
- **Planners have a long-range outlook**. They are trained to look at changing conditions and have historically planned five, 10, 20, or more years into the future. For climate considerations, however, they will need to improve their skills for much longer-term outlooks to prepare our communities for what the world will look like in 50 to 100 years. This will be particularly important when preparing for the potential long-term impacts from climate change and in making investments in climate mitigation and adaptation strategies.
- **Planning is one of the few professions that focuses on place-based problems and opportunities affecting health, safety, and general welfare.** Planners routinely deal with the community-wide spatial component of environmental, infrastructure, public safety, and quality-of-life issues.
- **Planners are trained to spot and deal with unintended consequences and long-term cumulative impacts**. This is particularly important in adapting to possible impacts from climate change and identifying sustainable and resilient climate solutions.
- **Planners have expertise in community engagement and consensus building**. They often act as conveners of stakeholders. They can play important roles in involving a community in discussions about taking actions to address and respond to climate change.
- **Planners are often strategically well placed within a city, town, or county to take a collaborative or leading role on such issues**. They are often tasked with facilitating critical and complex discussions among internal and external stakeholders.

Planning is the only profession working at the intersection of transportation, development, and land use—the sectors most critical to climate mitigation and adaptation. The comprehensive, interdisciplinary, and interconnected lens through which planners view cities, communities, and the built environment positions planners to lead the way toward climate resiliency.

## CLIMATE MITIGATION AND ADAPTATION

To help their communities move towards a climate-resilient future, planners need to rapidly advance their knowledge regarding climate mitigation and adaptation planning and implementation.

- Climate *mitigation* involves actions that reduce the levels of GHG emissions in the atmosphere or enhance carbon sinks (i.e., things that absorb more GHGs than they emit) (IPCC 2014a). Mitigation actions predominantly focus on keeping climate change from getting worse and are often advanced by planners through long-range policy-based plans and projects.
- Climate *adaptation* involves actions that reduce vulnerability of people, places, and ecosystems to the impacts of climate change (IPCC 2014a). Adaptation action predominantly focuses on protecting people and communities

against the impacts of an already changing climate—one that is projected to get much worse over time. Although planners can advance adaptation through traditional long-range policy-based plans, they will need to grow their comfort level and expertise to include structural and nonstructural adaptation projects.

A comprehensive approach to both mitigation and adaptation is needed. Each of these will further explored in the chapters to follow. This dual focus will help planners prepare their communities for a climate-resilient future.

## ABOUT THIS REPORT

This PAS Report focuses on providing an overview of the necessary information and tools needed by planners to take leadership roles in helping our communities respond to climate change. It summarizes essential historical and scientific background information so that planners can be informed participants in future collaborative discussions about climate change, and it offers comprehensive guidance on climate mitigation and adaptation so that planners are better prepared to advance climate resilience in their communities.

This chapter has provided an introduction to the climate emergency and explains why planners should be leading climate discussions moving forward. It argues that the time to start addressing this issue is now. The chapters that follow provide information, examples, and case studies focused on guidance for U.S. planners.

Chapter 2, **Climate Change and Its Effects**, describes the important information planners will need to understand and communicate regarding key scientific facts and trends related to climate change. It also highlights regional impacts of climate change most pertinent to each U.S. region.

Chapter 3, **Planning Responses to Climate Change**, introduces climate mitigation and adaptation approaches to planning and identifies why each is important to a planner's toolbox. It explores how the combination of both mitigation and adaptation can lead to climate-resilient communities.

Chapter 4, **Climate Mitigation: Emissions Generation and Reduction**, identifies the principal sources of emissions that planners need to be aware of to advance climate mitigation. It provides key background information for Chapter 5, **Climate Mitigation Planning**, which reviews the critical need for carbon reduction and highlights strategies and best practices planners can use to reduce GHG emissions in their communities.

Chapter 6, **Climate Change Impacts and Adaptive Responses**, reviews the impacts that climate change will have across key urban sectors—energy, transportation, land use, housing, waste management, the natural environment, and food systems—and the responses available to communities to manage and adapt to those impacts. It informs Chapter 7, **Climate Adaptation Planning**, which offers climate adaptation planning approaches to better equip planners to advance climate adaptation action.

The next two chapters share the experiences of communities that are putting climate mitigation and adaptation approaches into practice. Chapter 8, **Case Studies in Climate Mitigation**, highlights a series of case studies about climate mitigation action from across the United States. Chapter 9, **Case Studies in Climate Adaptation**, similarly highlights a series of case studies about climate adaptation action. The case studies reflect various types of jurisdictions or entities, scales, and geographic diversity and provide key takeaways planners can use to advance climate action. Links to additional resources and documents are provided to help connect planners to further information.

Finally, Chapter 10, **Taking Climate Action**, identifies a planner's role and principles for climate action, and it lays out a climate planning framework to help planners move quickly towards implementation. It also overviews several key climate tools developed by APA and APA's Sustainable Communities Division. It concludes with a call to action for all planners to take a leadership role in helping their communities to do their part in solving the climate emergency.

Several appendices provide additional helpful information for planners in addressing this climate emergency. Appendix A, **Glossary**, provides a glossary of climate-related terms and acronyms used throughout the PAS Report. Appendix B, **APA Climate Policy Resources**, provides an overview of the most relevant past reports and policies prepared by APA for planners. Finally, Appendix C, **Climate Mitigation and Adaptation Strategies**, provides a table of strategies that can help planners advance climate mitigation and adaptation solutions in their communities.

CHAPTER 2

# CLIMATE CHANGE AND ITS EFFECTS

Climate change refers to changes in long-term temperature, precipitation, and wind patterns resulting from higher levels of carbon dioxide ($CO_2$) and other greenhouse gases (GHGs) in the atmosphere (Climate Reality Project 2019).

Much like the transparent covering of a greenhouse, gases in our atmosphere allow the sun's rays to pass through and warm the Earth, but they prevent this warmth from escaping our atmosphere. Without naturally occurring, heat-trapping gases—mainly consisting of water vapor, $CO_2$, and methane—the Earth would be too cold to sustain life as we know it.

For thousands of years, the global carbon supply maintained a stable balance, as natural processes removed from the atmosphere as much carbon as was being released. However, modern human activity—including the burning of fossil fuels, deforestation, and intensive agriculture—has added massive quantities of $CO_2$ and other GHGs to the atmosphere. These gases upset the natural systems that regulate the Earth's climate, which has resulted in more extreme weather patterns.

Today's atmosphere contains 42 percent more $CO_2$ than it did at the start of the industrial era (David Suzuki Foundation 2017). Levels of methane and $CO_2$ are the highest they have been in more than 850,000 years (IPCC 2021).

This chapter provides planners with a basic background in how GHGs are heating the planet and summarizes how the increase in global temperature is changing the climate and affecting environmental systems—air, land, and water—around the world. Finally, the chapter draws on the National Climate Assessment to summarize the likely impacts of climate change within the various physiographic regions of the United States.

## EARTH SYSTEMS AND CLIMATE

To understand the basic mechanisms of climate change and its impacts, it is important to understand how $CO_2$ and other GHGs in the atmosphere affect global temperatures through the phenomenon known as the greenhouse effect.

### The Greenhouse Effect

The sun releases energy as radiation in the form of light waves. Upon reaching the Earth's atmosphere, about 29 percent of this solar radiation is reflected back into space, and 23 percent is absorbed by the atmosphere. The remaining 48 percent reaches the surface and warms the planet and its oceans.

In an ideal scenario, the energy that escapes the Earth's atmosphere as heat is roughly equal to the amount of solar radiation that enters the atmosphere. But increasing atmospheric concentrations of GHGs (including $CO_2$, methane, nitrous oxide, and water vapor) trap much of this heat within the Earth's atmosphere and reflect it back to the surface, resulting in an increasingly warmer planet (Figure 2.1) (Hartmann et al. 2013).

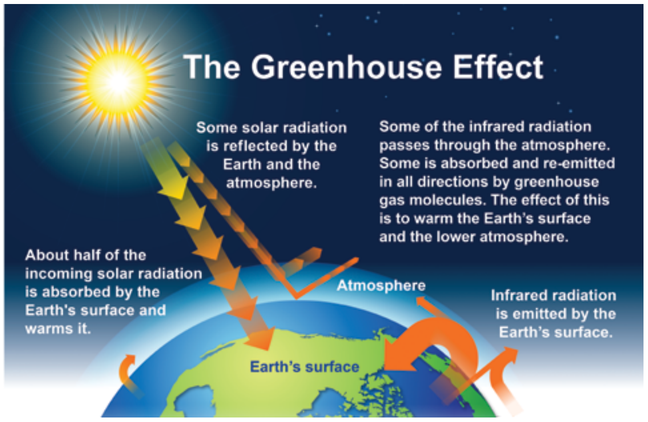



*Figure 2.1. The greenhouse effect (USGCRP 2018)*

## Key Contributors of Carbon

$CO_2$ is being released into the atmosphere faster than at any time in at least the last 66 million years (Zeebe et al. 2016). On average, 110 million tons of GHGs are released into the Earth's atmosphere every 24 hours (Climate Reality Project 2019).

Much of these gases are the result of human-related, or anthropogenic, activities, such as burning fossil fuels to produce electricity, heat, and energy (approximately 50 percent of emissions), industrial processes (25 percent), or national transportation (20 percent) (IEA 2019). Additional sources include unsustainable agricultural practices that dislodge $CO_2$ from soils; deforestation, or cutting down trees on a large scale for fuel, land, or other purposes; mining operations; and the building industry. And as the planet warms and Arctic permafrost begins to thaw, sequestered carbon and other GHGs, such as methane, are released.

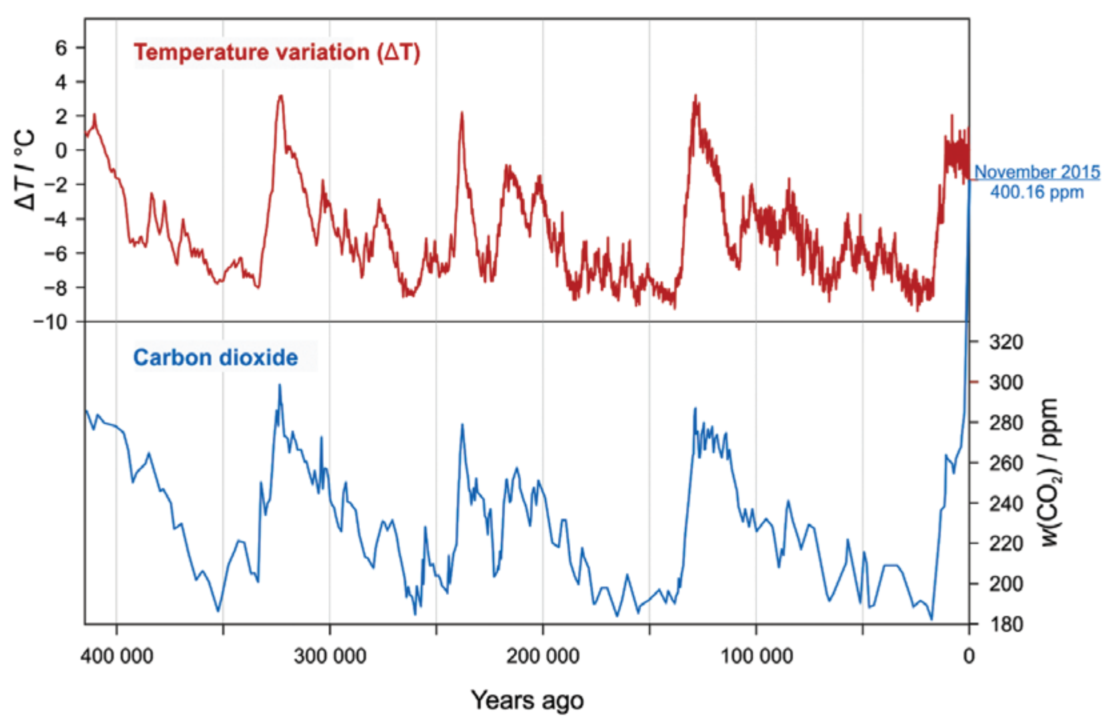
In 2020, China and the United States alone accounted for almost half of the world's carbon emissions. China led the world in carbon emissions, contributing 10,668 million metric tons of $CO_2$ (MtCO2), or about 31 percent of global emissions (7.41 metric tons of $CO_2$ per capita). The United States ranked second, with 5,676 $MtCO_2$, or about 16 percent of global emissions (14.24 metric tons of $CO_2$ per capita). India ranked a somewhat distant third place (1,678 $MtCO_2$) with about five percent of global emissions (1.77 metric tons of $CO_2$ per capita), and Russia was ranked fourth (1,613 $MtCO_2$), also with about five percent of global emissions (10.81 metric tons of $CO_2$ per capita) (Tiseo 2021a, 2021b, 2021c).

## Carbon Dioxide and Temperature

Ice cores drawn from Greenland, Antarctica, and tropical mountain glaciers indicate that the Earth's climate responds to changes in atmospheric levels of $CO_2$ and GHGs. Ancient evidence can also be found in tree rings, ocean sediments, coral reefs, and layers of sedimentary rocks. This paleoclimate record (Figure 2.2) provides irrefutable evidence that there is a direct relationship between atmospheric concentrations of carbon dioxide and temperature (NOAA 2021). Today's global warming is happening at a much faster rate today than it did in the warm periods between ice ages over the last million years.

In the United States, researchers have been measuring atmospheric concentrations of $CO_2$ for more than half a century at the National Oceanic and Atmospheric Administration's (NOAA) Mauna Loa Atmospheric Baseline Observatory in Hawai'i, as described in the sidebar on p. 19. First measured at 313 parts per million (ppm) at Mauna Loa in 1958, atmospheric concentrations of $CO_2$ have steadily

*Figure 2.2. Change of temperature and the amount of $CO_2$ on Earth through history as shown in data from ice excavated near the Vostok research station in Antarctica (Generalic 2011)*



## THE KEELING CURVE AND EARTH'S BREATHING CYCLE

Geophysicist Charles David Keeling of the Scripps Institution of Oceanography at the University of California–San Diego began measuring $CO_2$ emissions at the Mauna Loa Observatory in 1958 (Lindblom 2015). Located on the island of Hawai'i on the north slope of the Mauna Loa volcano at an elevation of 11,135 feet above sea level, the observatory provides researchers with a site for atmospheric and solar observations that is virtually free from human influences, vegetation, and dust (Figure 2.3).

Keeling noted that the air samples taken at night contained higher concentrations of $CO_2$ compared to samples taken during the day. He drew on his understanding of photosynthesis and plant respiration to explain this observation: plants absorb $CO_2$ during the day to photosynthesize, but at night they release $CO_2$ through transpiration.

By studying his measurements over the course of a few years, additional patterns emerged. Keeling recognized what appeared to be seasonal oscillations of $CO_2$, with peaks in May and lows in November. These variations reflected the impact of prevailing vegetation cycles across the Northern Hemisphere. Plants absorb $CO_2$ during the growing period, which typically lasts from April through August, thus reducing atmospheric $CO_2$ levels during these months. In the winter when plants lose their foliage, carbon stored within plant tissues and soils is released to the atmosphere, increasing $CO_2$ concentrations (National Geographic 2019).

This effect is further compounded by the fact that the continental land mass within the Southern Hemisphere is less than half of the area of the continental land mass within the Northern Hemisphere. As a result, when it is winter in the Northern Hemisphere and most of the trees have either lost their leaves or have gone dormant, the quantity of oxygen production due to photosynthesis is significantly less and the atmospheric concentration of $CO_2$ is much higher. Conversely, when it is summer in the Northern Hemisphere and winter in the Southern Hemisphere, the global amount of oxygen being produced by photosynthesis is significantly greater.

Keeling reported his initial findings in the geophysics journal *Tellus* in 1960, describing the seasonal pattern of $CO_2$ variations now known as "Earth's breathing cycle." As Keeling amassed measurements at the Mauna Loa Observatory over the years, he also found that for each succeeding year the atmospheric concentrations of $CO_2$ increased, as did the rate of increase, as illustrated in the well-known Keeling Curve (Figure 2.4).

Keeling's measurements became the foundation for a growing body of irrefutable evidence that the rate of acceleration of atmospheric concentrations of $CO_2$ is caused by increased burning of fossil fuels, the emissions of which contributes to increased global temperatures.

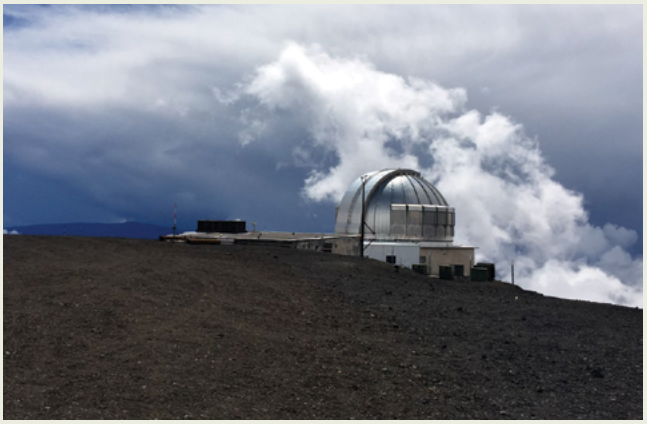


*Figure 2.3. Mauna Loa Observatory, Hawai'i (The Hippie Triathlete/Flickr ([CC BY-NC-ND 2.0](CC BY-NC-ND 2.0)))*

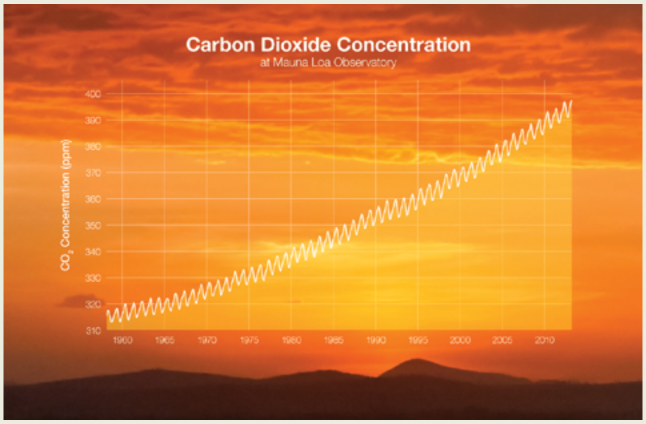



*Figure 2.4. The Keeling Curve shows the "breathing" of the Earth and increasing concentrations of $CO_2$ in the atmosphere (NASA/Shaftel 2018)*

increased each year, reaching 419 ppm in May 2021—the highest seasonal peak recorded in 63 years of observations (Lindblom 2015; NOAA 2021a).

The speed of this increase has also escalated over time. Starting at about 0.7 ppm per year during the early years at Mauna Loa, the annual average rate of increase was about 1.6 ppm per year in the 1980s and 1.5 ppm per year in the 1990s, and it has grown since then to about 2.39 ppm per year over the last decade (Lindblom 2015; NOAA 2021a).

## THE EFFECTS OF CLIMATE CHANGE

The increasing concentrations of $CO_2$ and other GHGs in the atmosphere are indisputably changing conditions on Earth. The rising global temperature is the most direct effect, and this is causing a wide range of related impacts across other Earth systems—with related effects on all of the Earth's inhabitants.

### Increasing Temperatures and Extreme Heat

As discussed, increasing levels of GHGs in the atmosphere are causing global average temperatures to rise. Eighteen of the hottest years on record have occurred since 2001, with the top six hottest years occurring since 2014 (NASA GISS 2019). According to the National Oceanic and Atmospheric Administration, July 2021 was the hottest month ever recorded on Earth (NOAA 2021b).

If GHG emissions are not significantly curtailed, the coldest and warmest daily temperatures are expected to increase by at least 5°F in most areas by mid-century, rising to 10°F by late century. The National Climate Assessment estimates 20–30 more days over 90°F in most areas by mid-century. A recent study projects that the annual number of days with a heat index above 100°F will double, and days with a heat index above 105°F will triple, nationwide, when compared to the end of the 20th century (C2ES 2017).

These temperature increases will cause more deaths from cardiorespiratory disease, along with heat-related illness and death due to heat waves (Dodman et al. 2012). Energy transmission and distribution may become overstressed because of increased incidence or duration of summer heat waves, in conjunction with energy demand for cooling. This will increase the frequency and duration of power failures, thus exacerbating illness and deaths due to heat stress (Shindell et al. 2020).

### Warmer Ocean Temperatures

Oceans cover three quarters of the Earth's surface, contain 97 percent of the Earth's water, and represent 99 percent of the living space on the planet by volume. Over three billion people depend on marine and coastal biodiversity as their primary source of protein. Globally, the market value of marine and coastal resources and industries is estimated at $3 trillion per year, or about five percent of global gross domestic product (GDP). Marine fisheries directly or indirectly employ more than 200 million people (UNESC 2019).

Oceans help to buffer the impacts of global warming by serving as a major carbon and heat sink, absorbing about 30 percent of $CO_2$ and 93 percent of the extra heat produced by anthropogenic global warming. From 1901 through 2020, ocean surface temperature has risen at an average rate of 0.14°F per decade, resulting in an increase of more than 3°F in some locations (Figure 2.5) (U.S. EPA 2022b). Warmer ocean temperatures are projected to have profound conse-

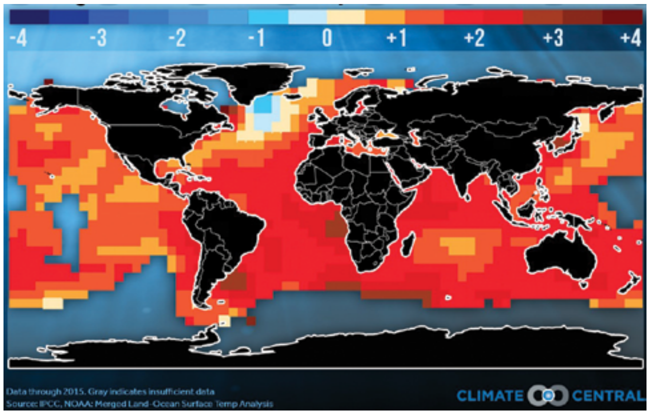



*Figure 2.5. Changes in sea surface temperatures (°F) since 1901 (Climate Central 2017)*

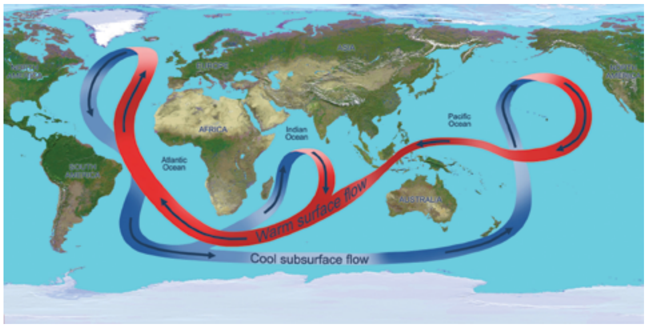



*Figure 2.6. The Atlantic Meridional Overturning Circulation (AMOC) current ([NASA/JPL](NASA/JPL))*

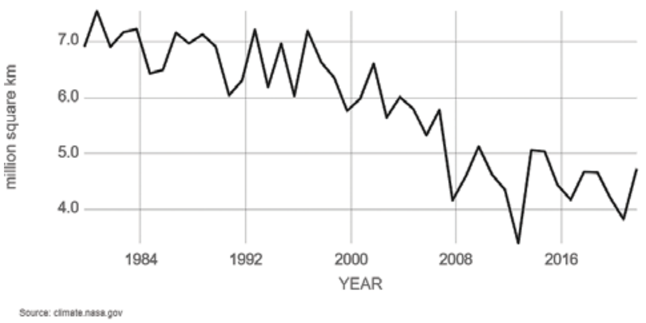



*Figure 2.7. Declines in annual Arctic sea ice extents, 1979–2021 (NSIDC/NASA)*

quences, including an increase in the quantity, intensity, and severity of storms; increased acidification; and sea level rise.

Oceans circulate heat around the world through massive surface and deep-water currents, including the Atlantic Meridional Overturning Circulation (AMOC) (Figure 2.6, p. 20). The AMOC, which helps regulate global climate and weather, is the largest carbon sink in the Northern Hemisphere, sequestering 0.7 petagrams of carbon per year (Jones 2016; Gruber, Keeling, and Bates 2002). The AMOC has undergone significant weakening in the last 150 years compared to the previous 1,500 years (Thornalley et al. 2018), including a weakening of around 15 percent since the mid-20th century (Caesar et al. 2018).

Projections indicate that the AMOC will likely continue to weaken, potentially by 24 to 34 percent, over the 21st century, though the exact timing and magnitude of this change remains uncertain (IPCC 2021). This slowdown could mean cooling across the entire Northern Hemisphere while parts of the Southern Hemisphere become hotter, which could result in massive sea level rise in eastern North America and shifting rainfall patterns that could dry up Europe's rivers (Jones 2016).

## Declining Arctic Sea Ice

Warmer oceans mean less sea ice, particularly in the Arctic, where the extent and thickness of sea ice has declined rapidly over the last several decades (Figure 2.7) (NSIDC 2019). Projections indicate that the planet is swiftly heading toward ice-free periods in the Arctic basin of three to four months a year, and eventually to five months or more.

The Arctic sea ice "death spiral" represents more than just a major ecological upheaval in the far north. In addition to accelerating sea level rise, it may have profound global climatic effects, or feedbacks, that are already intensifying global warming and could further destabilize the Earth's climate system. These effects include the following (Wadhams 2016):

- **Albedo effect**. The melting of Arctic sea ice is turning the far north from white to blue. The dark surfaces will absorb more heat, increase regional and global temperatures, and accelerate further ice melting and sea level rise.
- **Methane release.** Continued Arctic sea ice loss and subsequent rising temperatures will accelerate the thaw of offshore permafrost.
- **Greenland ice sheet melting.** The mass of ice in the Greenland ice sheet has already begun to decline. Rising Arctic air temperatures due in part to the melting of sea ice will lead to further melting of Greenland's ice sheet, adding 72 cubic miles of fresh water to the ocean annually and compounding challenges related to sea level rise (Yale Environment 360 2018). Between 2011 and 2014, satellite and modeling data found that the Greenland ice sheet lost an approximated 269 billion tons of snow and ice annually, raising sea levels about 0.74 millimeters each year (Kintisch 2017). The huge volume of freshwater may also significantly weaken the flow of the AMOC current, as described above, due to a major decrease in salinity and therefore ocean water density.
- **Increased atmospheric water vapor.** Warmer Arctic air temperatures will mean more evaporation. As a GHG, water vapor will trap more long-wave radiation, which will contribute to further warming the Arctic.

Similarly, glaciers, which store about 75 percent of the world's fresh water, have retreated at unprecedented rates over the last century (Climate Reality Project 2019). Some ice caps, glaciers, and ice shelves have disappeared altogether, and many more are retreating so rapidly that they may vanish within decades.

## Sea Level Rise

Sea level has risen by 6.5 inches since 1950, and nearly half of this increase (three inches) has occurred in the last 20 years. Sea levels are now rising by about one inch every eight years (Nerem et al. 2018) and that rate is expected to accelerate. This is due to ice melt from the Arctic, Antarctica, and Greenland; thermal expansion caused by increasing oceanic temperatures (1.2°F since 1950); a slowing Gulf Stream; and sinking land.

Higher seas mean more water and more flooding during high tides (which will continue to get higher), hurricanes, and rainstorms. This small increase in sea level has caused on average a 233 percent increase in tidal flooding across the United States. The Earth's oceans and seas are projected to rise another one to four feet by 2100 (Walsh et al. 2014).

Worldwide, more than 800 million people living in more than 570 coastal cities (those within 10 kilometers from the coast with an average elevation below five meters) are at risk of at least 0.5 meters of sea level rise and coastal flooding. Rising sea levels will result in wider coastal floodplains and greater tidal surges, which will exacerbate inland flooding and require substantial costs for coastal protection and relocation. Further, sea level rise will decrease groundwater availability due to saline intrusion into aquifers (World Bank Group 2011).

Additionally, by the 2050s more than 450 million people will be living in more than 230 cities that receive energy from coastal power plants that are vulnerable to 0.5 meters of sea level rise. Energy disruptions in cities will impact electricity, heating, healthcare, water, transportation, and other critical services (UCCRN 2018).

## Acidification of the Earth's Oceans

Climate change is also making oceans increasingly acidic, disrupting the natural processes of entire ecosystems.

As noted above, the ocean plays a critical role in the storage of carbon, holding about 50 times more carbon than the atmosphere. It absorbs carbon largely through a chemical reaction at its surface, in which $CO_2$ combines with sea water to form carbonic acid. This results in increased ocean acidity.

Ocean acidification makes it more difficult for creatures such as plankton, corals, and shellfish to produce calcium carbonate, which is the main ingredient in their hard skeletons or shells. It causes coral reefs to bleach and die off, with ripple effects up and down the food chain. This can lead to broader changes in the overall structure of ocean and coastal ecosystems, which can affect fish populations and the people who depend on them (U.S. EPA 2016b).

Further, warmer ocean temperatures combined with excessive nutrients such as phosphorous and nitrogen (often from agricultural fertilizer runoff that comes with increased precipitation) are conducive to rapid algae growth events known as algal blooms, which deplete the oxygen content necessary for marine organisms to live (U.S. EPA 2022a). Urban stormwater runoff also contributes to increased oceanic acidification (Feely et al. 2020).

## More Frequent and Intense Storm Events

The frequency of climate extremes will change in response to shifts in both mean climate and climate variability. Variability in weather and climate will inherently lead to increased occurrences of extreme weather or climate events.

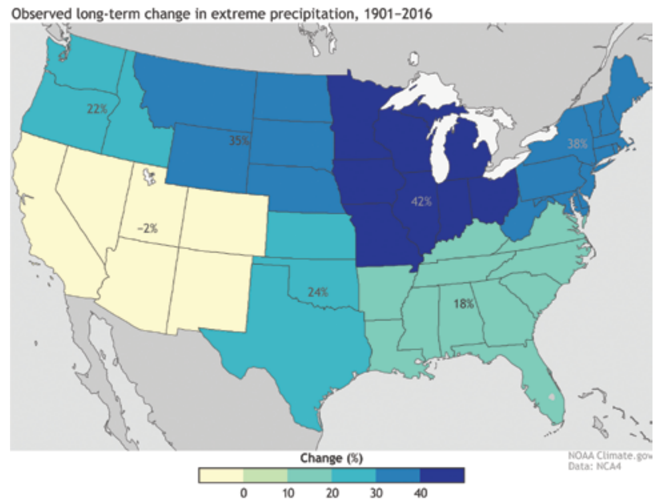



*Figure 2.8. Changes in U.S. extreme precipitation, 1901–2016 (Climate.gov/Scott 2019)*

These events, more unusual and more severe than normal or average weather, include heat waves (high temperature events), cold waves (low temperature events), downpours (heavy precipitation events), and droughts (low precipitation events) (van der Wiel and Bintanja 2021).

For each 1°C of warming, the air's holding capacity for water vapor goes up by almost seven percent (Center for Climate and Energy Solutions 2014). Warmer oceans and warmer air above the oceans result in more water evaporating from ocean surfaces into the atmosphere. The increase in atmospheric moisture content increases the risk of extreme precipitation events and subsequent flooding (Trenberth 2012; Coumou and Rahmstorf 2012). Warmer water also takes up more space. This, along with melting land ice, has caused global sea levels to rise, yielding storm surges that are higher and can move further inland than they otherwise would.

Most regions of the United States have seen increases in extreme precipitation since 1901 (Figure 2.8). In parts of the country, the amount of rainfall has increased approximately 42 percent over the last century and downpours are expected to become more frequent and intense as temperatures continue to rise. By mid-century, some places could experience two or more additional days per year on which the rainfall totals exceed the heaviest historical rains in that area (USGS 2018).

The precipitation rates of tropical storms, hurricanes, and typhoons are projected to increase due to enhanced atmospheric moisture associated with global warming. Also, the intensity of tropical storms is projected to increase further, bringing a greater proportion of storms having more damaging wind speeds, higher storm surges, and more extreme rainfall rates (Knutson et al. 2021).

Increased storm events will result in flooding, strong winds, and landslides. There will likely be disruptions in public water supply and sewer systems, and adverse effects on quality of surface water and groundwater. These events may result in withdrawal of risk coverage in vulnerable areas by private insurers. Extreme rainfall will likely affect the transport of disease organisms and other vectors into the water supply. Outbreaks of waterborne disease have been associated with contamination caused by heavy downfalls and flooding along with inadequate sanitation.

## Inland Flooding

Floods and other water-related disasters account for 70 percent of all deaths related to natural disasters (UNEP 2018). By 2100, the one percent annual chance (100-year) floodplain depth and lateral size of riverine Special Flood Hazard Areas (SFHA) is projected to increase, on average, by approximately 45 percent across the country. About 30 percent of these increases in floodplain area and flood depth may be attributable to normal population growth within these areas (which is projected to increase by approximately 130–155 percent); the remaining portion (70 percent) represents the influence of climate change (AECOM et al. 2013).

## Drought and Threatened Water Supplies

As the world gets warmer, the extra heat increases evaporation, pulling more water from the soil and causing deeper and longer droughts (Union of Concerned Scientists 2014). Soil moisture is projected to decrease globally, which could have potentially very dangerous consequences. As a result of climate change, short-term droughts (four to six months in duration) are expected to increase in frequency throughout the 21st century (Sheffield and Wood 2008).

The effects of drought can be broad and far-reaching, and they can increase other risks. When rainfall does come to drought-stricken areas, the drier soils it hits are less able to absorb the water, increasing the likelihood of flooding.

Water quality and quantity may be reduced by expected increases in droughts, especially from sources (e.g., snowpack) outside of city borders, with a host of consequences ranging from threatened drinking water supplies to reduced agricultural production that affects food security in cities. More than 650 million people living in more 500 cities worldwide will be vulnerable to reduced freshwater availability in the 2050s due to declines in streamflow of 10 percent or more. Global water demand is expected to increase by 55 percent. Cities will likely experience greater in-migration from rural inhabitants pressured by drought or other climate extremes while faced with greater stress on water resources from increased water demand and declining water quality. Declining water supplies will reduce energy production and supply from hydropower generation, and increased drought conditions will result in extensive land degradation, with lower agricultural yields and increased risk of food shortages and dust storms (World Bank Group 2011).

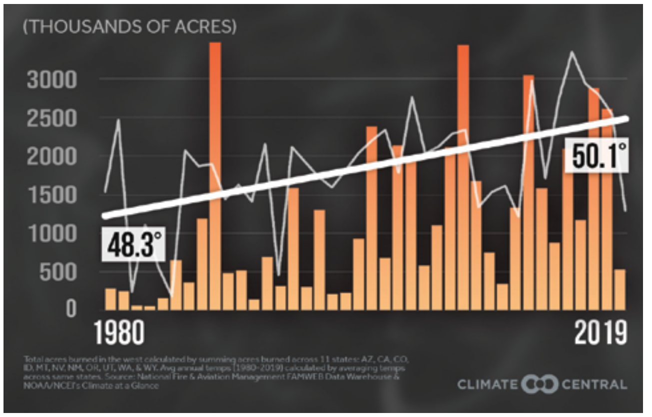



*Figure 2.9. Increased fire activity in western states as average annual temperatures increase ([Climate Central](#))*

## Increased Fire Activity

A hotter, drier climate leads to more fires. For much of the U.S. West, projections show that an average annual 1°C temperature increase would increase the median burned area per year as much as 600 percent in some types of forests (Vose, Peterson, and Patel-Weynand 2012). In the southeastern United States, modeling suggests increased fire risk and a longer fire season, with at least a 30 percent increase from 2011 in the area burned by lightning-ignited wildfire by 2060 (USGCRP 2017).

Multiple factors contribute to increased fire activity (Harvey 2017):

- Spring and summer seasons begin earlier and last longer, respectively, and come with more extreme temperatures.
- With an earlier arrival of the spring season, snowpack is melting sooner, resulting in less water availability during the hottest months of summer, giving vegetation more time to dry out.

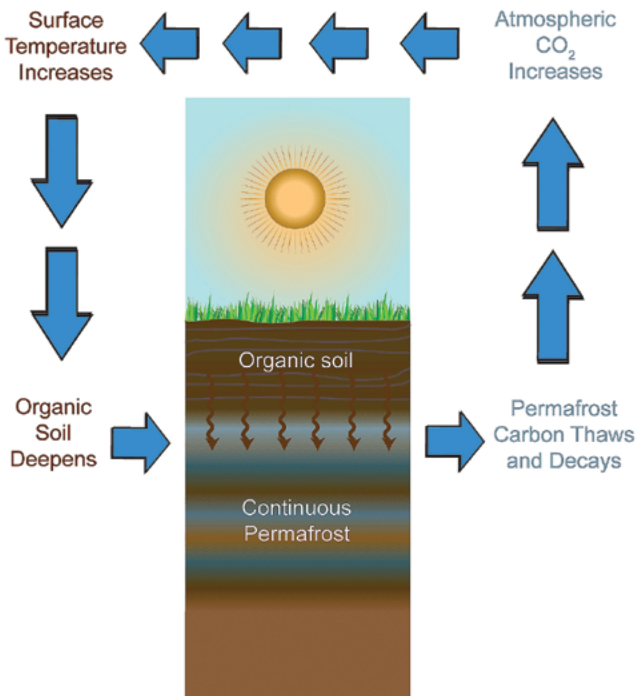



*Figure 2.10. Permafrost carbon feedback cycle (UNEP 2011a)*

- The higher the ambient seasonal temperature, the more moisture plants lose during transpiration, leaving them drier and more susceptible to fire.

Western states have seen a significant increase in large fires (more than 1,000 acres) since 1970, including those induced by lightning (Figure 2.9, p. 23). There are currently around 25 million lightning strikes per year in the United States, and this number is projected to increase by 12 percent or more for every 1°C of warming, to as much as 50 percent by the end of the century (Harvey 2017; Romps et al. 2014; Thompson 2014). Further, there is increasing evidence that climate change may cause more extreme winds in some parts of the world, fanning more flames when fires do break out (Thompson 2014).

### Melting Permafrost

As increasing temperatures continue to heat the soil, the rate at which carbon seeps out of the soil becomes accelerated in some places. This is of particular concern in the far north, where the frozen soil known as permafrost is thawing.

Permafrost contains rich deposits of carbon from plant matter that has accumulated for thousands of years because cold temperatures slow decay. When the soil warms, the organic matter decays, and carbon—in the form of methane and $CO_2$—is released into the atmosphere (Figure 2.10).

It has been estimated that five to 15 percent of the carbon stored in surface permafrost soils could be emitted as $CO_2$ by 2100, leading to 0.3–0.4°C of additional global warming. This estimation, however, does not factor in a process known as photomineralization, through which carbon can be converted to $CO_2$ by sunlight. Organic carbon from thawing permafrost soils flushed into lakes and rivers is highly susceptible to photomineralization by ultraviolet and visible light, which could add an additional 14 percent of $CO_2$ to the atmosphere (University of Michigan 2020).

## THE NATIONAL CLIMATE ASSESSMENT: REGIONAL IMPACTS

All communities throughout the United States are noticing shifts within larger environmental patterns. Climate scientists confirm that these observations are consistent with significant changes in the Earth's climatic trends. This is triggering wide-ranging environmental and economic impacts in every region of the United States.

The National Climate Assessment (NCA) collects, integrates, and assesses observations and research from around the United States to illuminate rapidly changing climatic phenomena and describe how these may impact peoples' lives and livelihoods now and in the future.

Produced by a team of more than 300 experts and guided by a 60-member Federal Development Advisory

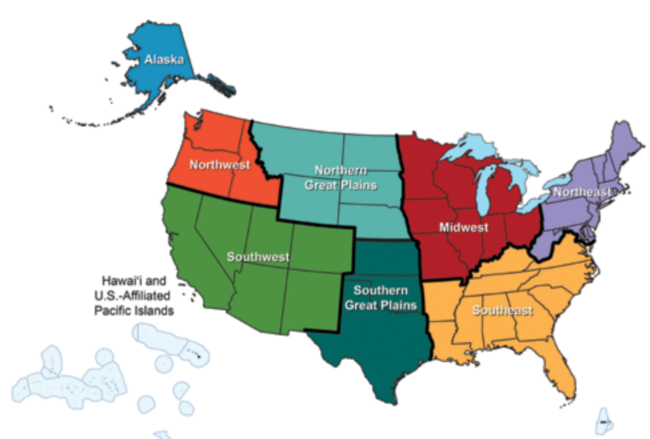



*Figure 2.11. Regions of the National Climate Assessment (USGCRP 2018)*

## TABLE 2.1. SUMMARY OF REGIONAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES

| Region | Climate Change Impacts |
|---|---|
| Northeast | Less distinct seasons with milder winter and earlier spring conditions will continue to alter ecosystems and environments in ways that adversely impact tourism, farming, and forestry. The region's rural industries and livelihoods are at risk from further changes to forests, wildlife, snowpack, and streamflow.<br>Warmer ocean temperatures, sea level rise, and ocean acidification will continue to threaten commerce, tourism, and recreation activities, all of which are important to the region's economy.<br>Significant negative impacts to critical urban infrastructure and economies will become more common with a changing climate.<br>Extreme weather, warmer temperatures, degradation of air and water quality, and sea level rise are expected to lead to health-related impacts and costs. |
| Southeast and U.S. Caribbean | Southeastern cities will continue to be particularly vulnerable to climate change compared to cities in other regions, with expected negative impacts to infrastructure and human health due to heat, flooding, and vector-borne diseases. The combined effects of extreme rainfall events and sea level rise will increase flooding events, which will impact property values and infrastructure viability in low-lying coastal cities.<br>Changing winter temperature extremes, wildfire patterns, sea levels, hurricanes, floods, droughts, and warming ocean temperatures will impact ecological resources that people depend on for livelihood, protection, and well-being.<br>More frequent extreme heat episodes and changing seasonal climates are projected to increase exposure-linked health impacts and economic vulnerabilities in the agricultural, timber, and manufacturing sectors. |
| Midwest | Projected changes in precipitation coupled with rising extreme temperatures before mid-century will reduce Midwest agricultural productivity.<br>Climate-related threats will interact with existing stressors, such as invasive species and pests, to increase tree mortality and reduce forest productivity, resulting in the loss of economically and culturally important tree species.<br>Health conditions will worsen due to increased frequency and intensity of poor air quality days, extreme high temperature events, and heavy rainfalls, extending pollen seasons and modifying the distribution of disease-carrying pests and insects.<br>Stormwater, transportation, and other critical infrastructure will be impacted from changing precipitation patterns and elevated flood risks. |
| Great Plains | Future changes in precipitation patterns, warmer temperatures, and the potential for more extreme rainfall events will make effective water management more difficult.<br>Rising temperatures and changes in extreme weather events will likely have negative impacts on agriculture in the Northern Great Plains.<br>Climate change and extreme weather events put fossil fuel and renewable energy infrastructure at risk, potentially impacting regional economies and national energy supplies.<br>Southern Great Plains cities are vulnerable to increasing temperatures, extreme precipitation, and continued sea level rise, particularly as infrastructure ages and populations shift to urban centers.<br>As temperatures rise, health threats will increase, including heat-related illness and diseases transmitted through food, water, and insects. Weather conditions supporting these health threats are projected to be of longer duration or occur at times of the year when these threats are not normally experienced. |
| Southwest | Intensifying droughts and occasional large floods, combined with critical water demands from a growing population, deteriorating infrastructure, and groundwater depletion will require flexible water management techniques. Increasing droughts and wildfire events will compromise the integrity of Southwest forests.<br>The ability of hydropower and fossil fuel electricity generation to meet growing energy use in the Southwest is decreasing as a result of drought and rising temperatures.<br>Increased drought, heat waves, and reduction of winter chill hours can harm crops and livestock; exacerbate competition for water among agriculture, energy generation, and municipal uses; and increase food insecurity.<br>Heat-associated deaths and illnesses, vulnerabilities to chronic disease, and other health risks will increase with more extreme heat, poor air quality, and conditions that foster pathogen growth and spread. |

| Region | Climate Change Impacts |
|---|---|
| Northwest | The Northwest will see wide variations in temperature and precipitation changes; declining snowmelt and stream flows; increasing ocean acidity, sea level rise, and coastal erosion and inundation; and increasing wildfire, insect outbreaks, and tree diseases.<br>Climate change is projected to increase the risks from many of these extreme events, potentially compromising the reliability of water supplies, hydropower, and transportation across the region.<br>The resulting reductions in water supply will lead to widespread tree die-off and long-term transformation of forest landscapes, as well as threats to marine and riverine fisheries. |
| Alaska | Alaska's marine fish and wildlife habitats, species distributions, and food webs are increasingly affected by retreating and thinning Arctic summer sea ice, increasing temperatures, and ocean acidification.<br>Alaska residents, communities, and their infrastructure continue to be affected by permafrost thaw, coastal and river erosion, increasing wildfire, and glacier melt.<br>A warming climate brings a wide range of human health threats to Alaskans, including increased injuries, smoke inhalation, damage to vital water and sanitation systems, decreased food and water security, and new infectious diseases. |
| Hawai'i and U.S.-Affiliated Pacific Islands | Dependable and safe water supplies for Pacific Island communities and ecosystems are threatened by rising temperatures, changing rainfall patterns, sea level rise, and increased risk of extreme drought and flooding. Islands are already experiencing saltwater contamination due to sea level rise, which is expected to catastrophically impact food and water security, especially on low-lying atolls.<br>Terrestrial habitats and the goods and services they provide are threatened by rising temperatures, changes in rainfall, increased storminess, and land-use change. These changes promote the spread of invasive species and reduce the ability of habitats to support protected species and sustain human communities.<br>By 2100, sea level rise will threaten the food and freshwater supply of Pacific Island populations and jeopardize their continued sustainability and resilience. |

*Sources: Dupigny-Giroux et al. 2018; Carter et al. 2018; Angel et al. 2018; Conant et al. 2018; Kloesel et al. 2018; Gonzalez et al. 2018; Mote et al. 2014; May et al. 2018; Markon et al. 2018; Keener et al. 2018.*

Committee, the NCA projects the following climate impacts to eight regions within the United States (Figure 2.11, p. 24; Table 2.1).

## Northeast

The Northeastern region consists of 12 states and is home to about 64 million people, most of whom live within the high-density urban coastal corridor that spans from Washington, D.C., north to Boston. While this region is largely urban, it contains a significant rural component of more than 180,000 farms with $17 billion in annual sales (Horton et al. 2014).

Heat waves, coastal flooding, and riverine flooding will pose a growing challenge to the region's environmental, social, and economic systems. This will increase the vulnerability of the region's residents, especially its most disadvantaged populations. Climate-related disruptions will only exacerbate existing issues with aging infrastructure (Dupigny-Giroux et al. 2018).

The frequency, intensity, and duration of heat waves is expected to increase. By mid-century, under continued increases in emissions, much of the southern portion of the region, including most of Maryland and Delaware and southwestern West Virginia and New Jersey, is projected to experience many more days per year above 90°F compared to the end of last century (Horton et al. 2014). Northeastern cities will tend to have higher temperatures than surrounding regions due to the urban heat island effect. Heat-related illness and death will continue to be significant public health problems (Petkova et al. 2017), which will result in a projected 650 additional premature deaths per year from extreme heat by 2050 (U.S. EPA 2017).

Throughout the Northeast the recent dominant trend in precipitation has been towards increases in rainfall intensity, exceeding those in other regions of the contiguous United States (Dupigny-Giroux et al. 2018).

Increases in oceanic temperature, acidification, storm frequency and intensity, and sea level rise are projected to negatively impact coastal and ocean ecosystems, which support fishing and aquaculture (Lowther and Liddel 2016) and the interconnected social and economic systems of local communities (Horton et al. 2014).

## Southeast

The Southeast and U.S. Caribbean are exceptionally vulnerable to sea level rise, extreme heat events, hurricanes, and decreased water availability. The geographic distribution of these impacts and vulnerabilities is uneven because the region encompasses a wide range of natural system types, from the Appalachian Mountains to the coastal plains (Carter et al. 2014). The region is home to more than 82.5 million people and draws millions of visitors every year.

Climate model simulations of future conditions project increases in both temperature and extreme precipitation within the Southeast United States. Cities across the Southeast are projected to experience more and longer summer heat waves (Carter et al. 2014).

Increasing temperatures and the associated increase in frequency, intensity, and duration of extreme heat events will affect public health, natural and built environments, energy, agriculture, and forestry. Summer heat stress is projected to reduce crop productivity, especially when coupled with increased drought (Carter et al. 2014). In the future, rising temperatures and increases in the duration and intensity of drought are expected to increase wildfire occurrence and reduce the effectiveness of prescribed fire practices. Warmer winter temperatures are also expected to facilitate the northward movement of problematic invasive species, which could transform natural systems north of their current distributions (Carter et al. 2018).

The net water supply availability in the Southeast is expected to decline over the next several decades, particularly in the western part of the region. Decreased water availability, exacerbated by population growth and land-use change, will continue to increase competition for water and affect the region's economy and ecosystems (Carter et al. 2014). Rising sea levels will contribute to increased coastal flooding and will pose daily risks to businesses, neighborhoods, infrastructure, transportation, and ecosystems in coastal cities within the region (Spanger-Siegfried, Fitzpatrick, and Dahl 2014). Sea level rise will result in the rapid conversion of coastal, terrestrial, and freshwater ecosystems to tidal saline habitats. Water demand by the energy, agricultural, and urban sectors will increase the competition for water, particularly in situations where environmental and energy-related water needs conflict with the need for potable water for people and animals (Ingram et al. 2013).

## Midwest

Comprising expansive agricultural lands, forests in the north, the Great Lakes, substantial industrial activity, and major urban areas, the Midwest region spans eight states and is home to more than 61 million people. Climate change will likely amplify existing climate-related risks and stressors impacting people, ecosystems, and infrastructure. Direct effects of increased heat stress, flooding, drought, and late spring freezes on natural and managed ecosystems may be exacerbated by changes in land uses, resulting in ecological disturbances and landscape fragmentation. Economic shocks and stressors such as crop failures or reduced yields due to extreme weather events may alter socioeconomic patterns and processes (Pryor et al. 2014).

Increased temperatures in the Midwest are projected to be the largest contributing factor to declines in the productivity of regional agriculture production. Increases in humidity in spring through mid-century are expected to increase rainfall, which will increase the potential for soil erosion and further reduce planting-season workdays due to waterlogged soil (Angel et al. 2018). Extreme heat in urban centers like Chicago, St. Louis, Cincinnati, Minneapolis/St. Paul, Milwaukee, and Detroit will exacerbate dangerous living conditions. Increasing precipitation, especially heavy rain events, will increase the risk of flooding and disruptions to the region's transportation infrastructure and damage to property and infrastructure. Land conversion and a wide range of other stressors will continue to reduce biodiversity in many of the region's prairies, wetlands, forests, and freshwater systems. The loss of species and the degradation of ecosystems will compromise essential ecological services that contribute to flood control, water purification, and crop pollination, thus reducing the potential for society to successfully adapt to ongoing changes (Angel et al. 2018).

The Great Lakes play a central role in the Midwest region and provide an abundant freshwater resource for water supplies, industry, shipping, fishing, and recreation, as well as a rich and diverse ecosystem. These important ecosystems are under stress from pollution, nutrient and sediment inputs from agricultural systems, and invasive species. Lake surface temperatures are increasing, lake ice cover is declining, the seasonal stratification of temperatures in the lakes is occurring earlier in the year, and summer evaporation rates are increasing. Increasing storm impacts and declines in coastal water quality can put coastal communities at risk (Angel et al. 2018).

## Great Plains

The Great Plains region is composed of eight very different states. It features relatively flat plains that increase in elevation from sea level in southern Texas to more than 5,000 feet at the base of mountain ranges along the Continental Divide in Montana. It is home to more than 41 million people, 29 million of whom live in Texas alone.

Anticipated challenges related to climate change will unfold against a changing backdrop that includes a growing urban population and declining rural population. The trend toward more dry days and higher temperatures across the southern part of the region will increase evaporation, decrease water supplies, reduce electricity transmission capacity, and increase cooling demands. These changes will add stress to limited water resources and affect management choices related to irrigation, municipal use, and energy generation (Colby et al. 2011). Rising temperatures have already resulted in shorter snow seasons, lower summer stream flows, and higher stream temperatures and have negatively affected high-elevation ecosystems and riparian areas, with important consequences for local economies that depend on winter or river-based recreational activities. Climate-induced land-use changes in agriculture can have cascading effects on closely entwined natural ecosystems, such as wetlands, and the diverse species and the recreational amenities they support (Conant et al. 2018).

The Northern Great Plains region will continue to play a critical role in national food security. Among other anticipated changes, projected warmer and generally wetter conditions with elevated atmospheric $CO_2$ concentrations are expected to increase the abundance and competitive ability of weeds and invasive species, increase livestock production and efficiency of production, and result in longer growing seasons at mid and high latitudes. Net primary productivity, including crop yields and forage production, is also likely to increase, although an increasing number of extreme temperature events during critical pollination and grain fill periods will likely reduce crop yields (Conant et al. 2018).

Competition for water resources, particularly in the Southern Plains, will increase within already-stressed human and ecological systems. The general lack of water will affect crops and energy production and reduce the ability of people, animals, and plants to survive. The region's ecosystems, economies, and communities will be further strained by increasing intensity and frequency of floods, droughts, and heat waves that will impact the lives and livelihoods of Great Plains residents (Shafer et al. 2014). Diminishing water supplies and rapid population growth will remain critical issues in Texas. Because reservoirs have high evaporation rates, it is likely that metropolitan areas will increasingly turn to subsurface aquifers for drinking water. The warming of coastal bay waters will directly affect water quality, leading to hypoxia, harmful algal blooms, and fish kills—thus lowering the productivity and diversity of estuaries (Kloesel et al. 2018).

Extreme weather results in both direct and indirect impacts to people; physical injury and population displacement are anticipated to result with climate change. Heat illness and diseases transmitted through food, water, and insects will increase human risk as temperature rises (Kloesel et al. 2018).

## Southwest

The Southwest region encompasses six states: California, Nevada, Utah, Colorado, Arizona, and New Mexico. This is an already parched region that is expected to get hotter and, particularly in its southern half, significantly drier. Increases in temperature will contribute to aridification (a potentially permanent change to a drier environment) in much of the Southwest through increased evapotranspiration, lower soil moisture, reduced snow cover, earlier and slower snowmelt, and changes in the timing and efficiency of snowmelt and runoff (Gonzalez et al. 2018).

Intensifying droughts and occasional large floods, combined with critical water demands from a growing population, deteriorating infrastructure, and groundwater depletion, suggest the need for flexible water management techniques that address changing risks over time, balancing declining supplies with greater demands. Higher temperatures intensified the recent severe drought in California and are amplifying drought in the Colorado River Basin. The reduction of water volume in both Lake Powell and Lake Mead increases the risk of water shortages across much of the Southwest (Gonzalez et al. 2018). Agricultural irrigation accounts for approximately three-quarters of water use in the Southwest region, which grows half of the fruits, vegetables, and nuts and most of the wine grapes, strawberries, and lettuce for the United States. Increasing heat stress during specific phases of the plant life cycle can increase crop failures. Increased evapotranspiration due to higher temperatures will reduce the effectiveness of precipitation in replenishing soil moisture and surface water (Gonzalez et al. 2018). Drought and competing water demands in this region pose a major risk for agriculture and food security for the entire country.

Extreme heat episodes in much of the region disproportionately threaten the health and well-being of individuals and populations who are especially vulnerable. Exposure to hotter temperatures and heat waves already leads to heat-associated deaths in Arizona and California. Mortality risk during a heat wave is amplified on days with high levels of ground-level ozone or particulate air pollution (Gonzalez et al. 2018).

With continued emissions, models project more wildfire across the Southwest region. Wildfire frequency could increase 25 percent, and the frequency of very large fires (greater than 5,000 hectares) could triple. Santa Ana and other dry seasonal winds increase fire risk in California (Gonzalez et al. 2018). Models project a doubling of burned area in the southern Rockies and up to a 74 percent increase in burned area in California, with northern California potentially experiencing a doubling under a high-emissions scenario toward the end of the century (Garfin et al. 2014).

## Northwest

The states of Washington, Oregon, and Idaho comprise the Northwest Region, an area that has a population of over 13.7 million people. The region is characterized by a rocky Pacific coast shoreline, glaciated mountains, fertile valleys, and a dry interior. Natural resources abound and include timber, fisheries, productive soils, and in most areas, plentiful water.

Climate change and extreme events are already endangering the well-being of a wide range of wildlife, fish, and plants, which are intimately tied to tribal subsistence culture and popular outdoor recreation activities. Climate change is projected to continue to have adverse impacts on the regional environment, with implications for the values, identity, heritage, cultures, and quality of life of the region's diverse population (May et al. 2018).

Reduced amounts of precipitation will result in drier summers, which will produce lower stream flows into the arid interior west of the Cascades and will increase the likelihood of wildfires throughout the region (Mote et al. 2014). Climate change will alter Northwest forests by increasing wildfire risk and insect and tree disease outbreaks, and by forcing longer-term shifts in forest types and species. Many impacts will be driven by water deficits, which increase tree stress and mortality, tree vulnerability to insects, and fuel flammability.

Region-wide summer temperature increases and, in certain river basins, increased flooding and winter flows and decreased summer flows will threaten many freshwater fish species, particularly salmon, steelhead, and trout. Rising temperatures will likely increase disease and mortality in several salmon species, especially for Chinook and sockeye salmon in the interior Columbia and Snake River basins during the spring and summer months (Mote et al. 2014).

Continued changes in the ocean environment, such as warmer waters, altered chemistry, sea level rise, and shifts in marine ecosystems, are also expected. These changes would affect the Northwest's natural resource economy, cultural heritage, built infrastructure, and recreation as well as the health and welfare of Northwest residents (May et al. 2018). In Washington and Oregon, more than 140,000 acres of coastal lands lie within 3.3 feet in elevation of high tide. As sea levels continue to rise, these areas will be inundated more frequently. Many coastal wetlands, tidal flats, and beaches will probably decline in quality and extent as a result of sea level rise. Ocean acidification will threaten the viability of culturally and commercially significant marine species. For example, oysters will be directly affected by changes in ocean chemistry, while Pacific salmon will be affected by changes in the marine food web. Northwest coastal waters will likely be among the most acidified worldwide, especially in spring and summer with coastal upwelling, combined with local factors in estuaries (Mote et al. 2014).

Existing water, transportation, and energy infrastructure already face challenges from flooding, landslides, drought, wildfire, and heat waves. Climate change is projected to increase the risks from many of these extreme events, potentially compromising the reliability of water supplies, hydropower, and transportation across the region. Healthcare and social systems will likely be further challenged with the increasing frequency of acute events, or when cascading events occur. In addition to an increased likelihood of hazards and epidemics, disruptions in local economies and food systems are projected to result in more chronic health risks (Mote et al. 2018).

## Alaska

Alaska is the only Arctic region in the United States. Almost 20 percent of the size of the lower 48 states, Alaska is rich in natural capital resources. Its diversity of marine, tundra, boreal forest, and rainforest ecosystems are home to abundant birds, wildlife, and fisheries. Alaska is also home to 40 percent of the 556 federally recognized U.S. tribes (Chapin et al. 2014).

Alaska residents, communities, and their infrastructure continue to be affected by permafrost thaw, coastal and river erosion, increasing wildfire, and glacier melt. These changes are expected to continue with increasing temperatures, which would directly impact how and where many Alaskans will live (Markon et al. 2018). Over the past 60 years, Alaska has warmed more than twice as rapidly as the rest of the United States, with statewide average annual air temperatures increasing by 3°F and average winter temperature by 6°F (with substantial year-to-year and regional variability). Because of its cold-adapted features and rapid warming, climate impacts in Alaska are already pronounced, including earlier spring snowmelt, reduced sea ice, widespread glacier retreat, warmer permafrost, drier landscapes, and more extensive insect outbreaks and wildfire (Chapin et al. 2014).

As temperatures increase across the Alaskan landscape, physical and biological changes are also occurring throughout Alaska's terrestrial ecosystems. Temperature increases have caused changes in coniferous and deciduous forest types in interior Alaska, and these changes are projected to continue with increased future warming and fire (Markon et al. 2018).

Degradation of permafrost is expected to continue, with associated impacts to infrastructure, river and stream discharge, water quality, and fish and wildlife habitat. In Alaska, 80 percent of land is underlain by permafrost, and of this, more than 70 percent is vulnerable to subsidence upon thawing. Thaw is already occurring in interior and southern Alaska and in northern Canada. Models project that permafrost in Alaska will continue to thaw, and near-surface permafrost may be lost entirely from large parts of Alaska by the end of the century. Uneven sinking of the ground in response to permafrost thaw is estimated to add between $3.6 and $6.1 billion (10 percent to 20 percent) to current costs of maintaining public infrastructure such as buildings, pipelines, roads, and airports over the next 20 years (Larsen et al. 2008). Permafrost soils throughout the entire Arctic contain almost twice as much carbon as the atmosphere, and warming and thawing of these soils increases the release of $CO_2$ and methane through increased decomposition (Chapin et al. 2014).

Alaska's marine fish and wildlife habitats, species distributions, and food webs, all of which are important to Alaska's residents, are increasingly affected by retreating and thinning Arctic summer sea ice, increasing temperatures, and ocean acidification. Continued warming will accelerate related ecosystem alterations in ways that are difficult to predict, making adaptation more challenging (Markon et al. 2018). Thawing of near-surface permafrost beneath lakes and ponds that provide drinking water may cause food and water security challenges for villages. Sanitation and health problems also result from deteriorating water and sewage systems, and ice cellars traditionally used for storing food are thawing (Chapin et al. 2014). The cost of infrastructure damage from a warming climate could potentially range from $110 to $270 million per year (Markon et al. 2018).

### Hawai'i and U.S.-Affiliated Pacific Islands

The U.S. Pacific Islands region spans millions of square miles of ocean and comprises more than 2,000 islands, all of which are at risk from climate changes that will affect nearly every aspect of life. Rising air and ocean temperatures, shifting rainfall patterns, changing frequencies and intensities of storms and drought, decreasing baseflow in streams, rising sea levels, and changing ocean chemistry will affect ecosystems on land and in the oceans, as well as local communities, livelihoods, and cultures (Leong et al. 2014).

Dependable and safe water supplies are threatened by rising temperatures, changing rainfall patterns, sea level rise, and increased risk of extreme drought and flooding. Islands are already experiencing saltwater contamination due to sea level rise, especially on low-lying atolls (Keener et al. 2018). On most islands, increased temperatures coupled with decreased rainfall and increased drought will reduce the amount of freshwater available for drinking and crop irrigation. As sea level rises over time, increasing saltwater intrusion from the ocean during storms will likely exacerbate limited freshwater availability (Leong et al. 2014). Severe droughts are common, making water shortages one of the most important climate-related risks in the region. As temperature continues to rise and cloud cover decreases in some areas, evaporation is expected to increase, causing both reduced water supply and higher water demand (Keener et al. 2018).

Sea level rise will disproportionately affect the tropical Pacific and potentially exceed global averages (Keener et al. 2018). By 2100, increases of one to four feet in global sea level are very likely, jeopardizing the continued sustainability and resilience of Pacific Island populations (Keener et al. 2018). The impacts of Pacific sea level rise include coastal erosion, episodic flooding, permanent inundation, heightened exposure to marine hazards, and saltwater intrusion to surface water and groundwater systems (Keener et al. 2018). Rising sea levels will escalate threats to coastal structures and property, groundwater reservoirs, harbor operations, airports, wastewater systems, shallow coral reefs, sea grass beds, intertidal flats and mangrove forests, and other social, economic, and natural resources. Agricultural activity will also be affected as sea level rise decreases the land area available for farming and periodic flooding increases the salinity of groundwater (Leong et al. 2014). Mounting threats to food and water security, infrastructure, health, and safety are expected to lead to more human migration, making it increasingly difficult for Pacific Islanders to sustain the region's many distinctive customs, beliefs, and languages.

## CONCLUSION

This is a time of unprecedented environmental change. The effects of climate change are not something of the future; they are happening now and at an alarming rate. To limit global warming to 1.5°C, rapid, wide-ranging structural and nonstructural changes are needed within multiple development sectors around the planet, including energy production, land use, buildings, and transportation.

These changes must primarily occur in cities and time is at a premium. All sectors must accelerate their transition to decarbonization to achieve this objective. Mitigation alone, however, will be insufficient to reduce vulnerability; adaptation measures must be employed to ensure continuity and resilience now and in the future. The following chapter delves into these equally vital approaches.

CHAPTER 3

# PLANNING RESPONSES TO CLIMATE CHANGE

As this PAS Report has already made clear, humans are continuing to exacerbate the warming of our planet through practices and systems that send carbon dioxide ($CO_2$) and other greenhouse gases (GHGs) into the atmosphere, and the consequences of little or no action will be severe.

Planners from communities of all sizes and geographic areas must advance climate mitigation to reduce GHG emissions at a scale, pace, and extent that does not exist today. This includes developing a deeper understanding of how our practices and systems generate or reduce the production of GHGs—and how planning can be used to harness transformational change in our built and natural environments. This also includes a commitment to create innovative solutions and a willingness to move action forward now.

It is also clear that GHGs emitted by human actions since the advent of the Industrial Revolution are already significantly changing the global climate—and at an increasing rate. Because $CO_2$ in particular can stay in the atmosphere for many hundreds of years, past GHG emissions will continue to warm the planet even if all emissions stop today. In some instances (e.g., sea level rise and melting ice sheets), these changes are irreversible for centuries to millennia (IPCC 2021).

The impacts of a warming planet and changing climate—from gradual increases in average temperatures to sudden extreme weather events—require planners to also place adaptation as a top priority to ensure the continued health, safety, and well-being of our communities. This is particularly true in cities, where climate change combined with urbanization will further intensify the severity of heat waves and flooding (IPCC 2021).

This means that planners must simultaneously advance climate mitigation and climate adaptation planning and implementation efforts. This chapter introduces mitigation and adaptation as the principal ways to lessen global warming and protect our communities against climate change impacts that will continue to worsen during our lifetimes and generations to come.

## MITIGATION PLANNING: REDUCING THE RATE OF GLOBAL WARMING

In the context of climate change, *mitigation* refers to actions taken to lower the concentration of GHGs in the atmosphere, thereby reducing the extent to which the global climate system changes relative to how it has been in the recent past. Mitigation principally involves (1) reducing or eliminating GHG emissions at the source and (2) sequestering GHGs out of the atmosphere using carbon sinks to meet the objective of reducing the rate of climate change and frequency and intensity of extreme events.

The global scientific community and many governmental leaders are galvanizing global action towards a 50 percent reduction in net GHG emissions by 2030 (compared to 2005 levels) and net zero by 2050 (The White House 2021, IPCC 2022). This is the best chance at limiting the increase in global average temperature by 1.5°C (2.7°F) as set out in the 2015 Paris Agreement. In 2021, participating nations adopted the Glasgow Climate Pact as an effort to turn the 2020s into a decade of climate action (see sidebar on p. 36).

Achieving net zero emissions and limiting increases of global average temperatures to 1.5°C (2.7°F) by 2050 will require wholesale global shifts in policies, technology, and behavior to a degree that has never been achieved before. To put the true extent into perspective, when the COVID-19 pandemic began in 2020, global GHG emissions dropped by roughly 2.3 billion tons from the previous year, the largest decline on record. But this seven percent drop in GHG emissions—the result of a near-complete worldwide shutdown of the entire global economy—represents almost the same reductions in global carbon emissions needed annually for the next decade to prevent the globe from warm-

## UNDERSTANDING INTERRELATED FRAMEWORKS

Responding to the climate emergency necessitates an all-hands-on-deck global response. Climate action can come in many forms and through different processes.

*Sustainability* is an overarching term and framework that comprises the necessary actions to respond to a changing climate. The United Nations Sustainable Development Goals (SDGs), adopted in 2015, provide an established framework that advances climate action while balancing social well-being, economic prosperity, and environmental protection (IPCC 2018). Some *hazard mitigation* efforts are related to climate change actions, while others would have no impact on mitigating GHG emissions or adapting to a changing climate. Similarly, *emergency response and recovery* planning, which focuses on stabilizing unstable situations and restoring critical community functions, may be a response to an extreme weather event related to climate change or may have no connection at all. *Climate resilience* involves both *mitigation* and *adaptation* efforts; because communities will not be able to avoid the serious consequences of climate change impacts, they will need to prepare for the anticipated shocks and stressors.

Table 3.1 offers definitions of these common frameworks and some associated examples. By understanding the interrelated nature of these frameworks, planners can better mobilize each where appropriate for an adequate and effective climate response.

## TABLE 3.1. INTERRELATED FRAMEWORKS FOR ADDRESSING CLIMATE CHANGE

| Framework | Definition | Examples |
|---|---|---|
| Sustainability or sustainable development | As defined originally by the Bruntland Commission in 1987 (WCED 1987) and in IPCC's Third Assessment Report, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (IPCC 2001). It is often described as a three-legged stool of people, profit, planet or social, economic, environment. Sustainability is an overarching lens under which many other frameworks fall. | Greenspace preservation; crop rotation; sustainable design and construction; water-efficient fixtures; renewable clean energy; materials management and reduction; waste to energy recycling; water conservation; full life-cycle use of resources and resource consumption (e.g., zero waste); fiscal sustainability |
| Hazard mitigation | A series of actions that lessen the severity or intensity of a hazard when it strikes. It involves sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards (Schwab 2010). | Promoting effective land-use planning; relocating critical infrastructure out of vulnerable areas; improving building codes; purchase of flood insurance; elevation of structures; acquisition and demolition of flood-prone structures |
| Emergency response/recovery | The response during and after an event to restore or return to the previous condition and in many cases to produce a better state. | Emergency response plans and training; disaster warning systems; pre-event public outreach and education |
| Climate mitigation | Human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs) (IPCC 2014); actions that seek to reduce or store GHG emissions and to limit future warming (DeAngelis, Briel, and Lauer 2019). | Reduction of fossil fuel consumption; increased energy efficiency and renewable energy production; development of carbon sinks |
| Climate adaptation | The process of adjustment to actual or expected climate and its effects (DeAngelis, Briel, and Lauer 2019); actions that seek to moderate or avoid harm or exploit beneficial opportunities from climate change (IPCC 2014). | Raising infrastructure and the base flood elevations (BFE) of buildings in coastal areas in response to sea level rise; modifying road design standards to respond to and withstand projected heat increases |
| Climate resilience | The ability to prepare and plan for, absorb, respond, recover from, and more successfully adapt to adverse events (Briel, DeAngelis, and Lauer 2019). This involves proactively developing strategies that anticipate and respond to the future projected changes in climate. | Development standards that anticipate and respond to the projected changing climate; regional grid self-sufficiency and optimization; critical services and business continuity planning |

ing more than 1.5°C above pre-industrial levels (Le Quéré et al. 2020). In 2021, however, global energy-related $CO_2$ emissions were on course to increase by almost five percent, which would be the biggest annual rise in emissions since 2010 coming out of the global financial crisis (IEA 2021).

The latest Intergovernmental Panel on Climate Change (IPCC) report identifies five new scenarios representing possible climate futures in 2100 based on the success of global efforts in reducing GHG emissions (IPCC 2021). Under all emission scenarios identified, global surface temperature will continue to increase until at least mid-century, and global warming of 1.5°C (2.7°F) will be exceeded during the 21st century unless extensive reductions in $CO_2$ and other GHGs occur in the coming decades (IPCC 2021).

## Types of Mitigation Actions

Climate mitigation can be achieved through two types of mitigation actions. The first is through reducing human-caused GHG emissions to near zero, and the second is through removing carbon directly from the atmosphere.

As identified by the World Resources Institute, there are 10 key solutions to reduce GHG emissions (Figure 3.1). These can be summarized as decarbonization of the following sectors:

- **Energy.** This includes phasing out coal plants, limiting growth in other fossil fuel-powered plants, and rapidly investing in clean and renewable energy and efficiency. For planners, this includes a proactive focus on strategies such as electrification and increased production of renewable energy, combined with a simultaneous focus on improving energy efficiency to reduce future demand.
- **Transportation.** This includes decarbonizing aviation and shipping, increasing public transport, and shifting to electric vehicles. For planners, this includes modifying land-use and transportation patterns to create walkable, bikeable communities with shorter commuting distances and more diversified, sustainable mobility choices.
- **Buildings and development.** This includes decarbonizing cement, steel, and plastics production; halting deforestation and restoring degraded lands; implementing land-use strategies that lead to lower emissions; using green building design and construction; and retrofitting existing buildings. For planners, this includes a focus on more sustainable community development patterns, green building design, and integration of nature-based solutions into the natural and built environments.
- **Food production and consumption.** This includes eating more plants and less meat, reducing food loss and waste, and eating more locally and seasonally. For planners, this includes allowing or promoting sustainable agriculture practices as an important part of overall community land-use patterns and better approaches to waste management.

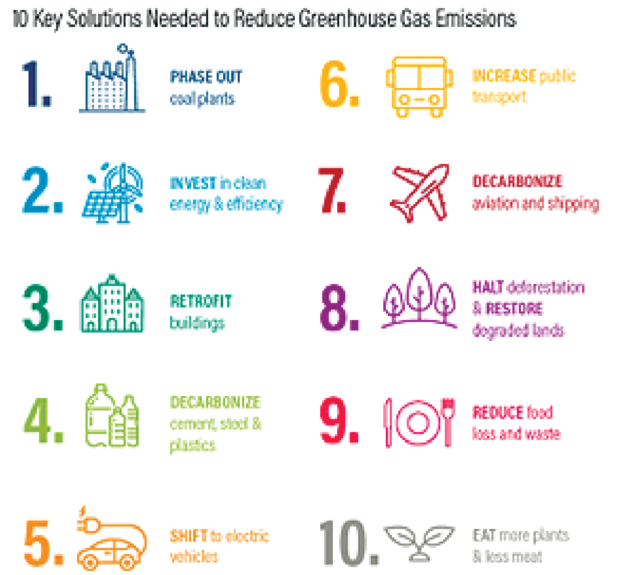



*Figure 3.1. Key solutions for reducing greenhouse gas emissions (World Resources Institute/Levin et al. 2019)*

As set out by the IPCC in its 2018 special report on global warming, there are no viable opportunities to keep global warming to less than 1.5°C (2.7°F) without carbon removal (IPCC 2018).

Many opportunities are being explored for carbon removal. Technological approaches such as bioenergy with carbon capture storage (BECCS) or direct air carbon capture and storage (DACCS) rely on future scientific advancements to bring them up to scale or to reduce costs to make them viable. For planners, there are many nature-based solutions that can be advanced locally to mitigate a changing climate. Some of these include reducing deforestation, practicing reforestation and afforestation (creation of new forests), land restoration, carbon farming and soil carbon sequestration, better sourcing of materials, sustainable diets, and reducing food waste (IPCC 2018). This also needs to include better land-use policy in incorporating nature as an important consideration in the development of our cities and surrounding areas.

In addition to removing carbon from the atmosphere, these nature-based solutions also provide co-benefits such as

## THE PARIS AGREEMENT AND GLASGOW CLIMATE PACT

In December 2015, at the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change, 196 countries adopted the Paris Climate Agreement, which called for pursuing efforts to limit global temperature rise to 1.5°C (2.7°F) (IPCC 2018). Human activities have already caused approximately 1.0°C (1.8°F) of global warming above pre-industrial levels. Temperatures are likely to reach 1.5°C (2.7°F) between 2032 and 2052 if warming continues at the current rate (IPCC 2018).

In November 2021, at COP26 in Glasgow, 197 nations adopted the Glasgow Climate Pact, which consisted of a series of decisions to curb GHG emissions and build climate resilience. This included, for the first time, a commitment to phase out coal power and to remove fossil fuel subsidies. It called for putting a price on carbon, implementing climate finance for developing countries, and protecting vulnerable communities. It also called for a revisiting of member country climate reduction goals (also known as nationally determined contributions, or NDCs) set during COP22, and resulted in the development of a rulebook to implement the Paris Agreement (UNFCCC 2021).

The latest research indicates, however, that even if the existing national climate pledges are achieved, the world is still on track for a global temperature rise of 2.7°C (4.8°F) by the end of the century (UNEP 2021).

improved biodiversity and local food security (IPCC 2018), improved wildlife habitat, and reduced heat island effect (Naturally Resilient Communities n.d.), as well as opportunities for alternate modes of transportation (e.g., greenway trails) and reduction of extreme weather event impacts (e.g., flooding).

Planners must advance specific practices, knowledge, regulations, and tools to help mitigate a changing climate. These include:

- **Local plans and regulations.** This includes local land-use or comprehensive plans, climate action plans, all derivative subplans, and all implementing mechanisms, such as codes and regulations, capital improvement programming, and others. Strategies could include climate-friendly future land-use and thoroughfare plans that reduce travel by limiting suburban expansion and encouraging active transportation, micromobility, and public transit within denser, more compact, walkable transit-oriented development.
- **Structural projects.** This includes modifying infrastructure and buildings to reduce embodied carbon in manufacturing and transportation of materials and from operations. It also includes focusing on the full life cycle of GHG emissions throughout a project's lifespan.
- **Natural systems protection.** This includes being proactive with land-use controls by fostering higher-intensity, concentrated development to protect greenspace, existing trees, soil quality, and other natural systems; better integration of natural watercourses and drainageways as part of green infrastructure networks; and other actions, such as reforestation, that reduce GHG emissions.

Planners have a wide variety of available tools that can lead to significant reductions in GHG emissions and mitigate a changing climate. These will be further explored in subsequent chapters.

## ADAPTATION PLANNING: LIVING WITH CLIMATE CHANGE

As defined by the IPCC, *adaptation refers* to "the process of adjustment to actual or expected climate and its effects" (IPCC 2014). This can involve reducing harm from climate impacts or exploiting beneficial opportunities. It can also refer to human interventions in natural systems (IPCC 2014).

Across the country, communities are increasingly turning to climate adaptation actions and projects to reduce their

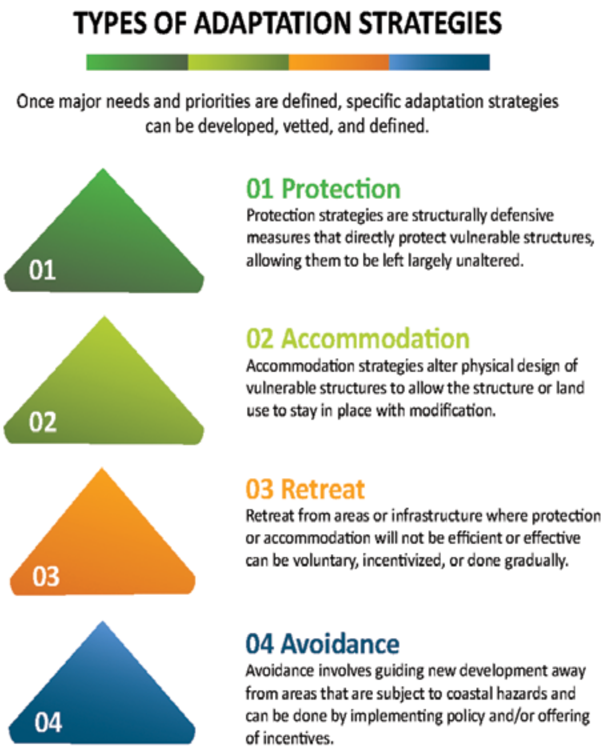



*Figure 3.2. Types of adaptation strategies (Florida DEP 2018)*

vulnerability to current climate impacts stemming from climate variability and extreme weather events. This requires innovation, experimentation, and some level of risk-taking.

It is important for planners to understand several key points related to climate adaptation planning. First, while climate mitigation efforts are realized globally (i.e., local reductions in GHG emissions contribute to globally aggregated reductions, benefiting all), climate adaptation is local. For example, building a sea wall to hold back a rising sea level is a local structural adaptation response that only benefits that particular community.

Second, planners must prepare U.S. communities to adapt to a moving target of an already changing climate. As noted, past GHG emissions have already changed global climate conditions and will continue to do even if current and future emissions are mitigated. As adaptation policies, projects, and programs are implemented, they will likely need to be adjusted over time to remain effective (Vogel et al. 2016).

Some communities are already taking action to adapt to changing climate conditions. However, many of these efforts, while moving the needle forward, are not part of a comprehensive and far-sighted approach. Such projects may only respond to a single vulnerability or climatic impact (e.g., sea level rise), address today's problems rather than known future conditions (e.g., raising a road by one foot today to address local flooding when three feet will be required within 25 years because of the increased intensity of rainfall), or are part of a response to some other community priority (e.g., an ancillary climatic benefit realized while fixing an unrelated drainage issue).

This needs to change. It is critical for planners to mobilize our communities today to directly and specifically respond to climate impacts. This requires planners to plan for a longer time horizon, beyond that of the usual 20-year timeframe of a traditional comprehensive planning process.

## Types of Adaptation Actions

There are four types of adaptation strategies or actions planners need to be aware of (Figure 3.2) (Florida DEP 2018):

- **Protection.** Protection strategies include hard and soft structurally defensive measures to mitigate the impacts of a changing climate. For example, sea walls, revetments, and levees ("gray" strategies) and beach renourishment and living shorelines ("green" or nature-based strategies) are examples of protection against rising sea levels.
- **Accommodation.** Accommodation strategies include altering physical design to allow a structure or land to stay in place despite changing conditions. For example, installing cool roofs and pavements (gray strategies) and planting more trees and vegetation (green strategies) are examples of accommodations related to increases in the urban heat island effect. Another example is retrofitting buildings to increase their resilience to extreme flood events (e.g., designing the first floor to flood but then be able to be reopened soon after the flood waters recede).
- **Retreat.** Retreat strategies entail removing infrastructure or uses that cannot be easily protected or accommodated from a high-hazard area. Impacts stemming from coastal sea level rise and inundation, more frequent and destructive urban riverine flooding, and intensifying wildfires are disrupting community livability and economic viability. As such, communities will increasingly need to consider retreat strategies as the public health and economic impacts of climate change continue to worsen over time. Home buyouts are an example of using retreat as a strategy to respond to a changing climate. The IPCC's Fourth Climate Assessment defines *managed retreat* as the "purposeful, coordinated movement of people and

assets out of harm's way," a controversial and often overlooked but transformative adaptation strategy that will be unavoidable for some U.S. communities (IPCC 2018).

- **Avoidance.** Avoidance strategies involve guiding new development away from areas that are at high risk from a changing climate. For planners, this is a particularly important strategy that increasingly needs to be explored in long-range planning. For example, siting standards (e.g., locating development away from steep slopes and heavily forested areas) can be used to prevent future development from further encroaching on the wildland-urban interface, and floodplain protection standards could require consideration of future flood elevations expected from a changing climate.

Other adaptation concepts planners must be aware of include the following:

- **Adaptive management.** This refers to a process by which management decisions can be regularly revisited based on receipt of new information (e.g., monitoring changes in conditions, new science, or other information). It explicitly recognizes future uncertainties and changing conditions, and therefore creates a process by which adaptation actions can be made over time. This approach promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. It encourages the selection of adaptation actions that can be adjusted over time (e.g., building a sea wall to which height may be added if evidence mounts that sea level rise is proceeding faster than originally believed). This is an important concept for planners who will need to help communities prepare and adapt to a changing climate, but where the scale and extent of adaptation is uncertain.
- **Disaster risk management.** This refers to reducing exposure and vulnerability and increasing resilience to the potential adverse impacts of climate change. Disaster risk is defined as the "likelihood over a specific time period of severe alterations in the normal functioning of a community or society" (IPCC 2012). Key considerations are understanding the intersection of vulnerability (populations with predisposition to be adversely impacted), exposure (the presence or location of people subject to future harm), and hazardous climate events (Figure 3.3).

These concepts also involve an understanding of the capacity of an individual, community, society, or organization to cope, adapt, or otherwise respond to a particular disaster or extreme event. Planners can play an important role in strengthening the adaptive capacity of communities as part of long-range planning and other community improvement efforts.

With these different approaches to choose from, planners need to be aware of a few key considerations. These include:

- **Knowing what level of severity to plan for.** This involves an understanding of what the community is planning and preparing for. This acknowledges that there may be trade-offs as a particular community assesses the overall risk reduction impact of a particular action. Risk reduction impact is defined as "how much a given action reduces risk in an urban setting" (Boland et al. 2021). For example, one community may prioritize the establishment of emergency evacuation routes over the construction of an emergency hurricane shelter, while another community may prioritize the shelter. This also necessitates an understanding of the functional lifespan of a particular investment. Should a community invest in a seawall or raise its roadways to adapt to rising sea levels? If the investment will address impacts projected 50 years from now, the answer may be yes. If that adaptation will be insufficient five years from now, the answer should be no.
- **Defending the rationale for an adaptation investment that may not be needed for several decades or during the lifetime of the project.** This involves proactive decision-making in anticipation of the actual need, such as making incremental decisions to address climate impacts based on targets of opportunity. Targets of opportunity are long-lifetime, climate-sensitive decisions that incorporate climate-related considerations into project design.

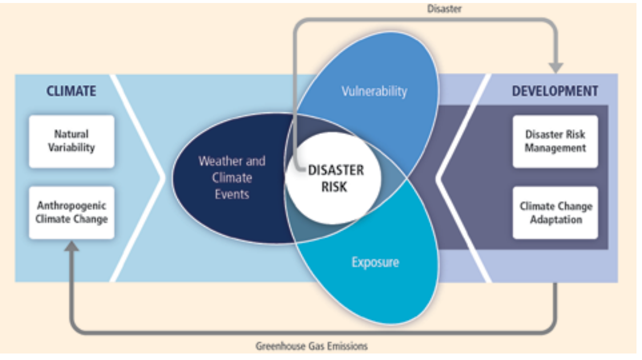



*Figure 3.3. Disaster risk management and climate change adaptation (IPCC 2012)*

## UNDERSTANDING RISK, VULNERABILITY, AND ADAPTATION

The assessment of risk occurs at the intersection of three factors—*hazards, vulnerabilities*, and *adaptive capacity*.

The term "hazard" can be defined as a threat (natural or human) that has the potential to cause loss of life, injury, property damage, socioeconomic disruption, or environmental degradation. The severity of a hazard can be evaluated in terms of duration, magnitude, predictability, regularity, frequency, spatial concentration, and areal extent.

Hazard is often confused with risk. While the two concepts are closely linked, there is an important difference. Whereas hazard refers to a source of risk, risk refers to outcomes (or consequences). In addition, risk involves the element of uncertainty and is dependent on context and circumstances.

A city's degree of vulnerability to risk is determined by a host of internal characteristics of the city set within a larger socioenvironmental context. In terms of climate adaptation planning, the term "vulnerability" can be defined as the degree to which people, places, economic sectors, and infrastructure are susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes (Davoudi et al. 2009). Vulnerability is a function of the character, magnitude, and rate of climate change, as well as the variability to which systems and places are exposed, their sensitivities, and their adaptive capacities.

The level of vulnerability varies among places, as well as demographic and socioeconomic groups. Some of the most vulnerable groups include children, the elderly, and the poor—those who are already sensitive to poor health and other externalities, and who are also therefore particularly prone to the negative consequences of climate change.

For example, construction of a sea wall could incorporate a target of opportunity by considering future sea level rise when designing the height of the sea wall. Basing the design on historical flood risks alone would likely result in inadequate protection against future floods.

- **Understanding that the extent and speed of the changing climate may necessitate more comprehensive adaptation approaches.** This is an acknowledgement that some approaches may not provide enough adaptation response to outpace the increasing extent of climatic impacts (e.g., retrofitting drainage structures to accommodate increasing levels of king tide inundation).

As with mitigation, planners will need to use a series of tools to help adapt to a changing climate. These include:

- **Local plans and regulations.** This includes local land-use or comprehensive plans, climate adaptation plans, all derivative subplans, and implementing mechanisms, such as codes and regulations and capital improvement programming. Strategies could include using planning to prevent new development from occurring within climate-sensitive areas (e.g., coastlines, floodplains, the wildland-urban interface), increasing the protection of natural resources (e.g., wetlands, forests, floodplains, steep slopes and soils), identifying opportunities to move existing populations to more climate-friendly locales (e.g., migration from the coasts, as happened after Hurricane Katrina), or promoting increased use of nature-based solutions (e.g., increasing tree canopy cover in urban areas to offset increasing urban heat island effects).
- **Structural projects.** This includes modifying infrastructure and buildings to improve adaptability to existing and projected climatic impacts (e.g., erecting sea walls to protect against rising sea levels, or improving drainage infrastructure to handle more extreme rain events).
- **Awareness and education.** This includes acknowledgement that communities will not be able to structurally build their way out of all harm. In this instance, planners will need to better understand how to promote awareness of risk and vulnerability and to implement solutions that improve emergency planning, response, and recovery.

Similar to planning for mitigation, planners have a wide variety of approaches that can be applied to help communities adapt to a changing climate. These will be further explored in subsequent chapters.

## PHYSICAL IMPLICATIONS OF MITIGATION AND ADAPTATION

There is widespread recognition that urban patterns of development have significant implications for both reducing emissions and adapting to the adverse effects of climate change. Thus, climate change must become an important consideration in the planning process, and mitigation and adaptation must be placed within the broader context of sustainable development (Biesbroek et al. 2009). As highlighted throughout this chapter, this will require planners to advance both structural (i.e., physical projects) and nonstructural strategies (e.g., policies and regulations).

Planners have traditionally played a larger role in advancing nonstructural strategies, but they must increase their knowledge and understanding of structural strategies. This will require them to partner with allied professionals (e.g., architects, landscape architects, and engineers) who are more comfortable advancing structural solutions.

There is still much to learn on the nonstructural side. New approaches and comprehensive reforms to policy-based planning and regulations are called for. And many planners will need to gain a broader range of skills and knowledge about such issues as hazard and floodplain mitigation, emergency management, renewable energy, and community resilience.

### The Importance of Regional Context

There are many environmental and climatic factors that impact the effectiveness of physical-based mitigation and adaptation strategies. The uniqueness of each region, which is determined by a combination of socioeconomic and biogeophysical processes, makes clear that there is no single approach or set of best practices to achieve practical solutions. Potential synergies and trade-offs between mitigation and adaptation need to be assessed in the context from which they originate (Biesbroek et al. 2009).

For example, addressing urban heat island impacts in hot-dry climates (e.g., Phoenix) requires very different strategies than in hot-humid climates (e.g., Houston). In a hot-dry climate, the ability of an urban form to mitigate high summer temperatures requires the close proximity of buildings to reduce solar exposure, appropriate street orientation that maximizes ventilation by harnessing the natural patterns of the prevailing wind direction, and lighter-colored building and infrastructure materials that reflect more radiant heat than is absorbed. In contrast, street layout and orientation play a much less significant role in modulating temperature in hot-humid climates. In these areas, low-density, spread-out suburban form in which buildings are detached and exposed to outdoor air and breezes on all sides can help to reduce ambient temperatures.

Clearly, many factors must be considered before determining the appropriate urban form strategy to adapt to specific global warming risks. The type and number of relevant risks will depend on the geographic context and climate. The U.S. Green Building Council's Leadership in Energy and Environment Development (LEED) rating system is a good example of a program designed for maximizing synergies and tradeoffs and adapting to regional context.

## TOWARD MORE CLIMATE-RESILIENT COMMUNITIES

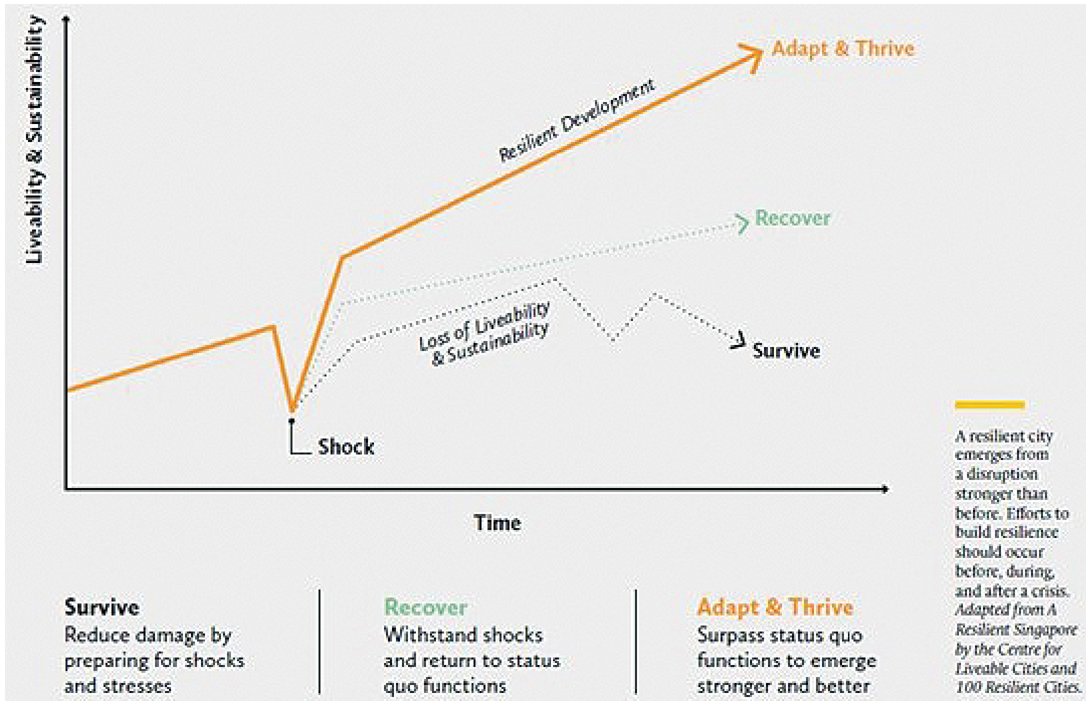
This chapter has highlighted the need for planners to advance both climate mitigation and adaptation solutions to help develop climate-resilient communities. A climate-resilient community is one that is adequately prepared to survive, recover, adapt, and thrive in the face of future shocks and stressors (Figure 3.4, p. 41).

This must be true not just for extreme weather events, but for a full spectrum of ecological, sociocultural, and economic issues. Many non-weather-related shocks and stressors have a direct link to climate change, as a warming planet induces and exacerbates problems across the natural and built environments alike. For example, a wholesale change from a fossil fuel- to a renewable energy-based global economy could have significant implications to the local economies of fossil fuel-producing areas, particularly if their local economies and workforces are not diversified. This change in the economic circumstances will subsequently induce changing migration patterns in that area (out-migration) and in receiving areas (in-migration), affect home ownership and vacancy rates, reduce the overall tax base, and lessen public spending on new infrastructure and maintenance, among other effects. Moving forward, planners will need to integrate resilience thinking as part of climate mitigation and adaption solutions to create sustainable, livable, and more climate-resilient communities.

## CONCLUSION

Climate mitigation and adaptation actions are integral components of developing sustainable, climate-resilient

*Figure 3.4. A climate-resilient community is prepared to respond to a full spectrum of shocks and stressors so that it emerges stronger than before (Centre for Liveable Studies and Urban Land Institute 2020)*




communities. The more effective mitigation efforts are in reducing GHG emissions, the less communities will have to adapt to a changing climate. But because of the changes that have already occurred in the Earth's climate and the impacts already affecting our communities, adaptation efforts will be key for surviving and thriving in an uncertain future.

The next four chapters of this report detail specific climate mitigation and adaptation considerations and strategies that will help planners gain the knowledge and skills needed for an effective response to plan for a warming planet. But it cannot be stressed enough: considering individual mitigation or adaptation actions is not sufficient, and climate mitigation and adaptation planning cannot be implemented in silos. The natural and built environments are intricately interconnected, and the resources needed to respond to the growing list of climate and other challenges to our communities are already in short supply. Planners must rise to the challenge to think both holistically and interdisciplinarily. Only through this lens can our actions lead to climate-resilient communities.

CHAPTER 4

# CLIMATE MITIGATION: EMISSIONS GENERATION AND REDUCTION

Nearly half of the planet's population live in urban settlements. As a result, cities are responsible for about 75 percent of the world's energy consumption and over 70 percent of global greenhouse gas (GHG) emissions (United Nations 2021). As the world's population becomes ever more urbanized, managing climate change will require a particular focus on the social, economic, infrastructural, and ecological systems that comprise urban areas (Gosling et al. 2011).

These systems include and are dependent upon a variety of important elements, such as buildings, which house people and provide spaces for social and economic interactions; transportation, the movement of people, goods, and materials to, from, and around cities; and the provision of food, sanitation, and clean water, as well as electricity, light, and heat (Rosenzweig et al. 2011). Many of these functions require the burning of fossil fuels.

As noted in previous chapters, the overarching aim of the Paris Agreement is to reduce GHG emissions so that global temperatures do not rise more than 2°C above preindustrial levels before the end of this century, and to ultimately pursue a scenario where temperature rise remains below 1.5°C (Figure 4.1, p. 44). Reaching a 1.5°C pathway will require limiting all future net emissions of carbon dioxide ($CO_2$) from now onward, implementing a global 570 gigaton carbon budget, and reaching net zero emissions by 2050, with the steepest emission declines happening over the next decade (Henderson et al. 2020).

The IPCC has set a 2030 deadline to reduce heat-trapping emissions by half to avoid climate change that is both irreversible and destructive (Barnard and Moomaw 2021). Achieving this threshold will require rapid declines in $CO_2$ emissions through a series of significant business, economic, and societal shifts, implemented with rigor, in every dimension of the global economy (Henderson et al. 2020). Urban and community planners are in key positions to address many of these proposed shifts because of their focus on urban systems, including energy and resource inputs, throughputs, and outputs.

This chapter describes the principal sources of GHG emissions in the United States and highlights the shifts that will need to take place in current practices to move societies towards lowering those emissions.

## PRINCIPAL SOURCES OF GHG EMISSIONS

In 2020, U.S. GHG emissions totaled 5,981 million metric tons of $CO_2$ equivalent (U.S. EPA 2022c). GHG emissions are generated from a variety of interrelated sectors, including transportation, electricity generation and transmission, land use (industry, agriculture, and forestry), buildings, materials, and waste management (U.S. EPA 2021d).

Achieving substantial reductions in energy-related emissions requires simultaneous mitigation actions across all sectors (Day et al. 2018). The following sections summarize the principal sources of emissions for each sector and the areas within which to focus mitigation strategies.

### Transportation

The transportation sector, which covers all journeys by road, rail, water, and air, generated 29 percent of U.S. GHG emissions in 2019—the largest share of GHG emissions in the United States (U.S. EPA 2021d). GHG emissions from transportation primarily come from burning fossil fuel for light-duty vehicles (58 percent), medium- and heavy-duty trucks (24 percent), planes (10 percent), ships and boats (two percent), trains (two percent), and other vehicles (five percent). When including emissions from nontransportation mobile sources, such as agricultural, lawn and garden, and construction equipment, mobile sources constituted 32 percent of total 2019 U.S. GHG emissions (U.S. EPA 2021d).

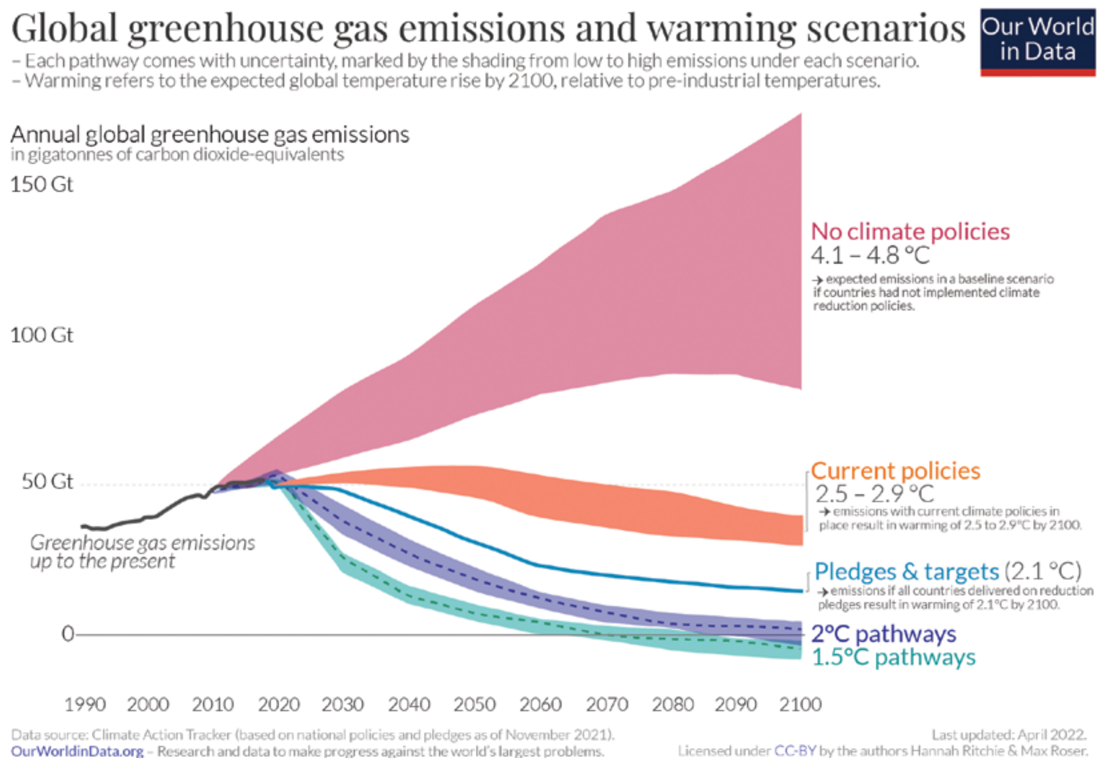



*Figure 4.1. Rapid declines in $CO_2$ emissions will be required to reach the 2°C or 1.5°C pathways of the Paris Agreement (Hannah Ritchie and Max Roser/OurWorldInData.org ([CC BY 4.0](CC BY 4.0)))*

This sector accounts for 70 percent of U.S. petroleum consumption. In 2020, about 90 percent of the fuel used for transportation was petroleum based, primarily gasoline and diesel (IPCC 2007; U.S. EPA 2021d). Urban areas account for approximately 50 percent of these emissions (IEA 2016). The road transportation sector, which includes passenger cars and trucks, buses, and other vehicles, contributes up to 15 percent of global $CO_2$ each year.

### Mitigation Approaches

Estimates suggest that by 2050 approximately two-thirds of all urban development and associated services will be either new or redeveloped, suggesting that interventions using land-use and transportation best practices could be effective in significantly reducing GHG emissions (Nelson 2006). To decarbonize, the transportation sector would need to shift rapidly to a cleaner source of energy for fuel, such as sustainably produced electricity (Henderson et al. 2020). By using efficient electric motors and plugging into a grid that distributes energy produced from renewable sources, plug-in electric vehicles (EVs) can significantly reduce GHG emissions.

Battery-powered electric vehicle fueling requires charging infrastructure, which includes chargers, connections to the electricity grid, software, and communications networks. Charging infrastructure is diverse in terms of cost and recharging speed, reflecting both technology options and consumer preferences. There are currently over 1.2 million charging ports in the United States, ranging from residential plug-ins to high-speed chargers in public areas, but millions more home chargers and rapid charging stations will be needed in the future (Leard et al. 2020). Planners will be required to plan for and implement EV charging infrastructure, including drafting regulations for siting (including accessibility, signage, preventative strategies for vandalism), installation, operation, and maintenance of charging stations.

In the interim, planning and urban design measures can substantially reduce the number and distance of vehicle trips by organizing human activity in more compact communities that provide a range of housing types, are close to reliable public transit to and from employment centers, and offer services within easy walking distance of neighborhoods. Strategies that reduce travel by limiting suburban expansion and encouraging active transportation, micromo-

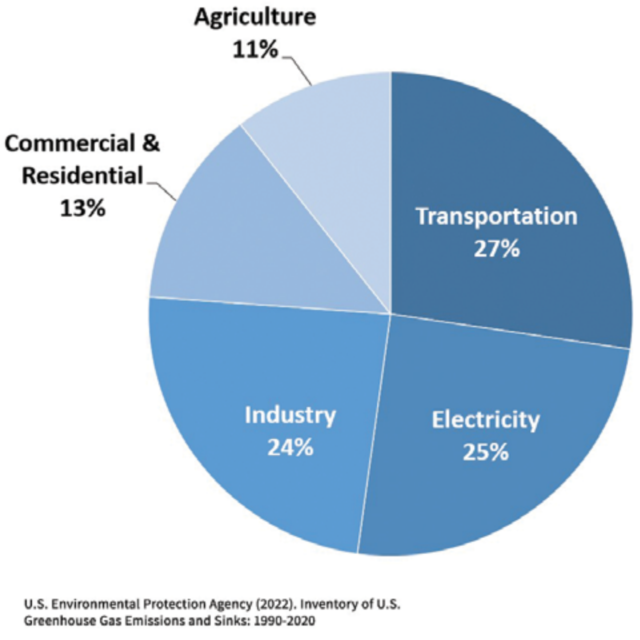



*Figure 4.2. Total U.S. GHG emissions in 2020 by sector with electricity distributed (U.S. EPA 2022c)*

bility, and electrified mass transit solutions within denser, more compact, and walkable transit-oriented development (TOD) could potentially reduce vehicle miles traveled by 20 to 40 percent compared to miles driven in more auto-dependent suburbs, resulting in significant trip reduction and decreases in GHG emissions of around 10 percent or more (Condon, Cavens, and Miller 2009).

Additional emissions reduction strategies within this sector include using alternative paving materials to conventional concrete and asphalt; employing green streets best practices, including green infrastructure (e.g., street trees and low-impact development strategies, tools, and techniques) and pervious paving; and implementing complete streets principles and facilities for multimodal, active transportation alternatives to the automobile.

## Electricity Production

The energy industry is both a major contributor to climate change and a sector that climate change will disrupt. Over the coming decades, the energy sector will be affected by global warming on multiple levels and by policy responses to climate change (Benn 2014).

Electricity production—the generation, transmission, and distribution of electricity—generates the second largest share of GHG emissions in the United States (25 percent of GHG emissions in 2020) (Figure 4.2) (U.S. EPA 2022c). One of the largest contributors to a city's GHG emissions, it includes the combustion of fuel in buildings and facilities, manufacturing industries, and construction, as well as power plants that generate grid-supplied energy. This sector also includes fugitive emissions, which typically occur during extraction, refinement, and transportation or transmission of primary fossil fuels (Fong et al. 2014).

GHGs are released during the combustion of fossil fuels to produce electricity. In 2018 coal was responsible for less than one-third (28.4 percent) of GHG emissions in this sector. Natural gas accounted for 34.1 percent of electricity generation, and petroleum (residual fuel oil, petroleum coke, and diesel fuel oil) equated to less than one percent. The remaining generation in 2018 came from the carbon-neutral, non-fossil-fuel sources of nuclear energy (20.1 percent) and renewable energy sources (16.7 percent), which include hydroelectricity, wind (seven percent of total U.S. electricity generation and about 42 percent of electricity generation from renewable energy in 2019), solar (two percent of total U.S. electricity generation in 2019), and biomass (one percent of total U.S. electricity generation in 2019) (U.S. EIA 2021).

### Mitigation Approaches

Mitigation actions related to electricity generation generally fall into two categories: (1) altering the supply source of energy combusted to generate electricity, and (2) reducing the demand for energy. Because changing the supply source—shifting from carbon-based to alternative renewable energy sources—will likely take decades, strategies to reduce demand are extremely important. As discussed, increasing the fuel efficiency of vehicles, promoting and incentivizing plug-in electric and hybrid vehicles and machinery, using high-performance green building construction methods and materials, and improving the energy efficiency of buildings provide sustainable paths to reducing demand (Condon et al. 2009). More profound measures, however, involve promoting shifts in societal behavior, sustainable lifestyles embracing "life-cycle thinking," and denser settlement patterns.

The form and function of human settlements can either reduce or increase the demand for energy, and can also influence how energy is produced, distributed, and used (Condon, Cavens, and Miller 2009). Opportunities to reduce GHGs associated with electricity generation, transmission, and distribution include the following:

- Increasing the efficiency of fossil fuel-fired power plants and fuel switching

### GHG EMISSIONS MANAGEMENT IN THE ENERGY SECTOR

One approach to managing emissions in the energy sector is considering measures to avoid, reduce, or offset GHG emissions for new energy generation projects.

GHG emissions avoidance represents the difference between the emissions that would occur in a reference scenario without a proposed project and the emissions from the project over a defined period (European Commission 2021). In the case of GHG emissions savings due to renewable energy generation, for example, the GHG emissions not produced by a coal-fired power plant compared to energy produced by a renewable energy project represents emissions avoided. In the case of GHG savings due to carbon capture and storage, the emissions produced by a coal-fired power plant may be captured and injected into a depleted oil reserve, resulting in no net gain of atmospheric GHGs.

Beyond avoidance, mitigation options can include the procurement of instruments. The common instruments in the United States are renewable energy certificates and offsets.

A renewable energy certificate, or REC, is a tradeable market-based instrument that represents the legal property rights to the "renewableness" or nonpower attributes of renewable electricity generation. A REC is created for every megawatt-hour (MWh) of electricity generated and delivered to the grid from a renewable energy source (U.S. EPA 2018). RECs are used to address indirect GHG emissions associated with purchased electricity by verifying use of zero- or low-emission renewable sources of electricity. RECs are used in the calculations of gross, market-based Scope 2 emissions based on the emissions factor of the renewable generation conveyed with the REC.

GHG offsets, also known as carbon offsets or carbon credits, are generated from activities that prevent or reduce the release of GHG emissions to the atmosphere or remove GHGs from the atmosphere through carbon capture or sequestration (U.S. EPA 2018). By compensating for GHG emissions that occur elsewhere, carbon offsets address the residual impact of major developments on the global climate, ensuring a no net increase in emissions.

An offset activity's emissions reductions must be real, permanent, and verifiable, and credits issued for verified emissions reductions must be enforceable. Offset project types include the following:

- Renewable power (e.g., wind, small hydropower)
- Fuel switching (e.g., use of less carbon-intensive fuels, biofuels)
- Composting, recycling
- Enhanced removal of atmospheric $CO_2$ from afforestation and reforestation projects

The reduction in GHG emissions from one place can be used to "offset" the emissions taking place somewhere else. Offsets (i.e., verified emissions reductions) are subtracted from organizational emissions to determine net organizational emissions; for example, the offset may be used to address direct and indirect emissions associated with an organization's operations (e.g., emissions from a boiler used to heat an organization's office building).

- Investing in renewable energy
- Increasing end-use energy efficiency in buildings and structures
- Employing regenerative energy solutions, such as harnessing and transferring energy produced by trains when they are slowing down or stopping (Mitsubishi Electric 2021)
- Offsetting GHG emissions through employing carbon capture and sequestration (CCS) practices

The sidebar above describes measures to reduce net GHG emissions for new energy generation projects, including renewable energy certificates and offsets.

## Industry

About 24 percent of U.S. GHG emissions in 2020 came directly from industrial sources, such as manufacturing, food processing, mining, and construction (U.S. EPA 2022c). Many different GHGs are produced by the on-site combustion of fossil fuels for heat and power, nonenergy use of fossil fuels, and chemical processes used in iron, steel, and cement production. In addition, refrigerants, foams, and aerosol cans used by industry and end consumers contain GHGs that can be released during use and disposal (Fong et al. 2014).

Industrial emissions also include indirect emissions from the centrally generated electricity it consumes, which represents about one-quarter of total U.S. electricity sales. If direct and indirect emissions are combined, the industrial sector is the largest emitting sector in the United States, responsible for 29.3 percent of total emissions (C2ES n.d.).

### Mitigation Approaches

Methods of reducing GHG emissions from the industrial sector include energy efficiency, fuel switching, combined heat and power (co-gen), use of renewable energy, and the more efficient use and recycling of materials. For many industrial processes, however, there is no existing low-emission alternative, and therefore carbon capture and storage will be required to mitigate emissions over the long term.

Embracing a more circular economy (Ellen MacArthur Foundation 2015) and boosting efficiency would enable a wide cross-section of industries to decrease GHG emissions, reduce costs, and improve performance. By 2050, for example, nearly 60 percent of plastics consumption could be covered by recycled materials. Similarly, steelmakers might be able to reduce GHG emissions by further leveraging scrap steel, which today accounts for nearly one-third of production. Replacing an additional 20 percent of inputs to the steel-production process with scrap steel would significantly lower emissions from iron ore use (Hundertmark 2018).

Cement manufacturers, meanwhile, will need to abate their current $CO_2$ emissions. These accounted for 4.7 percent of U.S. emissions in 2019 (U.S. EPA 2021d) and six percent of global $CO_2$ emissions in 2016, and this is estimated to increase by more than seven percent by 2030 (Henderson et al. 2020). Increasing the use of alternative building materials such as cross-laminated timber (CLT), which has a high weight-to-strength ratio, low carbon footprint, and speed and ease of construction, could reduce the demand for cement (Laguarda Mallo and Espinoza 2014).

Industrial subsectors with low- and medium-temperature heat requirements (e.g., construction, food, textiles, and manufacturing) will need to accelerate electrification of their operations by 2030. More than 90 percent of the abatement for these industries depends on electrifying production with power produced from clean energy sources (Henderson et al. 2020).

Achieving the IPCC's recommended 1.5°C pathway will require increased electrification to extend across a broad swath of industries as part of a collection of operational adaptations. Electrification of industries with high-temperature requirements, such as iron and steel or cement—among the biggest $CO_2$ emitters—will be much more difficult. For these subsectors, along with others such as chemicals, mining, and oil and gas that are also challenging and expensive to decarbonize, efficiency efforts (including recycling and the use of alternative materials) and innovation in hydrogen and clean fuels will be key in reducing emissions (Henderson et al. 2020).

For oil and gas companies, methane is the largest single contributor of GHG emissions. While capturing fugitive methane emissions during drilling is challenging—which is why most companies resort to flaring, or burning off the gas at the source—many abatement options are available and make good economic sense. Solutions for capturing methane from coal mining and other underground operations, however, are far more difficult and not yet economical (U.S. EPA 2015b).

## Agriculture

Agriculture represented close to 11 percent of all U.S. emissions in 2020. Direct GHG emissions from agricultural activities include the following (U.S. EPA 2022c):

- **Soil management.** Nitrous oxide emissions from farmland soils are associated with cropping practices that disturb soils and increase oxidation, which can release emissions into the atmosphere. Cropping practices include fertilization, irrigation, drainage, cultivation and tillage, shifts in land use, and application of livestock manure and other organic materials on cropland and other farmland.
- **Enteric fermentation.** Methane emissions from livestock operations occur as part of the normal digestive process in ruminant animals and are associated with the nutritional content and efficiency of feed utilization by the animal. Enteric fermentation from livestock represented 2.66 percent of all GHG emissions in 2018 (AFBF 2021).
- **Manure management.** Methane and nitrous oxide emissions come from livestock or poultry manure that is stored and treated in systems that promote anaerobic decomposition, such as lagoons, ponds, tanks, or pits.
- **Other production methods.** Methane and nitrous oxide emissions are also associated with rice cultivation, urea fertilization, liming, and biomass burning, as well as $CO_2$ emissions from fossil fuel combustion by motorized farm equipment, such as tractors.

Globally, agricultural emissions will likely increase 15 to 20 percent by 2050. The largest share of these emissions—almost 70 percent—is from the production of ruminant meat. Animal protein from beef and lamb is the most GHG-intensive food, with production-related emissions more than 10 times those of poultry or fish and 30 times those of legumes. Achieving a 1.5°C pathway by 2050 will require reducing today's consumption of ruminant animal protein by half (Henderson et al. 2020).

### Mitigation Approaches

Agriculture could play a prominent role in U.S. efforts to address climate change if farms and ranches undertake activities that either reduce GHG emissions or remove them from the atmosphere. Rather than functioning as a source of carbon emissions, croplands can become a carbon sink.

At both the regional and global levels, a growing body of scientific literature is identifying the potential that regenerative agricultural practices can play in sequestering carbon, helping to mitigate climate change while making croplands more productive and resilient as the planet warms. Underlying principles of regenerative agriculture include the following (Teal and Burkart 2022):

- Maintaining continuous vegetation cover on the soil as much as possible
- Reducing soil disturbance to promote stabilization of organic matter on soil mineral complexes
- Increasing the amount and diversity of organic residues returned to the soil
- Maximizing nutrient and water use efficiency by plants
- Restoring microbial life essential to soil health and biodiversity

These principles are designed to more closely mimic comparable native ecosystems. An array of practices can increase the amount of organic carbon added back into the soil while reducing the relative loss from erosion and soil respiration. For annual croplands, these practices include the following (Teal and Burkart 2022):

- Reduced tillage/no-till practices and cover crops
- Diverse crop rotations with higher frequency of perennial crops
- Grass cover for waterways and crop buffers
- Agroforestry (e.g., hedgerows, windbreaks, tree cropping)
- Conversion of marginal lands not suited for annual crops to perennial plantings
- Integrated livestock management with improved grazing management
- Reducing the amount of nitrogen fertilizer applied to crops and use of compost and organic waste to build soil health

New agricultural cultivation practices will be also required to reduce methane emissions resulting from rotting organic matter, as in the cultivation of rice (which currently accounts for 14 percent of total agricultural emissions) and the flooding of rice paddies.

Crop producers can change nutrient management practices to reduce emissions from nitrogen fertilizers and manure applied to their fields. Fertilizer application practices that help farmers reduce nitrogen applications without reducing yields include plant tissue testing, soil testing, precision application, use of slow-release fertilizers or nitrification inhibitors, and changes in application timing to better match plant uptake of nutrients (Smith et al. 2008).

Livestock managers can reduce methane emissions by adjusting livestock feeds. Studies have revealed that feeding one type of seaweed at three percent of the diet has resulted in up to 80 percent reduction in methane emissions from cattle. Fats and oils show the most potential for practical application to farming systems and have shown methane emission reductions of 15 to 20 percent (Curnow 2020).

Dairy and hog producers can install digesters to capture methane produced during manure storage and use the methane to generate electricity, replacing GHG emissions that would have come from electricity produced using fossil fuels (Horowitz and Gottleib 2010). In California, cap-and-trade funds have been used for the last several years to subsidize the installation of digesters by the dairy industry (CDFA 2022).

Farms and other agricultural enterprises emit $CO_2$ when they burn gasoline or diesel in vehicles and machinery. If farmers improve operating efficiency or adopt farming techniques that use less fuel, such as no-till practices, they will reduce their fossil fuel-based GHG emissions (Horowitz and Gottlieb 2010).

Finally, approximately one-third of global food output is currently lost in production or wasted in consumption. Curbing waste would reduce both the emissions associated with growing, transporting, and refrigerating food that is ultimately wasted, as well as the subsequent methane released as the organic material in wasted food decomposes (Henderson et al. 2020).

## Forestry

Since 1990, managed forests and other lands in the United States have absorbed more $CO_2$ from the atmosphere than they emit (U.S. EPA 2020b). Deforestation is one of the largest $CO_2$ emitters, accounting for nearly 15 percent of global $CO_2$ emissions. Removing a tree both adds emissions to the

## CARBON CAPTURE AND SEQUESTRATION

It is impossible to chart a 1.5°C pathway that does not include removing and offsetting ongoing $CO_2$ emissions. Developing a robust carbon capture, utilization, and storage (CCUS) industry will be critical.

The aim of CCUS is to prevent the release of large quantities of $CO_2$ into the atmosphere from fossil fuel use in power generation and other industries by compressing, transporting, and either storing it underground or using it as an input or feedstock for products (Henderson et al. 2020). $CO_2$ removal involves capturing and permanently sequestering $CO_2$ that has already been emitted, through either nature-based solutions or technology-based approaches that are only beginning to be developed.

Not all countries will have enough long-term $CO_2$ storage capacity to properly implement CCUS (Dooley et al. 2006). Scientists at MIT have estimated that the storage capacity for $CO_2$ in the United States is adequate for at least the next 100 years, but uncertainty remains about any time frame beyond that (Szulczewski et al. 2012).

It should be noted that CCUS technology is still in its infancy. At present CCUS remains cost-prohibitive and is not scalable to be implemented at a municipal level. That said, in September 2021, 11 multinational oil and gas companies headquartered in the Houston metropolitan area released a joint statement announcing their support of large-scale deployment of CCUS in the Houston area, an effort that could significantly reduce industrial $CO_2$ emissions and help the city of Houston achieve its goal of becoming carbon-neutral by 2050 (Oswalt 2021). Collectively, these companies believe Houston could capture $CO_2$ on an unprecedented scale: 50 million metric tons per year by 2030, and 100 million metric tons per year by 2040—enough to significantly decarbonize the Houston industrial area, one of the nation's largest manufacturing centers. This $100 billion initiative will require governmental support at all levels, including updated policies for $CO_2$ injection into subsurface caverns for permanent storage, expanded federal carbon capture and storage tax credits to encourage investment, and financial assistance and incentives such as direct loans, loan guarantees, and credit assistance (Oswalt 2021).

While carbon capture and removal technologies appear promising, large-scale, nature-based $CO_2$ removal will still need to be included in the mix of applications. Over the next decade, a massive global mobilization to reforest the Earth will be required to achieve a 1.5°C pathway. In scenarios developed by McKinsey (Henderson et al. 2020) and others, reforestation represents the key lever to compensate for the hardest-to-abate sectors, particularly for pre-2030 emissions.

At the height of a massive global reforestation effort, an area the size of Iceland (40,000 square miles) would need to be reforested annually. It is estimated that by 2050, on top of avoiding deforestation and replacing any forested areas lost to fire (according to the Insurance Information Institute (2021), more than 10.3 million acres were burned in 2020), the world would need to have reforested more than 300 million hectares (741 million acres)—an area nearly one-third the size of the contiguous United States (Henderson et al. 2020). While the land area is certainly available, massive reforestation of this magnitude—at this scale and at such a rapid pace—has never been accomplished.

atmosphere through clearing and burning and removes that tree's potential to sequester carbon. Currently, deforestation claims an area the size of Greece every year. To achieve a 1.5°C pathway, global deforestation rates will need to decrease by 75 percent (Henderson et al. 2020).

#### Mitigation Approaches

The sidebar above examines new technology-mediated approaches to carbon sequestration, but experts agree that reforestation on a global scale will be necessary to sufficiently mitigate GHG emissions. Land-use planning can help meet these challenges and protect forested areas. When successful, land-use plans allocate land efficiently and equitably. Planners assess the suitability of land parcels for different uses, put available land to its "best" use, meet diverse needs of multiple stakeholders, and create a lasting governance framework for people to resolve conflicts (Evans 2021). Planners can also establish policies and incentives to preserve forest canopy, particularly in urban areas, and encourage reforestation practices.

### Buildings

GHG emissions from buildings come from two principal sources: the manufacture of building materials and building operations. The embodied carbon of a building, or the amount of carbon generated through manufacturing building materials, transporting materials to construction sites, and the actual construction process, accounts for about one-quarter of a building's total life-cycle GHG emissions and about 11 percent of global emissions (Budds 2019).

Operational carbon emissions resulting from daily energy use come from powering lighting, heating, and cooling. Residential and commercial buildings generate direct emissions from fossil fuel combustion for heating and cooking needs, and management of waste and wastewater, as well as indirect emissions from their use of electricity generated by fossil-fuel power plants. Leaks from refrigerants are another source of emissions, as homes and businesses commonly use refrigerants that are potent GHGs (U.S. EPA 2022c). Globally, building operations account for about 28 percent of annual emissions (Budds 2019).

GHG emissions related to buildings are expected to double by 2050. To meet the goals of the Paris Agreement, the built environment's energy intensity—a measure of how much energy buildings use—must improve by 30 percent by 2030. The energy intensity of the building sector is improving by about 1.5 percent every year; however, global floor area is growing by about 2.3 percent annually, which offsets some of those energy intensity improvements (Budds 2019).

### Mitigation Approaches

Energy efficiency is the most cost-effective measure for securing the reliability of the energy system and reducing GHG emissions from the energy sector, while delivering outcomes for the economy, prosperity, social inclusion, and other development agendas (Henderson et al. 2020). In North America alone, energy efficiencies would result in reductions of at least 80 metric tons of $CO_2$ equivalent.

Space and water heating, which typically rely on fossil fuels such as natural gas, fuel oil, and coal, are the primary emission contributors. By 2050, electrifying these two processes where feasible in residential and commercial buildings would abate their 2016 heating emissions by 20 percent—though only if the electricity were to come from clean sources. In addition, reducing demand for space heating and cooling through better insulation and home-energy management could lower $CO_2$ emissions 30 percent by 2050 (McKinsey Center for Business and Environment and C40 Cities 2017).

Additional measures that have considerable emissions reduction potential in cities include standards for new buildings, technological improvements to energy supply systems including HVAC appliances and water heating, and modernization of lighting technologies (McKinsey Center for Business and Environment and C40 Cities 2017; Henderson et al. 2020).

Another approach is combined heat and power (CHP), also referred to as district heating and cooling or cogeneration, which supplies thermal energy to buildings while reducing peak demand, annual energy use, and total GHG emissions (Figure 4.3).

In CHP systems a central plant channels hot or cool water by way of a network of underground pipes to many buildings. Heat exchangers and heat pumps separate buildings from the distribution network, so that heating and cooling are centralized while thermostats remain independent. Rather than having boilers, furnaces, and air conditioners within each structure, CHP provides thermal energy collective and more efficiently (Hawken 2017).

District energy systems are sometimes found in densely populated areas or situations where multiple adjacent or nearby buildings are owned or controlled by the same owner,

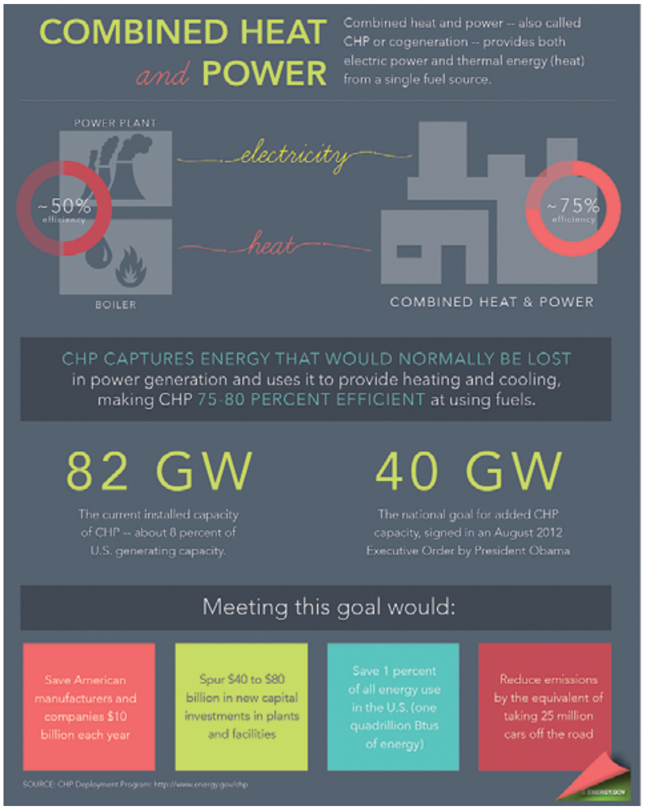



*Figure 4.3. Combined heat and power (U.S. DOE 2013)*

such as hospitals or college campuses (Fitzpatrick 2016). As of 2020, there were more than 4,600 CHP systems in operation in the United States providing nearly 81 gigawatts of electric generation capacity for commercial buildings, downtown districts, campuses, military bases, research facilities, and some residential locations (DOE-EERE AMO 2020).

While natural gas is currently the most prevalent fuel source for CHP systems, they can use a variety of energy sources, including waste heat from power generation, municipal solid waste incineration, and biomass. They can also be designed to use multiple fuel sources within a single plant.

The implications for climate mitigation and adaptation are of fundamental importance, but district-scale energy systems can bring benefits beyond supplying energy to communities, businesses, and individuals (Cooper and Rajkovich 2012). CHP systems allow developers, property owners, and building managers to save money on energy by operating and maintaining more reliable, centralized systems. Because individual buildings do not have to house their own heating and cooling systems, more space can be allocated to tenant uses. In larger cities the presence of CHP systems may promote increased density, walkability, and decrease sprawl by keeping urban cores highly invested and desirable. The entire community benefits because these systems can lower GHG emissions and other pollution, use more renewable energy sources, and encourage new infill development in existing neighborhoods (U.S. EPA 2015a).

### Materials and Waste Management

Municipal solid waste (MSW) comes from residential, commercial, institutional, and industrial sources. Cities produce most of the world's waste and often fail to properly manage it.

GHG emissions occur throughout the life cycle of products that are made and consumed during the extraction, transport, and distribution of raw materials; through the manufacturing process and from energy expended during product use; during the incineration of waste after the product is no longer useful; and as products break down in landfills through aerobic or anaerobic decomposition.

In 2018, the United States produced approximately 292 million tons of waste. Of that waste, 32 percent was recycled or composted, 12 percent was incinerated with energy recovery, and 50 percent was landfilled (U.S. EPA 2020).

Apart from clogging landfills and polluting oceans and waterways, plastics production is also responsible for significant GHG emissions. If plastics production and use grow as currently anticipated, by 2030, these emissions could reach 1.34 gigatons per year—equivalent to 295 new 500 MW coal-fired power plants—and by 2050 GHG emissions from plastics production could be more than 56 gigatons (U.S. EPA 2021b; Hamilton and Felt 2019).

#### Mitigation Approaches

Reducing, reusing, and recycling solid waste can help reduce GHG emissions by reducing energy consumption, as goods manufactured using recycled materials are less energy intensive; reducing emissions from waste incinerators, as recycling and reuse of materials diverts what would otherwise be burned; and reducing methane emissions, as recycling and waste prevention diverts materials away from landfills, which produce large amounts of methane through the decomposition process. Recycling paper reduces the harvesting of trees, which in turn can help to restabilize the climate system as trees sequester $CO_2$ from the atmosphere (Wotkyns and Gonzalez-Maddux 2015).

## UNSUSTAINABLE LIFESTYLES

According to the U.S. Census Bureau (Vespa, Medina, and Armstrong 2021), the U.S. population is expected to grow from 333 million in 2021 to 404 million by 2060. Pressure on the environment will increase unless consumption patterns are significantly adjusted to account for the Earth's finite natural resource base.

Of the natural resources currently used in America, 87 percent are nonrenewable. In response to this pattern of consumption, resource supplies will peak, decline, and will ultimately be exhausted. It is estimated it would take five Earths to support the human population if everyone's consumption patterns were similar to the average American's (CSS UM 2021d). The sidebar on p. 52 offers a detailed look at U.S. resource consumption data.

Notably, shortages or supply disruptions associated with just one nonrenewable natural resource could cause severe lifestyle disruptions. As Liebig's Law of the Minimum postulates, growth is controlled not by the totality of resources available, but by the scarcest resource, also called the limiting factor. Thus, a protracted shortage or supply disruption associated with one critical nonrenewable natural resource could be sufficient to trigger societal collapse (Clugston 2008).

Unsustainable development compromises the ability of future generations to meet their needs. Climate change, destruction of the ozone shield, acidification of land and water, desertification and soil loss, deforestation and forest decline, diminishing productivity of land and waters, and

### UNSUSTAINABLE LIFESTYLES

On average, each American family wastes 180 gallons of water each week—9,400 gallons of water each year—from household leaks. Household leaks can waste approximately nearly 900 billion gallons of water annually nationwide. That's equal to the annual household water use of nearly 11 million homes. In contrast, the average family can save 13,000 gallons of water and $130 in water costs per year by replacing all old, inefficient toilets in their home with WaterSense-labeled models (U.S. EPA 2022d).

Every year in the United States, approximately 31 percent (133 billion pounds) of the overall food supply is wasted, which impacts food security, wastes resources, and contributes to the 18 percent of total U.S. methane emissions that come from landfills (U.S. EPA 2016a). In 2019, 10.5 percent of U.S. households experienced food insecurity at some point during the year, reducing their access to adequate food for active, healthy lifestyles (CSS UM 2021a). Decreasing the amount of food waste sent to landfills can help ease the impact of climate change and also put food in the mouths of millions of people (U.S. EPA 2016a). Actions that prevent or divert food waste from landfills include source reduction, feeding hungry people, feeding animals, and composting (Platt 2017).

Total annual municipal solid waste (MSW) generation in the United States has increased by 93 percent since 1980, to 292 million tons per year in 2018. In 2018, the average American generated 4.9 pounds of MSW each day, with only 1.6 pounds recovered for recycling or composting. For comparison, MSW generation rates (pounds/person/day) were 2.20 in Sweden, 2.98 in the United Kingdom, and 3.71 in Germany (CSS UM 2021b).

The total amount of plastics combusted in MSW in 2018 was 5.6 million tons. This was 16.3 percent of all MSW combusted with energy recovery that year (U.S. EPA 2021a). The vast majority of plastic waste ends up in landfills, and none of it can be composted. To make matters worse, it can take up to 1,000 years to break down plastic (Everything Sustainable 2020). In 2018, landfills received 27 million tons of plastic. This was 18.5 percent of all MSW landfilled (U.S. EPA 2021a).

Each day, U.S. per capita energy consumption includes 2.3 gallons of oil, 7.89 pounds of coal, and 252 cubic feet of natural gas (CSS UM 2021c). With less than five percent of the world's population, the United States consumes almost 16 percent of the world's energy and accounts for 15 percent of world GDP. In comparison, the European Union has six percent of the world's population, uses 4.2 percent of its energy, and accounts for 15 percent of its GDP, while China has 18 percent of the world's population, consumes 20 percent of its energy, and accounts for 16 percent of its GDP (U.S. CIA 2021; U.S. EIA 2021). Energy and water demand are set to grow by 50 percent in the next 10 years, intensifying resource stresses and bringing new uncertainties to our sustainability as a nation and international relations (Tsui 2020).

extinction of species and populations all demonstrate that human demand is exceeding environmental support capacities. Population growth increases poverty, and impoverished people are often forced to undermine the productivity of the land on which they live. It is extremely difficult for people, or other species, to adjust to change at this rate (UIA 2021).

A recent study found that wealthy people have disproportionately large carbon footprints and the percentage of the world's emissions they are responsible for is growing. In 2010, the most affluent 10 percent of households emitted 34 percent of global $CO_2$, while the 50 percent of the global population in lower income brackets accounted for just 15 percent. By 2015, the richest 10 percent were responsible for 49 percent of emissions against seven percent produced by the poorest half of the world's population. Cutting the carbon footprint of the wealthiest might be the fastest way to reach net zero (Horton 2022).

Sustainable living means understanding how our lifestyle choices impact the world around us and finding ways for everyone to live better and lighter. People do not change behavior based on what they should do. They do not respond to data and statistics, nor to negative future scenarios. People act to fulfill their needs and aspirations. They make decisions based on price, accessibility, effectiveness, and additional criteria, such as well-being or trends. Sustainability is not the defining criteria (UNEP 2022a).

Decision makers often make choices about consumption or production without considering the full life-cycle perspective, or the broader implications on the environment, society, or the economy. This often leads to unintended trade-offs be-

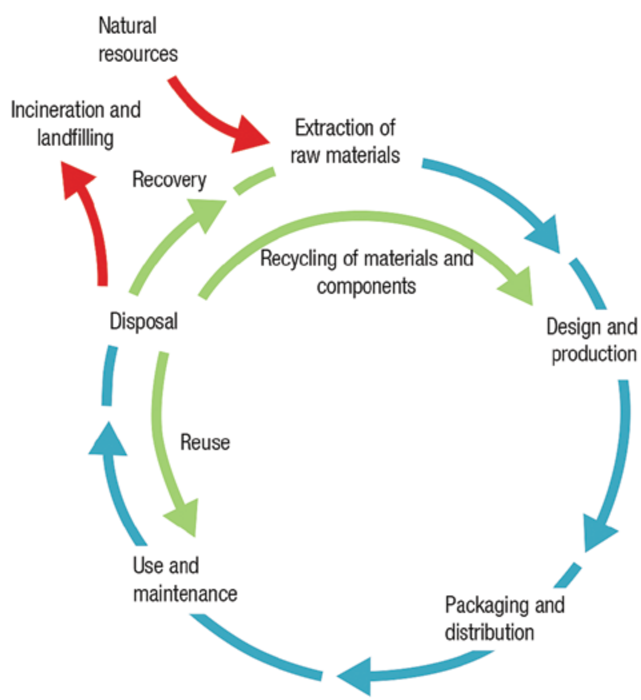



*Figure 4.4. Life-cycle thinking (UNEP 2012)*

tween environmental, social, or economic issues and means that progress towards sustainable development is impeded.

The best way to address sustainability is to start with a systems and life-cycle thinking approach. Life-cycle thinking, as defined by the United Nations Life Cycle Initiative, is a "way of thinking that includes the economic, environmental, and social consequences of a product or process over its entire life" (Acaroglu 2018). It goes beyond the traditional focus on production site and manufacturing processes to include environmental, social, and economic impacts of a product over its entire life cycle. As illustrated in Figure 4.4, in each life-cycle stage there is the potential to reduce resource consumption and improve the performance of products (Life Cycle Initiative 2022). If decision makers were to adopt life-cycle thinking, the UN Sustainable Development Goals (SDGs) could be achieved faster and more efficiently (UNEP 2022b).

## CONCLUSION

Business-as-usual practices in all sectors, from transportation, energy production, and industry to buildings, agriculture, and waste management, are leading us towards a future in which global GHG emissions continue to climb. The resulting impacts of global warming will continue to worsen, further threatening quality of life—if not life itself—for all species across the planet, including humans.

The only way to stave off this inevitable outcome is to take action now to mitigate climate change by reducing GHG emissions in pursuit of the aims of the Paris Agreement—limiting temperature rise to 2°C, or better yet, 1.5°C. Though the pathways and systems of climate change are global, reducing GHG emissions can only be done through decisions, policies, and regulations enacted at the local level. The next chapter offers guidance to planners for applying climate mitigation planning efforts in their communities.

CHAPTER 5

# CLIMATE MITIGATION PLANNING

Climate mitigation involves implementing policies and actions designed to avoid, reduce, and offset atmospheric concentrations of carbon dioxide ($CO_2$), methane, and other greenhouse gases (GHGs). This is principally accomplished through emissions avoidance, reductions, and offsets within urban systems and through the development of programs and projects to sequester and capture carbon (often referred to as carbon sinks).

To date, much of the climate mitigation policy discussion has centered on reducing GHG emissions through fuel substitution and fuel efficiency for vehicles and on energy efficiency for buildings and industries. At the same time, there is a growing acknowledgement by scientists and policy analysts that a substantial part of the global warming challenge may be met through the design and development of cities that are carbon neutral.

The form and function of human settlements can either reduce or increase the demand for energy, and can also influence how energy is produced, distributed, and used. As the world's population and resultant economic activity increase, aspects of urban form will play as important a role as reduced fuel consumption in diminishing the extent of avoidable climate change.

Urban planning solutions to address climate change must consider the form of settlement structures (mixed-use, compact communities) and the pattern of settlement expansion (reductions in sprawl, densification through infill development, transit-oriented development), as well as alternative energy systems (upgrading to more energy efficient systems, cogeneration of heat and power, district heating and cooling, microgrid technologies, and renewable energy systems).

The scale of intervention required to reduce GHG emissions will require action at all levels of government and society. International accords to limit overall carbon emissions will involve national governments. Setting carbon emission targets and standards by industry and sector, including fuel efficiency standards for vehicles, falls within the traditional purview of federal and state governments.

In the United States, some state governments are beginning to set GHG reduction targets. For example, Washington's State Agency Climate Leadership Act, which was updated in 2020, requires GHG reductions in some state agencies to be 45 percent below 2005 levels by 2030 (Washington State Department of Ecology 2022). Similarly, in 2016, the California Air Resources Board (CARB) extended its GHG emissions reduction targets by enacting SB 32, which requires GHG emissions reductions of 40 percent below 1990 levels by 2030 (Shields 2021). In 2019, Colorado enacted comprehensive climate legislation directing the state Air Quality Control Commission (AQCC) to promulgate implementing regulations aimed at achieving statewide emissions reductions below 2005 levels of at least 26 percent by 2025, 50 percent by 2030, and 90 percent by 2050 (Shields 2021).

Such state-level directives are important. However, most decisions about urban form are made at the local level—by public officials, practitioners, and residents in cities, counties, metropolitan organizations, and special districts. Because urban planners are largely responsible for shaping the built environment at the local level, they are in a unique position to advance solutions to address challenges related to climate change. Planners should step up and take responsibility for climate mitigation and adaptation planning, as they can make informed choices about the climate implications of local growth and redevelopment and how to measure the effects of those decisions (Preston-Jones 2020).

This chapter explores how planners and decision makers can develop practical plans to avoid, reduce, offset, or sequester GHG emissions within their communities, the implementation of which can be effective in addressing and advancing a variety of other sustainable development goals and objectives.

## CLIMATE MITIGATION PLANNING PRINCIPLES

Whether they are embedded within a comprehensive plan or included in a climate action plan, climate mitigation policies and strategies must be easily understandable (with respect to costs and benefits), effective, action-oriented, and implementable. Meerow and Woodruff (2020) emphasize that effective, integrated climate mitigation planning must be based upon the following principles:

1. **Set ambitious, yet attainable, goals.** Provide a clear purpose, vision for the future, and measurable objectives.
2. **Provide a strong fact base with the best available data.** Incorporate empirical data on current conditions (GHG inventory, vulnerability assessment), future projections, and modeled impacts to ensure strategies are well informed.
3. **Outline diverse strategies to achieve goals.** Include diverse strategies such as planning processes, policies and design standards, land use, physical infrastructure, green infrastructure, individual behavior, education, capacity building, technology, and research. Rank strategies in terms of their importance. Emphasize strategies with co-benefits and mitigation/adaptation win–wins.
4. **Engage the public and foster justice in all planning processes to promote climate awareness, education, and community participation in climate implementation strategies requiring individual action**. Use participatory techniques in planning processes and specific strategies to engage marginalized populations and address climate injustices. Plans should detail these efforts as well as how the public will be engaged in plan implementation, monitoring, and updates.
5. **Coordinate efforts to address climate change across actors, sectors, and plans.** Engage diverse stakeholders in the planning process, integrate climate change into all plans, and ensure different plans are connected and consistent.
6. **Include a clear process for implementation and monitoring.** Identify an implementation timeline, funding source, and responsible agency or organization for each strategy. Monitor plan implementation and progress to goals and evaluate distributional consequences.
7. **Address climate change uncertainty.** Identify sources of uncertainties and use different scenarios in plan-making. Use adaptive management to learn and iteratively plan and prioritize no- or low-regret robust strategies.

## MITIGATION POLICY AND REGULATORY FRAMEWORKS

Climate mitigation planning must be integrated within all aspects of community, environmental, land-use, and transportation planning. The approaches and methods used will vary according to geographic or spatial scale, whether for individual buildings, neighborhoods and districts, municipalities, or entire regions.

Without the leadership of planners, the climate mitigation planning process tends to focus more heavily on the accounting aspects for public-sector GHG inventories and forecasts. In most municipalities, however, municipal operations comprise a very small part—often well under two percent—of a community's overall GHG emissions. The greatest impact a municipality can have on GHG emissions is in shaping the urban form and transportation behaviors of a community, alongside coordination and policies to engage energy partners.

Effective climate mitigation planning requires knowledge of transportation systems, environment, land-use dynamics, development codes and ordinances, site planning, regulatory issues, public works and infrastructure, emergency services, and a host of other aspects, most of which interface with existing planning processes. As planners work within multiple spatial scales and deal with a range of both urban and environmental systems-related issues, they are well positioned to lead climate mitigation planning work in coordination with other departments and community partners.

Each scale of development is governed by a specific set of policies and guidelines found within different guidance documents. Development at the building or parcel scale is largely regulated using building codes and design guidelines. Development at the block, neighborhood, or district scale is best regulated using special area plans, zoning and subdivision regulations, and development guidelines. Development at the municipal scale is largely shaped by policies within comprehensive or subarea plans. At the regional scale, development is regulated through regional growth strategies and regional transportation plans (Condon, Cavens, and Miller 2009). At all scales, climate mitigation planning should be based upon certain principles, as described in the sidebar on p. 56.

Cities around the country have begun developing and adopting laws, policies, standards, and incentives through which to regulate and promote climate-sensitive development. Climate mitigation policies may be embedded in municipal and countywide comprehensive or general plans, which are community land-use plans used to guide public and private physical development and investment decisions such as transportation and utilities infrastructure projects. Cities have updated these plans to include elements or sections that address climate change.

Communities may also adopt stand-alone climate action plans, with integration of those policies into other planning documents. Other functional plans in which climate mitigation policies may appear include hazard mitigation plans, transportation plans, green infrastructure plans, sustainability plans, open space plans, and others.

These policies are implemented through climate mitigation ordinances, among other means. Climate mitigation ordinances are local laws that have been enacted by a city council or commission through which to regulate the development, implementation, performance, and enforcement of practices and projects which avoid, reduce, or offset GHG emissions.

## Climate Mitigation in Comprehensive Plans

Because it serves as the overarching policy guidance document for a community, it is important that the comprehensive or general plan addresses climate mitigation. The robust public engagement that is part of the comprehensive planning process provides an excellent opportunity to educate the community on the importance of planning to reduce GHG emissions.

Comprehensive plans comprise goals, objectives, policies, standards, and implementation measures, as well as maps and other graphics, that describe a community's vision for future development. Climate mitigation policies should be considered in the context of and integrated with key plan elements, including growth capacity and infrastructure, land use and character, urban design, transportation, housing and neighborhoods, public facilities, parks and recreation, and economic development. The interrelation of different elements is an important consideration when incorporating policies for GHG emissions reduction into a comprehensive plan and ensuring those policies are internally consistent throughout the plan (Lee and Yu 2009).

There is also value in adding a stand-alone climate change element to the plan that focuses on local implications of climate change and how specific mitigation strategies and actions can reduce GHG emissions. A climate change element may include goals, objectives, policies, and actions that focus specifically on mitigation, and lay out strategies through which to guide the community in working together to advance and implement climate action policies.

Effective mitigation strategies a community can implement include the following:

- Increasing the use of renewable energy and access to alternative fuels
- Providing options for active transportation
- Designing energy-efficient buildings and resilient infrastructure
- Protecting and enhancing natural systems and water resources
- Maximizing co-benefits of ecosystem services and green infrastructure solutions
- Purchasing climate-friendly products
- Educating the public on socioeconomic and public health impacts of climate change

Including a climate change element within a comprehensive plan provides a framework for integrating and addressing the economic, environmental, and social factors of climate change. It aims to mitigate the causes and address the local implications of global climate change to help build a sustainable, climate-resilient community (Broward County 2019).

## Climate Action Plans

A climate action plan (CAP) is a detailed and strategic framework for measuring, planning, and reducing GHG emissions and related climatic impacts. CAPs are comprehensive roadmaps outlining the specific activities that an organization, agency, or governing body will undertake to reduce GHG emissions.

CAPs are produced at regional, state, and municipal levels of government and build upon the information gathered through GHG inventories. Municipalities develop and use CAPs to make informed decisions and understand where and how to achieve the largest and most cost-effective emissions reductions that are in alignment with other municipal goals. At a minimum, CAPs include an inventory of existing emissions, reduction goals or targets, and analyzed and prioritized reduction actions (Burlington 2017). They provide evidence-based and preventative measures to reduce GHG emissions, thereby addressing the negative outcomes of climate change and focusing on activities that can achieve the greatest emission reductions in the most cost-effective manner. CAPs typically address the following key areas (ClimateCheck 2022):

- **Transportation**. Strategies include transitioning to electric and low-emission vehicles, reducing the number of vehicle miles traveled per person, and providing safe and equitable transportation options.
- **Energy transition**. Strategies include increasing investments in renewable and resilient energy, carbon capture technology, and energy innovation.
- **Building optimization**. Strategies include reducing building energy use through upgrades of existing structures and investments in new infrastructure.
- **Materials management**. Strategies include management of materials systems for waste, water, recycling, composting, and other outcomes with the goals of reduction and proper disposal.

As of October 2021, 34 U.S. states had released CAPs or were in the process of revising or developing one (C2ES 2021), and more than 600 U.S. cities have adopted CAPs that include GHG inventories and reduction targets since the 1990s (Markolf et al. 2020).

The principal elements of a CAP are as follows (UN-Habitat 2015):

1. A baseline inventory of current annual GHG emissions
2. Community engagement strategies to build awareness and understand concerns from a diverse set of stakeholders
3. A series of target emissions reduction goals and dates relative to a baseline year or amount
4. Models for planned emissions reductions and carbon offsets within each sector covered by the plan
5. A description of how the CAP links with other existing plans in the city and other local socioeconomic and environmental goals
6. A description of how the CAP links to other national and regional goals, regulations, plans, and processes
7. A technical and scientific summary including a statement on the science behind climate change and projections of climate impacts, and baseline assessments such as a GHG emissions inventory, a vulnerability assessment and health implications, or a local renewable energy potential assessment
8. Strategies for implementation, such as proposed regulations, community and business partnerships, and community guidelines
9. A comprehensive list of actions and initiatives to reduce or eliminate carbon pollution to achieve emission reduction targets
10. A summary of how actions were prioritized, and other decisions were made, including the criteria used
11. Financing details for actions and programs implemented under each section of the plan
12. A framework for outreach, education, communication, and reporting on dissemination results, and ensuring accountability
13. A monitoring and evaluation framework, along with key performance indicators, for measuring progress and updating actions
14. Interim target check-in dates to track compliance with the plan
15. A glossary to explain unavoidable technical terms
16. Simple graphics used throughout to illuminate key findings, goals, and strategies

CAPs may include additional elements through which to ensure community support, track and monitor implementation, and quantify reductions. It is important for planners to crosswalk and integrate CAPs with other planning processes and actions to achieve full implementation.

## Mitigation-Oriented Ordinances

Municipal ordinances, including zoning codes, can be geared toward mitigating the impacts of climate change through promoting reductions in GHG emissions or methods for sequestering emissions.

Local ordinances can address a wide range of mitigation efforts, including the following:

- Expanding or improving alternative and active transportation infrastructure
- Promoting connected, dense, and accessible land uses
- Implementing requirements or incentives for developers
- Greening city fleets and city infrastructure
- Assisting businesses and institutions in developing commuter benefits programs
- Educating the public and improving access to transportation-related information

- Collaborating with regional transit authorities to expand and improve public transit service
- Removing barriers to improving bicycle mobility
- Addressing the jobs–housing mismatch
- Implementing financial incentives and disincentives to reduce vehicle miles traveled and GHG emissions

Municipalities may adopt green building ordinances requiring that new construction and major modifications of municipal buildings, commercial buildings, and residential buildings be constructed to a specific high-performance, green building standard, such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification program. Green buildings use resources more efficiently and are built with more sustainable materials and practices than conventional buildings.

Other mitigation-oriented ordinances may promote the effective and efficient use of wind and solar energy resources, including provisions related to siting, permits, approvals, operation, and oversight of wind energy conversion systems, solar photovoltaic systems, and solar thermal systems (Sabin Center 2021).

## GHG Inventories

A GHG inventory quantifies the amount of anthropogenic GHG emissions and sources within a defined boundary over the course of a year. GHG inventories may be included in the climate action planning process, providing community stakeholders a comprehensive snapshot of local emissions to guide decision-making. They enable communities to do the following (Yewdall et al. 2009):

- Develop baseline energy/emissions data
- Identify emissions trends
- Create realistic emissions reduction targets
- Develop effective strategies for reducing emissions
- Monitor emissions reduction progress
- Make informed decisions when designing climate or energy programs and climate action plans
- Set goals and targets for future reductions

GHG inventories also can help cities meet legal and voluntary requirements to measure and report GHG emissions data (Fong et al. 2014).

A GHG inventory can be conducted at a range of spatial scales: multistate, regional, local, or project-specific. It can target a particular sector (e.g., transportation, energy production, municipal solid waste) or a specific GHG (e.g., carbon, methane). The methodology for conducting a GHG inventory should incorporate the following process steps:

1. **Set boundaries.** Define an inventory's physical, organizational, and operational boundaries.
2. **Define scope.** Determine which specific GHGs, emissions sources, and activity categories and subcategories should be included in the inventory. The scope and detail will drive the level of effort required. Having access to good quality data on GHG emissions is critical.
3. **Establish GHG reduction targets.** There are two broad types of GHG reduction target metrics—absolute emissions targets or intensity emissions targets. Intensity targets specify emissions reductions relative to productivity or economic output such as tons of $CO_2$/lbs. of product produced. Both intensity and absolute targets specify a reduction in emissions relative to a historical baseline year (ICUSD 2019).
4. **Set a baseline.** Baselines (also known as inventory and forecast, or I&F) include historical data and forecasted estimates of energy consumption, economic activity, resource management, and GHG emissions or other environmental metrics. A GHG baseline not only shows the source and quantity of GHG emissions, but also indicates the factors, or drivers, contributing to these levels; it is thus a key resource in providing guidance on mitigation priorities and strategies within business-as-usual development patterns and for assessment of future GHG reduction targets. Historic input data required to develop an energy and emissions baseline includes energy (fuels and electricity) supply and use, industrial and agricultural activity, materials management, natural resources management, and other factors across the economy and landscape of the planning jurisdiction (CCS 2016). When choosing a baseline year to provide a benchmark to compare progress going forward, consider whether (1) data for that year is available, (2) the chosen year is representative, and (3) the baseline is coordinated to the extent possible with baseline years used in other inventories.
5. **Engage stakeholders.** Bring stakeholders into the inventory development process. Stakeholders can provide valuable input on establishing a baseline, can help build public acceptance of policies to address climate change, and can provide data, information on data resources, and personnel resources, including outreach assistance.
6. **Consider certification.** Conducting a third-party review and certification of the methods and underly-

ing data in an inventory is important to assure that the inventory is high quality and that it is complete, consistent, and transparent. Certification may be required for participation in some GHG registries.

The resulting GHG inventory can be used to track emissions trends, assess the relative contributions of emissions sources, communicate with stakeholders, partner with other municipalities to create a regional inventory, develop mitigation strategies and policies, and measure progress toward meeting GHG reduction goals (U.S. EPA 2021c).

## CHALLENGES AND BENEFITS OF CLIMATE MITIGATION OPPORTUNITIES

Pursuing climate mitigation actions may be seen as an economic burden that may conflict with or hinder a particular development agenda. These concerns are often drawn from the historical coupling of GHG emissions with economic development and fears that reducing emissions will likely impede economic growth.

Advancing an economic development agenda, however, does not necessarily require increasing GHG emissions. This misconception is exacerbated by the understanding that resources expended on measures for climate action entail significant opportunity costs (i.e., the allocation of capital to something that will not reap a return), rendering capital resources unavailable for other uses, such as pursuing economic gains. This perception derives largely from the fragmentation of sustainable development issues. Measures for the decarbonization of the economy are often planned and assessed in climate- and environment-related policy silos, where decarbonization is the major objective and the comparative direct capital costs of measures is the primary assessment criteria (Day et al. 2018).

Recent estimates calculate that the overall global benefits of keeping future temperature increases to 1.5°C are likely in the tens of trillions of dollars. These benefits are more than 30 times greater than the most recent estimates of what it will cost to achieve this goal. According to Marshall Burke, assistant professor of earth system science at Stanford University, "For most countries in the world, including the U.S., we find strong evidence that the benefits of achieving the ambitious Paris targets are likely to vastly outweigh the costs" (Horton 2018).

Achieving the goals and targets of the Paris Agreement will require significant transformations within all cities, and yet climate change is far from the only topic on the agenda for residents and their leaders. As the world's urban population continues to increase at a staggering rate of 1.4 million additional people every week, municipal leaders must address, with increasing urgency, a confluence of multiple pressures, challenges, and priorities including, but certainly not limited to, overpopulation, aging and overstretched infrastructure, frustrated employment expectations, growing inequality, lack of adequate and affordable housing, deteriorating air quality, and insufficient access to amenities. When considering how to address these myriad challenges, it can be tempting for city leaders, and for community members as well, to see climate action as separate from other priorities such as inclusion, growth, or health. In some cases, these are even seen as being in direct conflict with each other when deciding where to focus attention, resources, and action. This instinctual prioritization of other agendas over climate can result in local stakeholders being unwilling to consider or support climate action, despite the reality that the human and economic costs of significant levels of global warming will be enormous.

Climate policies should be interrelated with sustainable development goals and deliver outcomes that enhance quality of life, improve economic well-being within communities, and advance other development agendas. Mitigating climate change through ambitious policies can help cities achieve their broader environmental, social, and economic agendas and deliver outcomes for health and prosperity (Day et al. 2018). Conversion from fossil fuel-based energy supplies to clean and affordable renewable energy not only results in significant reductions in GHG emissions, it also reduces air pollution and health risks, can stimulate local industrial enterprises and other economic opportunities, and enhances energy security. Making buildings and industry more energy efficient cuts household energy bills, reduces indoor air pollution and resulting illness, improves industrial efficiency and competitiveness, and ultimately extends the useable lifetime of the built environment through reductions in operating expenditures, particularly for lower-income groups. Promoting modal shifts from personal vehicles to public transit reduces emissions and resulting air pollution, increases accessibility and mobility options for poorer communities, reduces total energy demand and use of fossil fuels, and provides transportation infrastructure that meets the long-term needs of cities and their inhabitants.

In summary, many climate actions can produce multiple benefits, including improved health outcomes (and lower healthcare costs), reduced expenses, improved air quality, job opportunities, livability, and economic competitiveness. These benefits—if fairly distributed and accessible to all segments of the population—can become powerful tools for more and better-designed climate actions in cities and are critical to reducing barriers to action (Porteron 2018).

## CONCLUSION

Planners are well positioned to advance climate mitigation principles, policies, and best practices across a variety of spatial scales because they possess the ability and expertise to draft plans to avoid, reduce, or offset GHG emissions; communicate plan policies and strategies to a variety of stakeholder groups to ensure support and participation in plan implementation; and develop management and design standards through which to measure and track implementation progress. All of this will need to be accomplished for the well-being of future generations and the continued livability of our planet.

But while the climate crisis necessitates that all communities do their part in mitigating future GHG emissions, it also requires them to simultaneously prepare to adapt to the impacts of past (and future) emissions. A dual approach is needed to advance a climate-resilient future. The next two chapters will outline climate adaptation approaches for different sectors and detail a climate adaptation planning framework.

CHAPTER 6

# CLIMATE IMPACTS AND ADAPTIVE RESPONSES

Cities across the United States are already facing a variety of challenges resulting from climate change, as well as non-climate-related stressors that changing climate conditions threaten to exacerbate. As described in Chapter 2, climate-related risks include rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, drought, increased aridity, water scarcity, and air pollution, all of which will have widespread negative impacts on people's health, livelihoods, and assets, as well as local and national economies and ecosystems. Adaptation, introduced in Chapter 3, is essential to reducing vulnerability to dangerous outcomes of climate change.

As discussed in Chapter 4, a wide range of sectors vital to the built environment and urban systems—energy, transportation, land use, housing, waste management, the natural environment, and food systems—produce greenhouse gases (GHGs) that contribute to climate change. These sectors are all likewise affected by climate change, with resulting impacts on infrastructure systems, services, the built environment, and ecosystem services. These interact with other social, economic, and environmental stressors, aggravating and compounding risks to individual and community well-being.

It is critical for communities to understand the climate impacts that they will increasingly be facing in the coming years and to identify the range of potential responses that will help them prepare for those impacts and adapt to these changes. This chapter discusses climate impacts and adaptation approaches by sector, providing important background information for planners preparing to help their communities become more climate resilient.

## ENERGY

The energy industry is both a major contributor to climate change and a sector that climate change will disrupt. Over the coming decades, the energy sector will be affected by global warming on multiple levels, and by policy responses to climate change (Benn 2014).

Urban prosperity and quality of life depend largely on the services of this sector to support the energy needs of households, businesses, transportation, health care, water management, and food systems. These needs include lighting, heating, and cooling in both residential and commercial buildings, and fuel for transportation and industrial systems and processes (U.S. EIA 2021). Many cities currently import energy from distant locations, and city governments often do not have direct control over what energy is generated or what supplies are available.

### Impacts

Extreme weather events and acute temperatures can impact energy reliability for city users. Resulting damage to renewable energy facilities and electricity transmission and distribution lines can lead to interruption or complete loss of electricity supply, as well as voltage fluctuation, which can damage electrical equipment. A recent example of this was California's rolling blackouts in August 2020, which were the result of high demand due to a massive heat wave—considered a one-in-30-year weather event attributable to climate change (Morehouse 2021). Oil and gas pipelines in coastal areas will be impacted by rising sea levels, while those in cold climates will be at risk due to thawing permafrost.

Climate change will likely alter patterns of urban energy consumption, especially for cooling and heating (Mideksa and Kallbekken 2010). Extreme heat can increase demand for cooling in occupied buildings, putting even more pressure on local electricity supply. Energy disruptions that make electricity and air conditioning unavailable in these circumstances pose health risks and potential fatalities for elderly, disabled, and hospitalized individuals (Klinenberg 2002).

Energy production and operations may be vulnerable to even small shifts in climate. Thermal power plants will be affected by the decreasing efficiency of thermal conversion due to rising ambient temperatures. Reduced water supplies for cooling and increasing water temperatures could lead to reduced power operations or temporary shutdowns (Benn 2014). Hydropower generation is especially vulnerable due to its direct dependence on hydrological factors, including variations in precipitation, declining seasonal snowpack, and the volume and timing of stream flows. Significant fluctuations in water levels in Lake Mead and subsequent power produced by the Hoover Dam have raised the possibility that Los Angeles may lose a major power source and Las Vegas could face a severe decline in drinking water availability (Gober 2010) (Figure 6.1).

Climate change may also affect emerging energy technologies, such as biomass and biofuels, which may be affected by potentially lower crop yields associated with changing temperatures. Wind and wave energy generation also depend on climatic variables, such as wind speed, energy density of wind, atmospheric motion, and water vapor content.

## Adaptation Approaches

A sustainable energy system that integrates energy efficiency, low-carbon urban development strategies, and renewable energy sources is an important characteristic of urban resilience. Developing these approaches at the municipal level, especially diversified and distributed renewable energy, may be quicker and more effective at building local energy security than waiting for large-scale energy solutions. These approaches can also yield numerous co-benefits and can prepare a city for a future in which GHG emissions and the use of fossil fuels for energy may be limited through enhanced regulations.

*Figure 6.1. Decreasing water levels in Lake Mead impede hydroelectric power generation (Mjponso (talk)/Wikimedia Commons (CC BY-SA 3.0))*

Conservation and efficiency programs can reduce peak electricity demand and limit the risk of blackouts, while distributed energy systems involving cogeneration, large-volume energy storage, and local renewable energy can buffer the effects of interruptions in transmission. At the same time, these investments can yield multiple potential benefits, including financial savings, job creation, and business growth; reduced GHG emissions and improvements in local air quality; and reduced dependence on fossil fuels through diversified local energy production (UN-Habitat 2015; World Bank Group 2011). The World Resources Institute has developed a series of logical decision trees for energy projects that analyze system and project vulnerabilities resulting from climate impacts and suggest multiple adaptation strategies (WRI 2019).

Municipal planners can work with energy utilities and emergency response officials to conduct specific vulnerability assessments, create or enhance emergency warning systems, revisit planning timeframes, and adjust design standards to reflect climate impacts on the energy sector (UNEP 2011b). In planning for potential energy disruptions, cities and other stakeholders can consider such factors as the availability of backup power, the length of time before serious consequences of energy disruption are felt, the specific nature of consequences from interrupted energy supply, and the demographics of those affected (World Bank Group 2011).

Energy sector adaptation should also involve other sectors, such as buildings, land use, and water resource management. For example, buildings that integrate passive solar practices, natural forms of shading, and highly reflective surfaces or materials can reduce energy demand for cooling or heating (Foster, Lowe, and Winkelman 2011). Cities can regulate design and retrofit standards to encourage such investments in both new and old buildings.

When developing energy infrastructure, cities should require that it be located away from vulnerable locations, such as low-lying coastal areas. River basin management can be essential in protecting hydropower resources. Although city officials may not directly control hydropower generation, knowledge of water resource management issues can help ensure that plans effectively and equitably balance competing citywide and regional demands for hydropower, drinking water, irrigation, and fisheries (World Bank Group 2011).

## TRANSPORTATION

Transportation infrastructure comprises an extensive range of both public and private assets and services. It can be grouped into four primary categories: roads, bridges, and tunnels; passenger and freight rail; ports and inland waterways; and airports.

Because transportation infrastructure is essential for both people and commerce, in daily life as well as in times of emergency, climate adaptation planning in this sector stresses emergency preparedness. Planners should ensure that climate change is addressed in transportation planning and develop strategies to remove infrastructure from threatened areas (CCS 2011).

### Impacts

Extreme storm events can paralyze transportation infrastructure, further isolating vulnerable communities with limited provisions, such as food or medicine, during emergencies. Increased storm intensities can overwhelm the capacity of existing infrastructure, such as bridge clearances or drainage capacity. Airports can be affected by changing wind patterns and extreme weather events.

Acute heat can cause a range of negative impacts across the transportation sector. Loss of vegetation because of extreme heat or drought can lead to increased stormwater runoff, which may wash away roads and bridges (Lwasa 2010). Roads may suffer from pavement deterioration and buckling caused by high surface temperatures that can lead, in turn, to problems with expansion joints and long-term damage. This was exemplified in the Pacific Northwest during the summer heat wave in 2021, when roads throughout the region cracked and buckled, including Interstate 5 (Graff 2021). Extreme heat conditions can cause the expansion of train rails, which may require slower speeds and cause delays. Heaving in both roads and rails may shut down traffic or cause accidents (World Bank Group 2011) as well as delay emergency transportation responses.

### Adaptation Approaches

Adaptation planning principles for all transportation networks include the avoidance of flood-sensitive areas as much as possible and the incorporation of climate change into all relevant decisions concerning transportation infrastructure (Coffee et al. 2010).

For cities exposed to flooding, relocating existing storage yards for buses and train cars out of floodprone areas can reduce the risk of damage to or loss of equipment. During construction, cities can "build once" to a higher standard (or greater capacity), rather than build to lower standards initially and then be forced to retrofit or enlarge later. Examples of this include increasing bridge clearances to accommodate higher water levels, increasing design specifications for culvert diameters, and reconsidering the design of road underpasses to account for heavy rains and flooding.

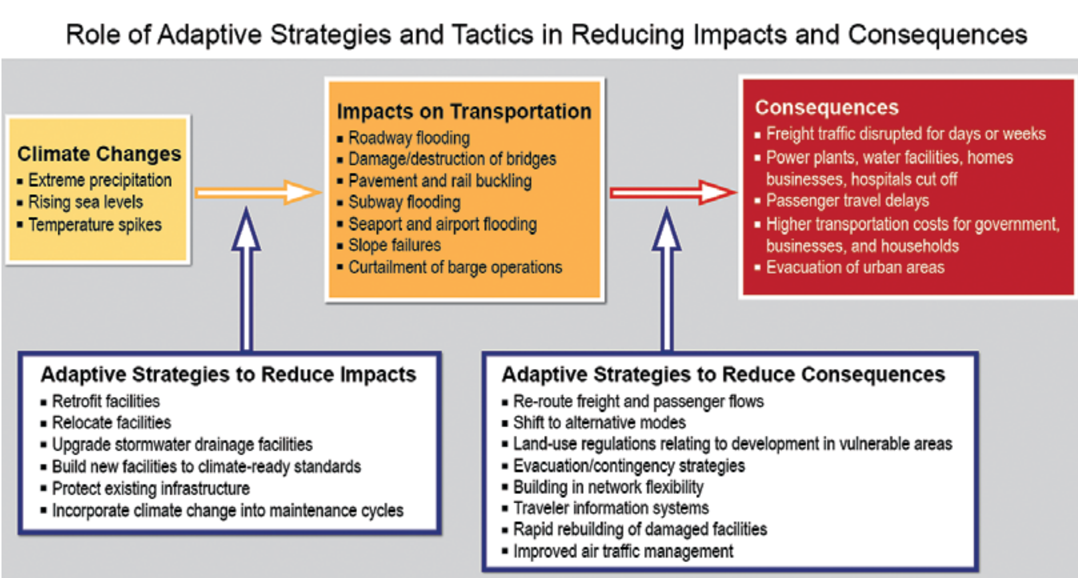



*Figure 6.2. Adaptive strategies and tactics to reduce climate change impacts to the transportation sector (USGCRP 2014)*

Many projected climate impacts and resulting consequences on transportation systems can be reduced through a combination of infrastructure modifications, improved information systems, and policy changes (USGCRP 2014) (Figure 6.2, p. 65).

It is critical to expand transportation infrastructure and transit-oriented development as necessary to ensure alternative evacuation options in cases of emergency. Coastal cities expecting sea level rise can work with ports and maritime businesses to synchronize shipping schedules around high tides to avoid problems with bridge clearance (World Bank Group 2011).

Cities have a variety of low-cost options for adaptation in the transportation sector. When resources are limited, cities can consider less expensive business practices or investments in shorter-lived infrastructure. Adaptation strategies in the transportation sector are especially important in the following areas (USGCRP 2014):

- **Transportation and land-use planning.** Deciding what infrastructure to build and where to build it, as well as planning for vulnerable areas of the community and impacts on specific population groups.
- **Vulnerability and risk assessment.** Identifying existing vulnerable facilities and systems, together with the expected consequences.
- **Capital improvement planning.** Embedding climate risk assessments into capital improvement planning processes at the municipal and county levels as a cost-effective means of building community resilience to climate-related threats (UMEFC 2018).
- **New infrastructure design.** Adopting new infrastructure designs that anticipate changing environmental and operational conditions to avoid getting locked into systems that are hard to adapt.
- **Asset management.** Adapting existing infrastructure and operations to respond to current and anticipated conditions, including changed maintenance practices and retrofits.
- **Emergency response.** Anticipating expected disruptions from extreme weather events and developing emergency response capabilities.

## LAND USE

Land-use policies and practices can have unintended as well as intended effects, and they require clear communications for communities to grasp the implications of specific development decisions. For example, increases in the percentage of impervious surface—such as pavement in roads, sidewalks, driveways, and parking lots—in rapidly growing areas can increase exposure to flood hazards, urban heat islands, and poor air quality. The responsibilities for planning, economic development, land tenure, and other functions that direct growth are often distributed among local, regional, and national governments and their subsidiaries, making coordination of climate adaptation planning difficult.

### Impacts

Localized flooding due to sea level rise and inundation of low-lying areas and coastal areas will disproportionately impact vulnerable communities located in high-risk urban areas. The urban poor often end up living in areas of highest environmental risk. These neighborhoods are often located on marginal lands, such as within low-lying floodplains that are affected disproportionately by increased rainfall and are often the last areas to be provided with drainage infrastructure.

Future land-use plans that enable development in environmentally sensitive areas, such as arid or forested regions prone to periodic drought and wildfires; floodplains, which are subject to flooding; coastal areas, which are susceptible to storm surges and extreme weather; and areas with steep terrain, which may be subject to erosion, may increase the likelihood of damage to property and risk of life.

### Adaptation Approaches

Understanding which areas of a city are most likely to be affected by sea level rise or localized flooding is an important initial step in taking action to reduce climate vulnerability. It is also important to consider information about new infrastructure and planning needs related to climate change in the context of existing development.

Municipal planners can develop and enforce land-use plans that minimize climate vulnerabilities and promote growth in resilient locations. Community resilience can be significantly increased by a sound land-use plan that addresses climate vulnerabilities and is well enforced. Transportation and utilities infrastructure siting should be consistent with the plan, and adaptation-related improvements should be built into a municipality's capital improvement program (CIP).

As urban populations expand into new geographic areas, one of the top priorities for planners is preventing critical land uses—residential, commercial, and institutional development and infrastructure investments—from occurring in vulnerable locations, such as along waterways, in floodplains, or on steep slopes. The most practical land-use plan informs a city's choices about the location of transportation, housing, environmentally protected areas, and wastewater and drainage infrastructure investments, viewing these activities in the context of the whole community.

Comprehensive land-use planning that anticipates likely climate impacts can accomplish the following community-wide goals (World Bank 2011):

- Encouraging coordinated transportation and housing investments, so that people can afford to live in safe conditions with transportation choices in cases of emergency
- Promoting green infrastructure and sound watershed management (including urban forestry and watershed protection outside of city limits), which can reduce storm water runoff, mitigate the urban heat island effect, and improve public health
- Rehabilitating wetland riparian or estuarine habitats (for example, coastal mangroves) that provide natural ecosystem services, such as flood protection
- Reducing the long-term cost of development by building in areas that are less vulnerable to climate impacts and costs

## WATER INFRASTRUCTURE

Water and sanitation infrastructure will similarly be affected by systemic and cascading climate risks across interconnected urban systems.

Across the United States, much of the critical water infrastructure is aging, deteriorating, or nearing the end of its design life. Estimated reconstruction and maintenance costs for dams, levees, aqueducts, sewers, and water and wastewater treatment systems could run into the trillions of dollars. Compounding this issue is that, to date, there has not been a comprehensive assessment of the climate-related vulnerability of the nation's water infrastructure. Consequently, actual risks to U.S. water infrastructure may be underestimated (U.S. Climate Resilience Toolkit 2020).

Rising temperatures and changing precipitation patterns are leading to significant changes in the quantity and quality of water resources available in the United States. Geographic location, engineering methods, and types of materials used to construct infrastructure are factors that determine its resilience, as well as the resilience of the communities that rely on it. Examples of traditional infrastructure's inability to meet the challenges of climate change include sites located on low-lying or marginal land prone to flooding and leakages from pipes due to structural deficiencies (World Bank 2011). To promote gravity flow of wastewater to a water recycling facility, these facilities are often located at the lowest point topographically and therefore may be at risk from sea level rise or flooding.

### Impacts

Projected climate impacts to water infrastructure systems include altered precipitation and runoff patterns in cities, sea level rise and resulting saline ingress, reductions in water availability and quality, and heightened uncertainty in long-term planning and investment in water and wastewater systems (Fane and Turner 2010; Major et al. 2011; Muller 2007).

Climate change will increase the risk and vulnerability of urban populations to reductions in groundwater and aquifer quality, subsidence, and increased salinity intrusion (Praskievicz and Chang 2009; Taylor and Stefan 2009). High levels of groundwater extraction may create serious subsidence problems that can damage buildings, fracture pipes, and increase flood risks (Jha, Bloch, and Lamond 2012). These problems may be exacerbated in coastal cities, where saline intrusion can reduce groundwater quality and erode structural foundations.

In rapidly developing cities, particularly in the Southwest, population growth will likely heighten water stress and negative impacts on available water quality and quantity. Decreases in shared resource supply will likely alter relationships among water users, exacerbating tensions and conflicts between residential, commercial, industrial, agricultural, and infrastructural end users (Roy et al. 2012; Tidwell et al. 2012).

Wastewater and sanitation systems, particularly if combined, will be increasingly overburdened during extreme precipitation events if attention is not paid to maintaining and increasing the often-limited capacity of drainage systems in older cities (IPCC 2013). The impacts of flooding are increased when urban sprawl paves over natural drainage channels and occupies floodplains. Poor maintenance of existing drainage channels, which can be blocked by the buildup of solid wastes, may also exacerbate flood impacts.

### Adaptation Approaches

Water-use reductions may be achieved through urban densification, increased water prices, and water conservation measures (Bolin, Seetharam, and Pompeii 2010). Stringent demand and supply policies can ameliorate climate impacts and enable future population growth, but this would require dramatic changes to supply-side management of groundwater and groundwater storage combined with extensive demand-side measures (Colby and Jacobs 2007).

Supply-side structural options for city-level adaptation include desalination of sea water, expansion of rainwater storage, removal of invasive nonnative vegetation from riparian areas, and wastewater reuse for irrigation, street cleaning, and even drinking water, the latter of which will require higher levels of treatment.

Demand-side structural options for city-level adaptation include improvement of water-use efficiency by recycling water and making physical improvements to water transmission infrastructure and delivery systems (e.g., water-efficient shower heads, dual-flush toilets). Nonstructural approaches include promotion of traditional practices for sustainable water use; expanded use of economic incentives, including metering and pricing, to encourage water conservation; and raising awareness about water conservation and reclaimed water (World Bank 2011). Seattle has used demand-side strategies, including aggressive conservation measures, system savings, and price increases, to cut water consumption (Vano et al. 2010).

To support climate adaptation, water infrastructure management should reflect the importance of reducing vulnerability and building climate resilience by incorporating the following actions:

- Placing adaptive Integrated Water Resources Management (IWRM), an approach to planning and managing urban water systems to minimize their impact on the natural environment, maximize their contribution to social and economic vitality, and engender overall community improvement, at the center of planning and investment for climate adaptation (UNDESA 2014; Whitler and Warner 2014)
- Promoting investment and implementation that incorporates installation, management, restoration, and sustainability of green infrastructure and its ecosystem services (Figure 6.3)
- Supporting actions to build climate resilience by combining watershed management, sustainable infrastructure, empowerment, and learning through adaptive institutions

## BUILDINGS AND HOUSING

Most of the buildings in the United States were not designed or constructed to withstand the impending range of climate conditions and increased frequency of extreme weather

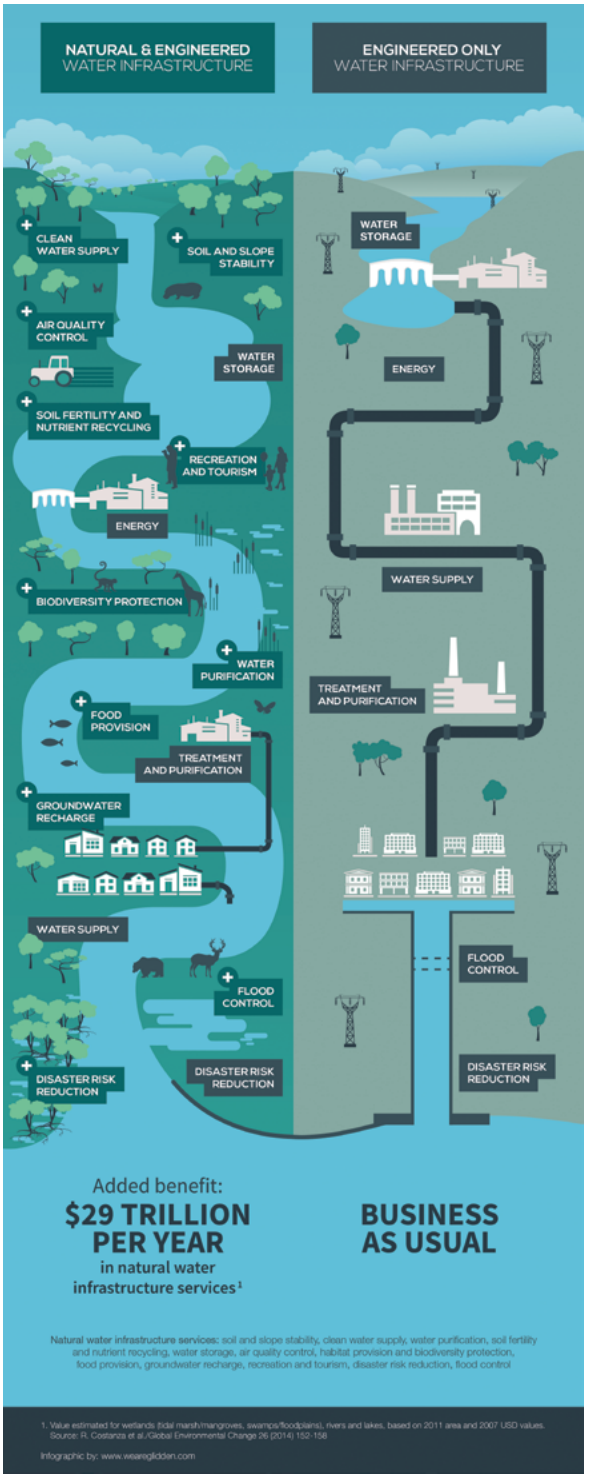



*Figure 6.3. Natural infrastructure reduces vulnerability and builds climate resilience (IUCN 2015)*

events projected for the future. For example, mechanical systems may not be sufficient to cool homes and businesses during extreme heat. In coastal areas, homes that cannot withstand the winds of tropical storms can become a source of flying projectiles that damage other structures.

While the application and enforcement of up-to-date model building codes is expected to reduce vulnerability and increase public safety, many codes are based on historical data and do not reflect future risks, including the impacts of climate change (U.S. Climate Resilience Toolkit 2016).

## Impacts

Beyond sea level rise, inland flooding poses significant risks for homes and buildings, particularly those located adjacent to or within the floodplains of rivers and deltas. The immediate impact of flooding includes property damage and risks to public health. Longer-term impacts may include increased dampness, which may result in mold growth, particularly in humid climates.

Increases in the frequency and severity of heat waves pose additional risks for occupants of homes without cooling methods. Very young children, the elderly, and those with infirmities are most susceptible to heat strokes and other health risks associated with extreme heat (World Bank Group 2011).

## Adaptation Approaches

High-performance green buildings can have both mitigation and adaptation co-benefits, and their construction can be incentivized by offering tax credits and low-interest loans to homeowners who incorporate these strategies into the planning and design of new homes. Individual residential structures can be built or retrofitted to better protect households, and the reduced insurance premiums that result can help households maintain financial stability (Martin and Arena 2019).

Adaptation approaches are best implemented at the time of construction, although existing buildings can be modified to increase resilience to climate impacts. Structural strategies range from the retrofit of homes and buildings with additions such as green roofs or sun shading, water storage space, and smart ventilation, to significant upgrades, such as raising the finished floor elevation of an existing building or other floodproofing measures (Figure 6.4). Retrofits can be attractive and effective solutions in cases where new construction is too expensive or otherwise not possible, especially for low-income or middle-income residents. Simple, inexpensive strategies, such as installing light-colored roofs, can provide cooling effects at relatively low cost (IPCC 2014b).

Because homeowners may be unaware of the extent of their homes' structural vulnerability, cities can supplement regulatory action with transparency efforts, such as a requirement for developers to assess and provide full disclosure of the geographic or structural risks of a housing development, and simultaneous public outreach to spread knowledge about homeowner risks.

If residential risks in a given location are too high to warrant staying or rebuilding, such as in the case of flooding events that repeatedly damage structures, local governments can use buyout programs to persuade homeowners to relocate. This requires significant financial resource capacity, however. In response to dramatic sea level rise, some cities may decide to pursue a larger and longer-term managed retreat strategy in very high-risk areas (World Bank Group 2011).

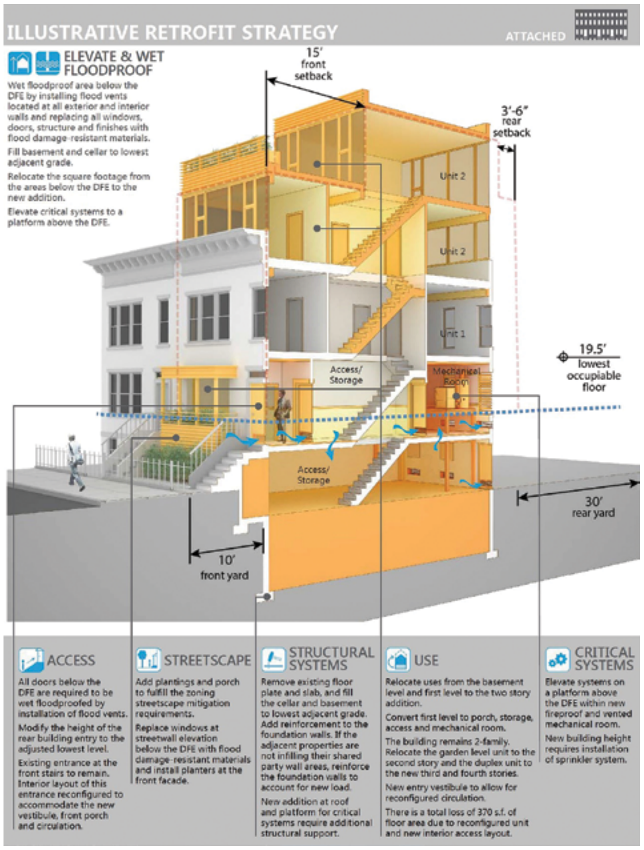



*Figure 6.4. New York City's design guidance for retrofitting attached residential buildings for climate change resiliency (Used with permission of the New York City Department of City Planning. All rights reserved.)*

## MATERIALS AND WASTE MANAGEMENT

As summarized in PAS Report 587, *Planning for Sustainable Material and Waste Management* (Ning and Green Leigh 2017), drivers of changes in materials and waste management (MWM) include health and environmental concerns, waste disposal capacity shortages, resource constraints and scarcities, the significant growth of the waste management industry, and social injustice concerns. Adaptation planning for sustainable MWM infrastructure involves determining facility needs, considering perceived and potential environmental hazards and risks, determining appropriate locations, and financing construction, operation, and maintenance of new, existing, and closed MWM facilities.

### Impacts

Climate change-related impacts to the management and storage of municipal solid waste and hazardous materials include temperature increases and subsequent drought and wildfires, increased storm events, and sea level rise. Temperature increases and sustained changes in average temperatures may result in changing exposure rates or potential for spread of contamination from existing waste management sites. Increased frequency and intensity of wildfires may impact exposure and safety of existing waste and contaminated site management facilities. Increased intensity of hurricanes may lead to the spread of contaminants or damage to management structures. Sea level rise, increased storm surge, and more intense and frequent storm events may all affect site assessments, risk analyses, and cleanup designs (U.S. EPA 2021e).

Major storms and other climate-related disaster events can generate an abundance of debris and waste, often greater than the amount of waste many communities handle each year. Large natural disasters can generate mixed waste, which can contain high concentrations of hazardous chemical, biological, and medical wastes, much of which is not typically handled by municipal waste management facilities. Communities should prepare for:

- Larger quantities of waste resulting from disaster events
- Wider varieties of generated wastes at one time, including atypical wastes in greater quantities
- Wider areas of impact, possibly affecting more than one jurisdiction
- Increased GHG emissions from waste management activities, such as the transportation, treatment, and disposal of large amounts of waste
- Insufficient waste management capacity to handle surges in necessary recycling, treatment, and disposal of generated wastes
- Greater chances of waste management facilities being impacted by the disaster event, resulting in possible decrease to existing capacity for generated wastes and reduction of available waste management options

Waste management sites, including Superfund sites, corrective action sites, brownfields sites, landfills, and underground storage tanks, are vulnerable to flooding and other climate impacts, and will be more difficult to manage and clean up in the future (U.S. EPA 2021a).

### Adaptation Approaches

The U.S. Environmental Protection Agency (EPA) has developed a pre-incident waste management planning program that can help communities prepare for these potential waste streams caused by disaster events (U.S. EPA 2022e). Waste management planning encompasses source reduction and hazard mitigation activities aimed at reducing the total amount of waste generated by an incident, especially for a large-scale natural disaster.

The EPA's pre-incident waste management planning process is designed to help communities prepare for an incident's waste management needs through initiating, creating, updating, and implementing a comprehensive waste management plan. Such pre-incident waste management planning can save valuable time in recovering from an event and can boost a community's resiliency through reducing distractions to broader response and recovery efforts and limiting the possible spread of contamination.

The EPA recommends that a pre-incident waste management planning program follow these steps:

- Identify those stakeholders who have critical information or resources related to various waste management-related activities (e.g., transportation, sanitation, emergency response, environmental health, public health, public works, zoning, and key industry and business leaders) and determine their roles and activities in responding to an incident.
- Inventory the types of waste streams that an incident may generate, considering the full range of land uses within a community.
- Consider the quantity of waste that may be generated and how that waste may be reduced by means of source reduction, reuse, and recycling.

- Develop waste collection strategies for separating waste into different waste streams before it is removed from the site of the incident.
- Determine locations that would be suitable for storing (composting, recycling, treating, and disposing of) contaminated waste.

Beyond pre-incident waste management planning, recommended improvements to MWM site operations and infrastructure include the following (U.S. EPA 2021b):

- Constructing “soft” seawalls (through techniques such as replenishing sand and vegetation) and jetties or groins to stabilize and shield a shoreline from erosion; in some cases, “hard” seawalls (such as those made of reinforced concrete) may be warranted
- Constructing structures to retain or divert floodwater, such as vegetated berms, drainage swales, levees, dams, or retention ponds
- Stabilizing on-site river and stream banks through installation of “soft” armor (such as synthetic fabrics and deep-rooted vegetation) or “hard” armor (such as riprap, gabions, and segmental retaining walls)
- Relocating selected system components to locations more distant or protected from potential hazards; for flooding threats, this may involve elevations higher than specified in the community’s flood insurance study

## GREEN INFRASTRUCTURE AND ECOSYSTEM SERVICES

Ecosystem-based adaptation—the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change—is becoming an integral approach to adaptation (Secretariat of the Convention on Biological Diversity 2009).

*Green infrastructure* refers to interventions to preserve the functionality of existing green landscapes (including parks, urban forest canopy, wetlands, or green belts). It can reduce impacts to an urban environment through phytoremediation and water-management techniques and by introducing productive landscapes (Foster, Lowe, and Winkelman 2011; La Greca et al. 2011; Revi et al. 2014). Section 502 of the Clean Water Act defines green infrastructure as “the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters” (U.S. EPA 2022e).

*Ecosystem services* refer to the direct and indirect contributions of ecosystems to human well-being. There are four major categories of ecosystem services: provisioning, regulating, cultural, and supporting services (Figure 6.5, p. 72) (MEA 2003). A provisioning service is any type of benefit to people that can be extracted from nature, including food, water, wood fuel, natural gas, and textiles. A regulating service is the benefit provided by ecosystem processes that regulate or moderate natural phenomena, such as pollination, decomposition, water purification, carbon storage, and climate regulation. Cultural services are the nonmaterial natural benefits that contribute to the cultural and creative advancement of people, such as the aesthetic importance of sunsets, or seascapes as subjects of artistic expression. Supporting services include those natural processes that sustain life on Earth, such as photosynthesis, the creation of soils, and nutrient and water cycles (Chivian and Bernstein 2008).

### Impacts

Climate change is altering ecological systems, biodiversity, genetic resources, and the benefits derived from ecosystem services. It is inducing shifts in habitats that often cannot accommodate key indicator species, which leads to changed ecosystems, local and global extinctions, and the permanent loss of genetic diversity.

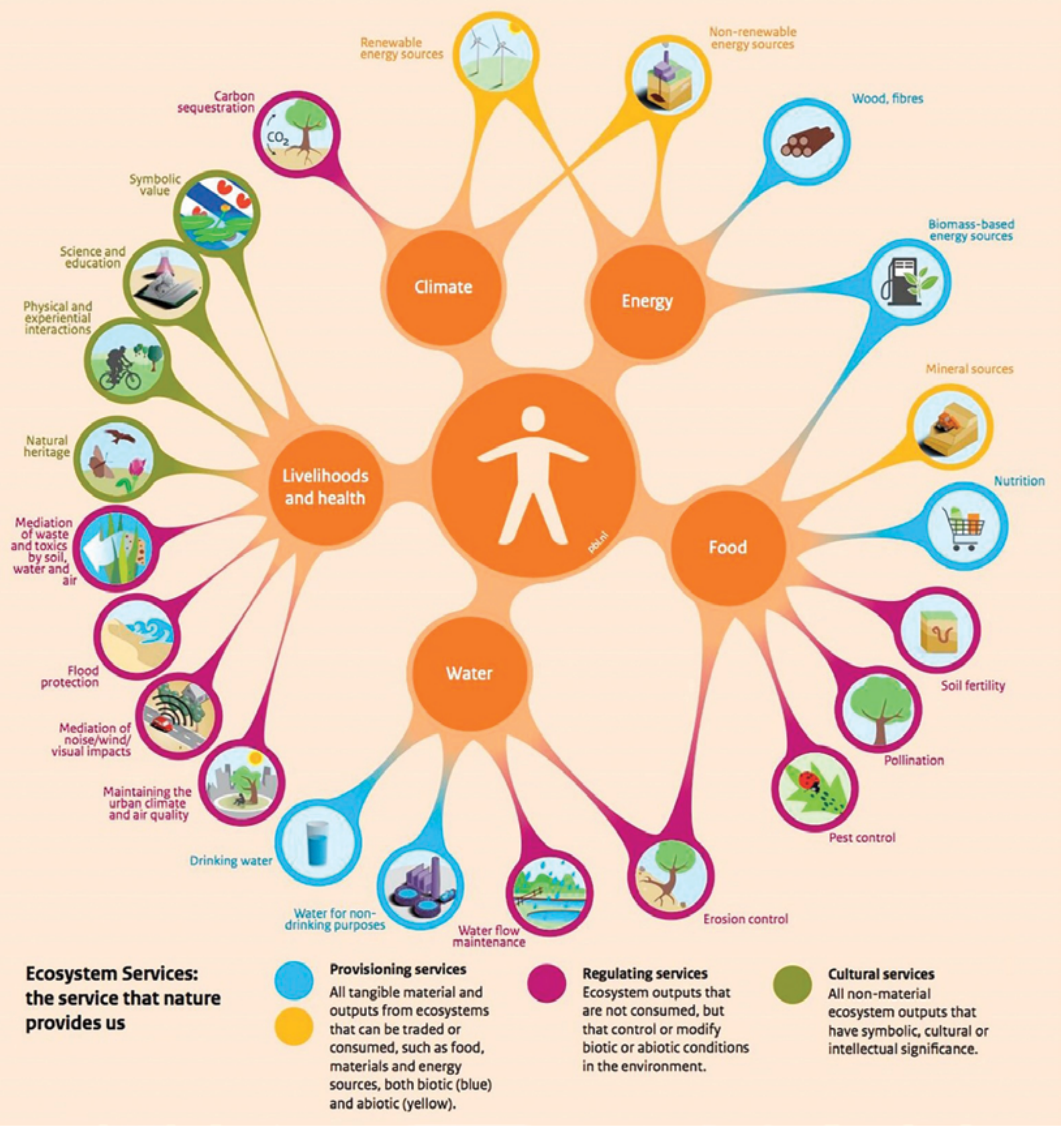
Ecosystem services that are already under threat from the impacts of climate change include pollination, pest, and disease regulation; climate regulation services; and potable water supply (Noble et al. 2014). Trees in urban environments will be increasingly prone to heat stress and attacks by pests, including new nonnative pathogens and pests that can survive under warmer or wetter conditions (Tubby and Webber 2010). In New York City and other coastal communities, remnant coastal wetlands will be lost to sea level rise because bulkheading and intensive coastal development will prevent their natural movement inland (Fagherazzi et al. 2019).

### Adaptation Approaches

Ecosystem-based adaptation in urban areas as part of a climate adaptation strategy is based on a detailed understanding of the ecology of indigenous ecosystems and how biodiversity and ecosystem services can reduce the vulnerability of ecosystems and people.

Strategies to achieve biodiversity goals (e.g., developing corridors for species migration, enlarging core conservation

*Figure 6.5. Ecosystem services (PBL Netherlands Environmental Assessment Agency 2017 ([CC BY 3.0](CC BY 3.0)))*




areas, and identifying areas for improved management to enhance ecological viability) can have significant adaptation co-benefits. Natural systems adaptation looks at how ecosystem restoration and conservation can contribute to food security, urban development, water purification, wastewater treatment, and climate adaptation and mitigation (Roberts et al. 2012).

The growing attention to ecosystem services includes adaptations in urban, suburban, and rural areas that use ecosystem management, conservation, and restoration to provide services and increase resilience to climate extremes. Ecosystem services deliver co-benefits, including purifying water, absorbing runoff for flood control, cleansing air, moderating temperature, and preventing coastal erosion, while helping contribute to food security and carbon sequestration (Foster, Lowe, and Winkelman 2011; Newman 2010; Roberts et al. 2012).

Effective structural green infrastructure and ecosystem services adaptation strategies for a variety of contexts include ecological restoration, wetland and floodplain conservation and restoration, increasing biological diversity, afforestation and reforestation, barrier island conservation and development, wildfire reduction and prescribed burning, urban forest canopy enhancements using shade trees and green roofs, conservation and replanting of mangrove forests, fisheries co-management and controlling overfishing, assisted migration or managed translocation, ecological corridors, ex-situ conservation and seed banks, community-based natural resource management, and adaptive land-use management (Noble et al. 2014).

## FOOD SYSTEMS

Urban areas typically produce very little of their own food, leaving urban residents overwhelmingly reliant on food supplies imported from distant rural areas and transcontinental shipping. Local food supplies are often subject to a range of demographic and economic trends at national, regional, and local scales, including population growth, changes in consumption patterns as income levels rise, competition for agricultural land, and energy and transportation costs. These factors, combined with climate impacts, are likely to strain food supplies, raise food prices, and increase cities' vulnerability to food shortages (World Bank Group 2011).

*Food security* can be defined as having a sufficient quantity and quality of food available in the right place at the right time. *Food access* requires that people have adequate resources and the social right to produce or purchase suitable foods for a healthy diet. Stability of access is achieved when the food supply remains uninterrupted. *Food consumption* concerns the elements or processes surrounding food that allow for healthy consumption patterns.

### Impacts

Climate change is likely to affect global, regional, and local food security by disrupting food availability and decreasing access to food. Areas with limited transportation accessibility risk being cut off from food supplies during heavy storms, inland flooding, or coastal storm surges. Similarly, power outages during storm events may result in widespread spoiling of food supplies. Adapting urban food systems


*Figure 6.6. A wide range of sustainable land management practices can contribute to climate adaptation ([World Wildlife Fund 2020](#))*

represents a major challenge and will necessitate radical changes in food production, transport, storage, and processing, including waste reduction (Godfray et al. 2010).

Climate-related constraints on agricultural production affect urban consumers through reduced supplies and higher prices. Falling production and incomes reduces farmers' demands for urban goods and services. Disruption to urban centers can mean disruption to the markets, services, or remittance flows on which agricultural producers rely (Tacoli 2003). Thus, strengthening urban food security needs to take account of complex rural-urban linkages (Revi 2008) and responses must bridge rural and urban boundaries.

The United States is part of a highly integrated global food system. Climate-driven changes in the United States will influence other nations, and changes elsewhere will influence the United States (Brown et al. 2015). The future may bring larger and more frequent shocks to food supplies and rises in global food prices. The impacts will be serious for the most vulnerable populations, such as impoverished urban residents, who will likely be the first to be affected when food prices rise.

### Adaptation Approaches

Adaptation across all dimensions of the nation's food system will be important to manage climate effects on food security. The technical feasibility of an adaptive intervention is not necessarily a guarantee of its application, however. Adaptation strategies are subject to highly localized conditions and socioeconomic factors, such as affordability and timeliness in its provision of benefits. The accurate identification of agricultural needs and vulnerabilities, and the effective targeting of adaptive practices and technologies across the full scope of the food system, are central to improving national and international food security in the midst of a changing climate (Brown et al. 2015).

The agricultural sector has a strong record of adapting to changing environmental conditions through sustainable land management practices (Figure 6.6, p. 73). There are still many opportunities to bring more advanced methods to low-yield agricultural regions, although water and nutrient availability may be limiting factors in some areas, as is the ability to finance expensive technologies. The Natural Resource Conservation Service (NRCS) has identified at least 32 on-farm conservation practices that are known to improve soil health and sequester carbon while producing important adaptation co-benefits, including increased water retention, hydrological function, biodiversity, and resilience (Carbon Cycle Institute 2021).

Other promising approaches for food system adaptation include innovative packaging and expanded cold storage that lengthens shelf life, improvement and expansion of transportation infrastructure to move food more rapidly to markets, and changes in cooking methods, diets, and purchasing practices (Brown et al. 2015). Effective adaptation measures to ensure urban food security can reduce climate vulnerability, especially for low-income residents in urban areas.

Cities can develop local food governance structures (such as food policy councils), raise awareness, and build partnerships to advance food security. Through partnerships with regional farmers and universities, cities can position themselves as centers of innovation and leaders on food awareness, and they can leverage existing regional networks of institutions focused on agricultural innovation (World Bank Group 2011). Promoting community gardening as a supplementary source of food is a practical means through which to raise public awareness about the complexities of food production, and it can provide local food sources in times of crisis (Mougeot 2006).

## CONCLUSION

As this chapter makes clear, climate change will impact many sectors, including energy, transportation, land use, housing, waste management, the natural environment, and food systems. Planners must understand the impacts of a changing climate on these sectors and become familiar with adaptation responses to create resiliency and maintain the sustainability of their communities. This will prepare them to take action through climate adaptation planning, which is the focus of the next chapter.

CHAPTER 7

# CLIMATE ADAPTATION PLANNING

As described in the previous chapter, climate change will impact cities and societies across all sectors. Adapting to these new conditions will be challenging and will demand strategic and creative thinking from planners and allied disciplines. Planners must use the best resources available, along with inclusive participatory processes, to inform decision-making in ways that protect people and the assets which contribute to and sustain their livelihoods.

Building the adaptive capacity to withstand the shocks and stressors of climate change requires an anticipatory and integrated approach in which the likelihood of events has been forecasted and the resulting climate actions (e.g., policies, programs, and projects) have been mainstreamed through existing municipal and regional plans, strategies, and processes. Planners and professionals from allied fields must continue to build the professional capacity to address these issues (UN-Habitat 2014).

This chapter provides information on approaches that planners can use to help their communities adapt to anticipated climate impacts. It reiterates the reasons why cities must take a proactive approach to climate adaptation, describes fundamental adaptation concepts, and summarizes the principal elements contained within a local climate adaptation planning program.

## ADAPTING TO CLIMATE UNCERTAINTY

As explained in Chapter 3, climate adaptation consists of initiatives and measures to reduce the vulnerability of natural and human systems to actual or expected climate change effects (IPCC 2007). The goal is resilience, or the ability of urban centers (their populations, enterprises, and governments) and the systems on which they depend to anticipate, reduce, accommodate, and recover from the effects of a shock or chronic stressor in a timely and efficient manner. To manage risks and build long-term resilience, a city must understand its exposure and sensitivity to a given set of environmental impacts and develop responsive policies and investments that address these vulnerabilities (World Bank Group 2011).

Urban governments are at the heart of climate adaptation because assessing local climate risks and integrating adaptation strategies into local investments, policies, and regulatory frameworks is necessary to achieve climate-resilient outcomes. But many cities lack the requisite capacity, resources, and funding to do so (Starkman 2017). This underscores the many important roles that planners can play to achieve desired outcomes: synthesizing information from many sources, integrating planning concepts and strategies to achieve multiple benefits, translating often complex concepts and ideas into language that reaches a broader audience to achieve buy-in, implementing structural and nonstructural adaptation strategies, and tracking progress through replicable indicators and metrics.

Climate adaptation is not an end goal. It is the process of preparing for, and adjusting proactively to, a changing climate—the negative impacts as well as the potential opportunities. Effective climate adaptation planning requires assessing vulnerabilities to specific hazards—many of which can interact in ways that amplify outcomes—and formulating potential adaptation actions to build resilience, often while addressing competing or more immediate needs (Starkman 2017). Because cities face differing climate impacts, their adaptation strategies must be location-specific and tailored to address local circumstances.

### Vulnerability

Vulnerability in the context of climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007). It is a function of the character, magnitude, and rate of climate change and variation

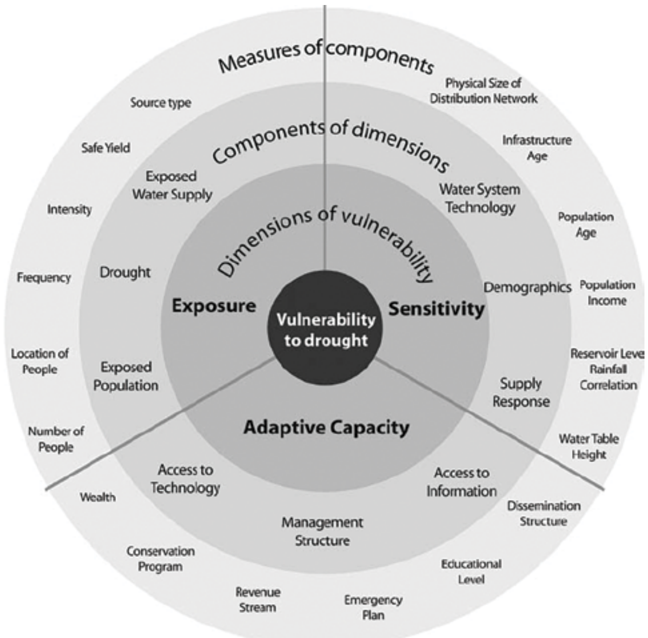



*Figure 7.1. An example of a vulnerability scoping diagram for community water systems exposed to drought (Howe et al. 2014)*

to which a system is exposed, its sensitivity, and its adaptive capacity (Figure 7.1) (CAFE 2017):

- *Exposure* is the amount and rate of change that a species or system experiences from the direct (e.g., temperature, precipitation changes) or indirect (e.g., habitat shifts due to changing vegetation composition) impacts of climate change.
- *Sensitivity* refers to characteristics of a species or system that is dependent on specific environmental conditions, and the degree to which it will likely be affected by climate change (e.g., temperature or hydrological requirements).
- *Adaptive capacity* is the ability of a species or system to cope and persist under changing conditions through local or regional acclimation, dispersal or migration, adaptation (e.g., behavioral shifts), or evolution.

This definition includes people's inability to anticipate a hazard and take measures to avoid it or limit its impact, cope with it, and recover from it. The concept of vulnerability can be applied to multiple sectors, including electricity generation and transmission, transportation, land use, buildings, and materials and waste management, as well as their cross-linkages, including the dependency of perishable commodities such as food production. For example, tourism, a service-oriented sector, is sensitive to climate change, the results of which can damage or destroy key tourist assets such as coral reefs and beaches or make particular locations less attractive to tourists because of dangerous and more extreme weather conditions.

The vulnerability of natural systems and ecosystems (e.g., mangroves, coastal wetlands, a community's urban forest canopy) must also be assessed, as the destruction of these resources can have profound consequences that will only increase the vulnerability of those who live in urban areas. Conversely, by increasing the adaptive capacity of these systems, the impacts of climate change will not be as debilitating, particularly in urban areas.

## Adaptive Capacity

Adaptation depends greatly on *adaptive capacity,* or the ability of an affected system, region, or community to anticipate and respond to change, minimize the consequences, recover, and take advantage of new opportunities (Cinner et al. 2018). Enhancement of adaptive capacity is a necessary condition for reducing vulnerability within states, regions, and socioeconomic groups.

Adaptive capacity is not about simply having the necessary resources at hand; it requires the willingness and capability to convert resources into effective adaptive action. To address climate change, adaptive capacity must span five interlinked domains (Figure 7.2, p. 77) (Cinner et al. 2018):

- *Assets* are the financial, technological, and services-oriented resources that people can draw upon in times of need.
- *Flexibility* reflects opportunities for modifying or switching between adaptation strategies and represents the diversity of potential adaptation options available. The greater the flexibility, the better able an organization is to adapt to climatic impacts.
- *Social organization* has to do with the ways in which society is organized to enable and support cooperation, collective action, and knowledge sharing.
- *Learning* reflects people's capacity to recognize and respond to change, including generating, absorbing, and processing new information about climate change, adaptation options and strategies, and ways to live with and manage uncertainty.
- *Agency* refers to the ability of people—individually or collectively—to make decisions and act in responding to environmental change.

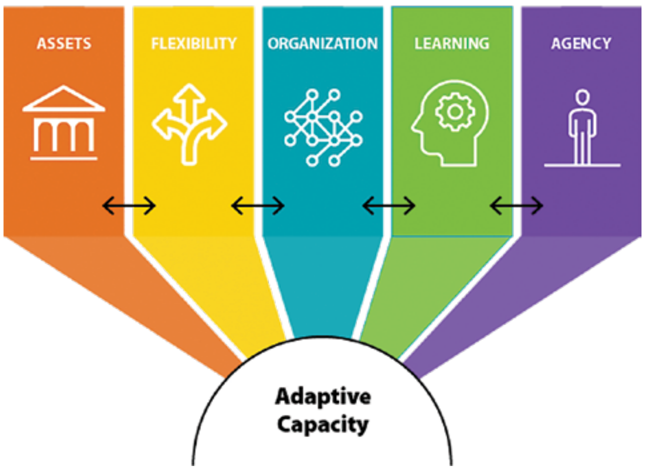



*Figure 7.2. The five domains of adaptive capacity to climate change (from Cinner et al. 2018)*

Activities required for the enhancement of adaptive capacity are consistent with those that promote sustainable development. Sustainable adaptation entails measures that reduce vulnerability and promote long-term resilient outcomes in the face of a changing climate. Building adaptive capacity both strengthens resilience and reduces vulnerability to a wide range of hazards, while addressing the amount, diversity, and distribution of assets and actively facilitating alternative strategies.

The adaptive capacity of a community can be determined by evaluating its socioeconomic and environmental characteristics. Adaptive capacity can be constrained by a lack of resources, poor institutions, and inadequate infrastructure, among other factors.

## Advancing Sustainable Adaptation Strategies

*Sustainable adaptation* can be defined as adaptation that contributes to sustainable development pathways, including social justice and environmental integrity (Eriksen et al. 2011). The road to sustainable adaptation begins with the understanding that adaptation is a process, rather than a prescriptive list of actions and measures that address specific climate impacts.

To pursue sustainable adaptation, it is necessary to address the structural and contextual factors that create vulnerability in the first place. For example, research indicates that vulnerable populations, such as those with low incomes, disempowered racial groups, the elderly, and the physically challenged, are less likely to be prepared for disasters, will suffer more losses as a result, and will have a more difficult path to recovery (Fothergill et al. 1999). While many studies point to the vulnerabilities of low-income and disadvantaged communities, few interventions are designed to reduce those vulnerabilities and improve community and household outcomes in the face of climate duress. Instead, higher-income, high-amenity places typically receive greater attention to the likely impacts of climate change and as a result are the beneficiaries of adaptation investments (Kahn 2010; Martin and Arena 2019).

It is important to identify the synergies between adaptation and sustainable development to ensure that multiple benefits can be derived from adaptation actions. Developing urban adaptation actions that deliver multiple co-benefits can be a powerful, resource-efficient means to address climate change and to realize sustainable development goals.

Not every adaptation strategy is necessarily a good one, however, and it is critical to "get adaptation right" to solve, rather than aggravate, problems of social equity and biodiversity. *Maladaptation* is an outcome of increasing concern to adaptation planners, whereby intervention in one sector could increase vulnerability in another sector or increase the vulnerability or diminish the welfare of a group to future climate change (Noble et al. 2014). It is therefore important to identify the synergies between adaptation and sustainable development to ensure that multiple benefits can be derived from adaptation actions. For example, climate adaptation and social equity goals can be jointly pursued through advancing initiatives that promote the welfare of the poorest members of society through improving food security, facilitating access to safe water and health care, and providing shelter and access to other resources (Smit et al. 2001).

Adaptation actions should be integrated into development policy and planning at every level. This will incur incremental adaptation costs relative to plans that ignore climate change—but inaction will be far more costly than adaptation (Stern 2006). Maladaptation may occur when development policies and measures deliver short-term benefits or economic gains but lead to greater vulnerability in the medium to long term, such as in cases where the construction of "hard" infrastructure reduces the flexibility and range of future adaptation options (Adger et al. 2003). City planning and infrastructure decisions can "lock in" maladaptive urban form, such as sprawl and other unsustainable land-use patterns, for long periods of time, especially when physical investments have extended life spans (World Bank 2011).

### ADAPTATION PRINCIPLES

Planners should use the following 10 principles to ensure adaptation actions result in beneficial outcomes for communities (Vogel et al. 2016):

1. Go beyond climate variability and extreme events; address the anticipated impacts of climate change.
2. Incorporate climate change systematically in relevant decision-making processes (mainstreaming).
3. Design decision processes to adjust over time in response to changing climate conditions (adaptation pathways).
4. Avoid measures that result in an increase in vulnerability to changing climate risks.
5. Consider the implications of an adaptation action over both the near and long terms to ensure an action is effective over time.
6. Avoid adaptations that shift vulnerability from one sector or community to other locations, sectors, or natural systems unless there are clear net benefits and compensations.
7. Ensure that the needs of more vulnerable populations are addressed.
8. Consistently build adaptive capacity across populations within a community, particularly the most vulnerable.
9. Engage in monitoring and evaluation of climate adaptation progress.
10. Ensure that climate adaptation and mitigation actions are consistent with, integrated, and supportive of each other.

Any action is maladaptive that:

- Increases emissions of GHGs
- Disproportionately burdens the most vulnerable
- Has high opportunity costs
- Reduces incentives to adapt
- Creates path dependency

An example of maladaptation would be the construction of a climate-resilient network of roads engineered and designed to withstand current and future climate extremes to enable new settlement into coastal areas highly exposed to future climate impacts. The question remains whether the immediate benefits to the community of a reliable road system (providing an evacuation route from hurricanes and resulting tidal surges) outweigh the longer-term risks associated with inappropriate settlement patterns and the potential consequences (Lamhauge et al. 2011).

Planners should develop and use criteria to screen adaptation decisions for their potential detrimental impacts. The sidebar on this page offers principles that adaptation actions should align with to reduce the potential for maladaptation.

## CLIMATE ADAPTATION PLANNING

The objective of a climate adaptation program is to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience. This can be accomplished through integrating climate adaptation practices into relevant development planning policies, processes, and strategies within multiple sectors (UNFCCC 2022). The intention is to limit the cost of climate change and help build more resilient communities (Woodruff 2019).

Adaptation planning is an iterative process that consists of a series of stages, with each stage building off the previous stage. The five principal stages are (1) awareness, (2) assessment, (3) planning, (4) implementation, and (5) monitoring and evaluation. The process is iterative because adaptation requires continuing risk evaluation and management; it does not have an end point, as communities are never fully resilient in the face of a continually changing climate. Even as they take steps to build resilience and reduce risk, communities may need to return to previous steps repeatedly to consider new hazards and changing vulnerabilities (U.S. Climate Resilience Toolkit 2021).

Adaptation planning is accomplished by working with agency officials, stakeholders, technical experts, and the broader public to identify and assess risk and vulnerability, and then recommending, designing, and analyzing measurable adaptation actions that will achieve preferred outcomes while simultaneously considering other important opportunities and tradeoffs (CCS 2011). In some cases, communities may defend themselves against climate's effects with major new infrastructure and land-use planning. Other communities may deploy more nuanced combinations of programs, policies, and services, from community emergency networks to alternative housing and transportation solutions. A few communities may relocate en masse away from areas vulnerable to the riskiest climate effects. In all cases, people should exercise meaningful power over decisions about where, how, and how much to adapt to local climate effects.

Regardless of the combination of physical and social interventions communities adopt, inclusion and equity must be fundamental to both the process of selection and the outcomes of the options selected (Martin and Arena 2019). As previously discussed, disenfranchised and marginalized communities typically have the least access to information sources and lack the capacity to participate in climate preparation and planning. Moreover, while it is rarely intentional, these groups are typically excluded from adaptation planning and decision-making processes. They are therefore more likely to suffer greater losses from climate change and have a more difficult path to recovery afterwards.

## Awareness: Identifying Assets and Risks

The adaptation process begins once a community or organization becomes aware of a changing climate as either a threat or an opportunity, and, consequently, recognizes the need to adapt. Developing an awareness of the magnitude of the problem helps to identify which adaptation options may provide the most effective solutions to reducing exposure and vulnerability and building resilience (PRAC 2022).

Adaptation is a complex, cross-sectoral, multi-issue and multilevel decision-making area. This initial awareness stage builds the foundation for a successful adaptation process and includes the following steps (Climate ADAPT 2022):

- Obtaining and assuring a high level of political support to give prominence to the adaptation process
- Establishing a core team with an explicit mandate for the management of the process
- Identifying stakeholders and liaising with all relevant administrative bodies that will need to be involved in the adaptation process, from both within a city and the surrounding areas upon which a city is dependent, which requires a coherent approach to the rural-urban interface and coordination with neighboring municipalities
- Setting up adequate coordination mechanisms, clarifying roles and responsibilities, and ensuring that a continuous communication process is put in place for the engagement of different target audiences
- Identifying readily available information, including existing work on actual and potential future climate-related effects, ongoing adaptation activities, and examples of best practices within or outside the city
- Defining objectives and scope based on identified climate variables
- Identifying and obtaining human and technical resources required, based on the level of exposure and vulnerability of the urban area to climate risks, the size of its population, the assets under threat, the range of sensitive sectors, and the existing institutional setup
- Identifying and obtaining adequate and sustained financing and funding for ongoing planning, implementation of adaptation projects, and monitoring and evaluation of project outcomes

## Assessment: Vulnerabilities

An essential step in climate adaptation planning is to determine the areas that will receive priority focus when considering and developing adaptation policies. To identify priority areas, planners should consider vulnerability factors specific to particular impacts, including risk level and type, consequence, scope and range, and frequency (CCS 2011).

Whereas risk assessments focus primarily on the projected changes in climatic conditions, inventory of potentially impacted assets, the likelihood of the impact happening, and the resulting consequences, vulnerability assessments are focused on identifying the degree of exposure, sensitivity, and the adaptive capacity of systems, assets, and populations. Integrated risk and vulnerability assessments address both the vulnerability to and the impacts of current and future climatic hazards to existing social networks and ecological and urban systems and assets (Climate ADAPT 2022).

Because no planning effort can give equal and adequate treatment to all possible consequences of climate change, identifying the priorities for consideration is a fundamental early part of the adaptation planning process (CCS 2011). Climate change vulnerability assessments (CCVAs) are emerging tools that can be used as an initial step.

From an ecological systems perspective, a CCVA may focus on species, habitats, or systems of interest, and helps identify the greatest risks to them from climate impacts. It identifies factors that contribute to vulnerability, which can include both the direct and indirect effects of climate change, as well as non-climate stressors (e.g., land-use change, habitat fragmentation, pollution, and invasive species). A CCVA combines this background information with climate projections to identify the specific elements of exposure, sensitivity, and adaptive capacity that contribute to the overall vulnerability of a particular species or system (Figure 7.3) (Glick et al. 2011). From an urban systems perspective, CCVAs should begin with learning more about the extreme weather events that have occurred in the past, to help municipalities better understand the risks they face currently and how their city might be affected by climate impacts in the longer term when the present risks are intensified.

Additional elements of CCVAs focused on urban environments include the following (Climate ADAPT 2022; DeAngelis et al. 2019):

- Identifying urban sectors that are likely to be more affected due to their higher vulnerability or lower capacity to adapt. The ability of a given sector to adapt to and cope with climate impacts may be a function of wealth, technology, information, skills, infrastructure, institutions, equity, empowerment, and the ability to spread risk. Potentially vulnerable urban sectors and fields of activity include public health, social well-being, buildings, energy, transportation, infrastructure, industry, and information and communication technologies.
- Projecting trends for climate variables (e.g., average and extreme temperature, number of days with extreme heat, intensive rainfall events, snow cover, etc.), ideally based on a range of different climate scenarios
- Determining expected direct and indirect impacts (threats and opportunities) by identifying the most relevant hazards as well as the areas of the city that are at most risk given an overlay of the spatial distribution of the total population, vulnerable populations (e.g., low-income, elderly), economic activities and economic values, and concentrations of infrastructure
- Understanding the vulnerabilities of surrounding areas upon which the city is dependent for water supply, agricultural food production, energy production, and other services
- Establishing a timeframe, such as short, medium (e.g., 2050s) or long-term (e.g., end of century)
- Indicating the level of confidence (e.g., high, medium, low) for such impacts, with a view of facilitating the decision-making process given the degree of uncertainty attached to the results

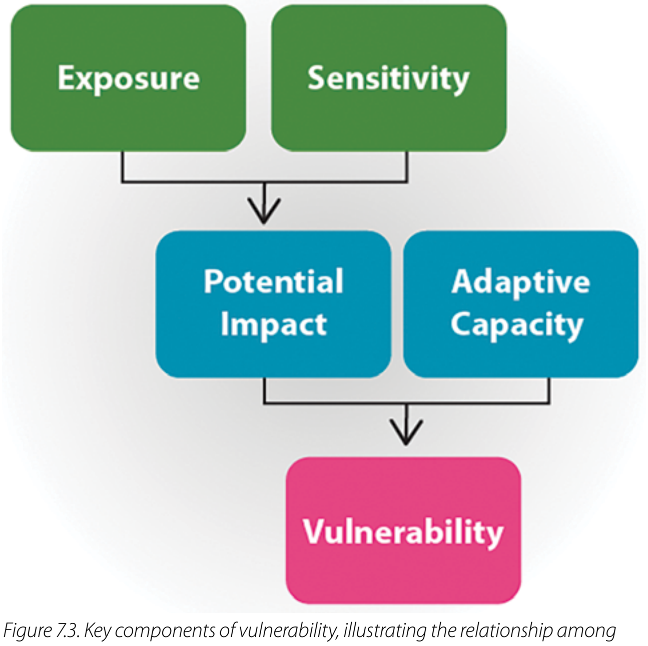



*Figure 7.3. Key components of vulnerability, illustrating the relationship among exposure, sensitivity, and adaptive capacity (from Glick et al. 2011)*

The sidebar on p. 82 presents a list of criteria planners can use to characterize and rank vulnerability.

## Planning Adaptation Options

A climate adaptation plan should demonstrate how a city will deliver on its commitment to reduce the impacts of climate change through building community resilience.

While a climate action plan focuses on developing a framework for measuring and reducing greenhouse gas (GHG) emissions and related climatic impacts, as summarized in Chapter 5, the climate adaptation plan anticipates future climate impacts and plans for structural and nonstructural interventions to reduce vulnerability and increase adaptive capacity to those impacts. That said, a climate adaptation plan should build upon the work of a climate action plan, because the act of intentionally reducing GHG emissions (mitigation) is an essential step in the process of adapting to a continually changing climate: the more that emissions can be reduced and eliminated right now, the easier it will be to adapt to the changes that can no longer be avoided.

A climate adaptation plan should accomplish the following objectives (C40 Cities 2020):

## RANKING VULNERABILITY

Several criteria may be used to assess and rank vulnerability (World Bank Group 2011; CCS 2011; IPCC 2007; IPCC 2014), including the following:

- **Degree of sensitivity.** Susceptibility to harm and lack of capacity to cope and adapt.
- **Importance of a vulnerable system or affected resource.** A subjective judgment of the inherent priority, importance, or value of the vulnerable system or asset.
- **Certainty of impact.** The level and confidence of the impact occurring, or the assessment that any statement about an outcome will prove correct. The likelihood of some impacts occurring are more certain than others (e.g., a rise in sea level, which is certain, versus a particular change in precipitation, which will be less certain).
- **Timing of impact.** How soon an impact will be observable or significant, including the expected date range (for example, decade, year, or season), and rate at which the impact is likely to take place. Some significant climate impacts may already be happening or may become significant within years or a few decades, while others may take many decades to become significant.
- **Severity of impact.** The extent of impact on a sensitive resource, including degree of magnitude and scale (e.g., the geographic area or number of people affected) and intensity (e.g., the degree of damage caused).
- **Capacity for autonomous adaptation.** The degree to which an affected resource can respond and adapt to climate change. Some sectors or structures have a relatively high degree of adaptive capacity, while others have less.
- **Persistence and reversibility of impact.** The assessment as to whether the impact is expected to continue over a long period of time, and whether it can be reversed.
- **Potential for adaptation.** The assessment of activities which can be undertaken to lessen the projected harm, and the degree of intervention required.
- **Distribution.** The spread of climate impacts across regions, demographic categories (e.g., income, gender, or age), and sectors.

- Demonstrate how the city will adapt and improve its resilience to the climate hazards that may impact the city now and in future climate scenarios
- Engage with the community to inform the plan; outline the social, environmental, and economic benefits expected from implementing the plan; and establish ways to ensure equitable distribution of these benefits to the city's population
- Detail the city's governance, powers, and capacity, and identify the partners that will need to be engaged to accelerate the delivery of the city's adaptation targets and resilience goals
- Consider adaptation and mitigation in an integrated way, identifying interdependencies to maximize efficiencies and minimize investment risk
- Set an evidence-based, inclusive, and deliverable plan for achieving transformational mitigation and adaptation, centered on an understanding of the city's powers and wider context
- Establish a transparent process to monitor delivery, communicate progress, and update climate action planning in line with governance and reporting systems

As hubs of human activities, urban areas can be impacted by several consequential climate hazards simultaneously. Therefore, adaptation measures need to cover a broad range of issues, including technological, informational, organizational, behavioral, ecosystem-based, and socioeconomic, at various governance and sectoral levels. Developing a catalog of implementable measures (e.g., policies and actions that can address the previously identified climate challenges), and preparing a detailed plan of action, which lays out how, when, and by whom specific adaptation measures should be implemented, is crucial to achieving adaptation on the ground.

During the development of a climate adaptation plan, potential adaptation options can be prioritized through the application of vulnerability ranking criteria to be implemented over various timeframes. Adaptation options can range from actions that build adaptive capacity (e.g., knowledge creation and information sharing, creating a more supportive institutional framework) or establish management systems and supportive mechanisms (e.g., better land management planning, insurance mechanisms), to adaptation actions implemented on the ground, such as gray (traditional infrastructure) or green (ecosystem services-based) measures (Climate ADAPT 2022). Chapter 6 describes a wide range of adaptation actions across the major urban sectors.

In determining the most appropriate types of policies and actions for a community's adaptation plan, planners and decision makers can draw from three types of approaches, all of which rely upon inclusive and representative public engagement, participation, and well-informed decision-making at the local level (Martin and Arena 2019). The first approach focuses on addressing the earliest physical disruptions from climate change through incrementally extending existing tools, policies, and mechanisms, such as expanding insurance, using existing financing mechanisms (e.g., Community Development Block Grant disaster recovery funding) to pay for structural adaptation solutions, and improving infrastructure and emergency preparedness. Anticipating increasingly severe climate impacts, the second approach involves more proactive rethinking and reformulating of land use, building techniques, property rights, and related governance changes to adapt more comprehensively to climate change. And finally, as the effects of climate change become more costly and untenable, the third approach involves the decisions and actions communities must make to relocate to safer ground (Martin and Arena 2019). Strategies from each of these approaches can be important elements of a local adaptation plan.

#### Adaptation Pathways: Monitoring the Planning Process

Developing adaptation plans can help guide decision makers in communities and governments who are responsible for planning for an uncertain future. Adaptation to the impacts of climate change is at once both a critical long-term need and a short-term imperative, so the most effective adaptation efforts must address both a community's current situation and the changes it will likely face over time.

The concept of *adaptation pathways* describes sets of analytical approaches and sequences of policy actions or investments in institutions and infrastructure that can be deployed over time to achieve specified objectives under uncertain changing conditions. Local governments can use this approach to support the development of more agile and nimble plans that can better deal with conditions of deep uncertainty, recognizing that the social and economic contexts for adaptation will inevitably change over time and today's solutions might not be the best solutions for tomorrow (Kay et al. 2021).

The adaptation pathways process establishes a series of interlinked pathways in which "signals" of change alert the decision maker of a pending "trigger" (time when a decision should be made) to switch pathways. The trigger must provide sufficient lead time to adapt before the "adaptation threshold" is reached. The need to change pathways may be delayed if a climate-related event occurs more slowly than anticipated, or it may come earlier if the climate event is more rapid than expected—emphasizing the crucial role of monitoring and reviewing triggers (Stephens, Bell, and Lawrence 2018).

An adaptation threshold (or adaptation tipping point) occurs when the present pathway is no longer effective in meeting objectives and a new action or pathway is necessary. Adaptation thresholds are based on performance; for example, when storm-tide flooding becomes too frequent for a viable community to function, or when beach nourishment or a sea wall is no longer providing effective protection from coastal erosion. They also relate to the coping capacity of people as service levels change and losses and harm occurs. Adaptation thresholds are often framed in terms of extreme events that cause social disruption, but they can be identified through community engagement and detailed modelling and risk assessments ahead of such events (Stephens, Bell, and Lawrence 2018).

The pathways approach promotes adaptive management of the adaptation plan—it enables adaptation planning to be ongoing by incorporating flexibility and adaptability into the decision-making process. Not all decisions must be made immediately and options can remain on the table. This prevents decisions being made now that lock decision makers out of other options in the future. Other advantages of the adaptation pathways approach include the following (CoastAdapt 2017; Kay et al. 2021):

- **Buys time** to plan and reduces the pressure of making decisions now. An ongoing process of monitoring and evaluation identifies the trigger points at which future decisions or actions will need to be undertaken
- **Reduces uncertainty** by using events, not time, as the triggers for decision points
- **Ensures flexibility** when considering political uncertainty alongside other societal, economic, environmental, and technological changes, as well as early warnings that signal when decision makers may want to switch to another pathway, allowing decisions to be tailored to local conditions
- **Provides cost effectiveness** through assessing various strategies over time, thus enabling practitioners to spread or defer large capital costs for future projects over time and allowing efficient planning and funding of projects
- **Allows for learning** from the outcomes of past decision-making and incorporation of that learning into future decision-making to build a better understanding of managing future risks

- **Provides transparency** in decision-making because triggers and thresholds are set ahead of time, allowing for transparent integration of climate adaptation considerations into existing decision-making processes, which can support implementation

Given the level of uncertainty as to the degree and magnitude of climate impacts and the resources that will be required to achieve resilient outcomes, this approach supports strategic, flexible, and structured decision-making and allows decision makers to plan for, prioritize, and stagger investment in adaptation options. Trigger points and thresholds help identify when to revisit decisions or actions.

The pathways approach is about keeping options open and avoiding path dependency. It can reduce unnecessary expenditure, preventing organizations from being locked into actions that may not be the best solutions for what is a long-term problem. While not all decisions can be made now, they can be planned, prioritized, and prepared for (CoastAdapt 2017).

## Implementation

Implementation involves taking concrete actions to reduce vulnerability (risk or exposure) to climate change. Adopting an adaptation plan is an important step. The pathway from planning to taking action, however, can present significant obstacles for many communities.

Barriers to implementing adaptation actions may include lack of funding, staff resources, or the capacity to take on adaptation activities; uncertainty about projected climatic impacts and the lingering political blowback stemming from disbelief in climate change, which can result in organizational or institutional inertia; concerns about lost property tax revenue resulting from limiting development in vulnerable areas; and limited ability to monitor and measure the effectiveness of adaptation responses in the short and long terms (Mills-Knapp, Scott, and Rose 2019).

When implementing adaptation actions to reduce climate vulnerability, communities may want to consider employing several tactical approaches, including integrating adaptation actions into existing processes, regulations, and mechanisms, such as hazard mitigation plans, special area plans, or comprehensive plans; focusing on actions that may achieve multiple community and sustainable development co-benefits; engaging in small actions that appeal to specific local audiences; and engaging dedicated technical staff who can devote the necessary time and resources to implementing adaptation actions (Vogel et al. 2016).

The implementation action plan accompanying the adaptation plan sets out what needs to be done to turn the prioritized adaptation options into actions. At minimum, an implementation action plan contains the following elements (Climate ADAPT 2022):

- Details of each action and initiative (and subactions, if applicable) and associated processes and synergies
- Roles and responsibilities in coordinating and undertaking actions
- Timeframe for implementation
- Estimation of human and financial resources needed and available funding schemes
- Information needs, open research questions, and ways to close knowledge gaps
- Indicators of success for monitoring and evaluation

Planners can review several conventional planning documents to identify options and strategies for integrating urban adaptation. These may include zoning regulations, existing and future land-use plans, development guidelines, covenants, codes, and restrictions (CCRs), district planning manuals, building codes, urban development plans, sustainable development strategies and plans, disaster risk management and emergency response plans, and other specific sectoral strategies and plans.

From a risk management perspective, a useful approach may be to not focus on climate change per se but rather on improving preparedness, robustness of decision-making, and cross-sectoral resilience. Risk management approaches will help target specific strategies to the most urgent, affordable, or highest net-benefit activities.

Mainstreaming adaptation action into municipal and sectoral budgets is essential, particularly with respect to acquiring and prioritizing resources by way of fiscal impact analyses and capital improvement programming. Moreover, mainstreaming adaptation into governance will enable implementation over time within existing budgets and by balancing incremental costs with the economic, environmental, and social values produced (Climate ADAPT 2022).

### Integrating Mitigation and Adaptation

Mitigation of the impacts of climate change through reduction of GHG emissions and adaptation to the risks posed by climate change represent two complementary approaches to addressing climate change that must be integrated to successfully achieve their respective aims. As with sustainable development goals, various adaptation measures can contribute to the achievement of mitigation goals and vice versa, thus maximizing the potential co-benefits.

To align mitigation and adaptation decision-making, it is highly recommended that stakeholders representing mitigation planning and implementation are involved in the adaptation planning and implementation cycle for continuous feedback and cross-checking, while considering the following questions (Climate ADAPT 2022):

- **Do adaptation actions impact mitigation objectives?** For example, some adaptation measures may require increased energy use; choosing to use energy from renewable sources will enable fewer negative tradeoffs with mitigation.
- **Do mitigation actions impact adaptation objectives?** For example, afforestation aimed at increasing carbon sequestration as a mitigation measure in an arid region might cause higher demand for limited and diminishing water resources, therefore limiting adaptation potential. Competition for land resources might also arise between mitigation and adaptation measures. Integrated planning is therefore highly recommended for the identification of the most beneficial combination of mitigation and adaptation measures.
- **Are there other processes that impact both mitigation and adaptation actions?** These could be processes in various policy and decision-making areas that have the potential to indirectly impact both mitigation and adaptation, e.g., land-use and urban spatial planning, water resources planning, disaster risk management, strategic development planning, capital improvement programming, infrastructure projects, or health and social policies. Mainstreaming mitigation and adaptation considerations in all relevant decision-making areas is essential to ensure coherence between the various strategic aims.

In all cases where decisions are made that will have direct impacts on both adaptation and mitigation, it is highly recommended that processes are set up to anticipate and explicitly address their interactions. The main urban sectors with the most synergies between adaptation and mitigation are spatial planning, energy production and consumption, and the construction and operation of buildings.

Because of the synergies that may accrue as co-benefits of mitigation and adaptation, many communities are now developing climate action and adaptation plans (CAAPs). The goal of a CAAP is to appropriately address these interconnections, including the need for mitigation to be considered when identifying, assessing, and selecting adaptation options, and for adaptation to be addressed in mitigation efforts to achieve GHG emissions reduction goals (Climate ADAPT 2022).

To meet a community's climate goals, a CAAP typically includes three types of initiatives (Watsonville 2022):

- **Climate mitigation actions** taken to reduce GHG emissions, such as transitioning to low-carbon energy sources like solar or wind energy
- **Climate adaptation strategies,** which focus on preparing for climate impacts such as increased droughts, wildfires, and flooding
- **Climate restoration,** which consists of goals and actions that draw excess carbon out of the atmosphere and help restore balance to ecological systems, such as tree planting and regenerative agricultural practices. Restoring natural systems facilitates the removal of carbon dioxide from the air, supports clean water and healthy soils, and acknowledges that humans are part of a global ecosystem that must be sustained for the survival of humans and many other forms of life.

## Evaluation and Monitoring

Measuring and evaluating the effectiveness of adaptation actions and related assumptions and uncertainties provides the feedback necessary for improved management (PRAC 2022). As stressed throughout this chapter, adaptation is not a one-time effort but an ongoing cycle of preparation, response, and revision. It is a dynamic process that should be revised over time based on new information. Those cities that can integrate adaptation policies and strategies with a broad spectrum of existing planning processes and goals, including priorities in disaster risk reduction, sustainable development, and poverty reduction, will be best positioned to thrive in this new era of climate change. Underpinning the strongest adaptation processes will be leadership and commitment to measuring progress, assessing effectiveness, and refining the process as appropriate along the way.

Establishing a clear set of indicators and metrics through which to measure progress is essential to ensuring that cities invest often-scarce resources in ways that achieve maximum co-benefits while avoiding unintended consequences.

Measurement, reporting, and verification has become an increasing priority for practitioners, policy makers, and development partners who need to know whether their climate adaptation activities are having the desired effects.

## TABLE 7.1. CLIMATE ADAPTATION METRICS

| Category | Examples of Metrics |
| --- | --- |
| **Climatic Condition** | Change in annual temperature |
| | Mean monthly temperature |
| | Number of hot days |
| | Change in annual precipitation |
| | Monthly precipitation |
| | Extreme precipitation events |
| **Impacts of Climate Variability and Change on Socioecological Systems** | Human deaths and injuries from extreme weather |
| | Number of people permanently or temporarily displaced due to flooding, drought, or sea level rise |
| | Number of properties lost due to coastal erosion per year |
| | Number of buildings damaged or destroyed by extreme weather events |
| | Total length of water and wastewater trunk lines at risk from climate hazards |
| | Percentage of total livestock killed by drought |
| | Percentage of ecosystem area that has been disturbed or damaged |
| | Total forest area impacted by wildfire per year |
| | Urban heat island effect in summer |
| | Financial losses to businesses due to extreme weather events |
| **Implementation of Adaptation Strategies** | Number of properties with retrofitted flood resilience measures, water meters, water efficiency measures, or cooling measures |
| | Number of water efficiency measures used in energy generation or extraction |
| | Number of climate-resilient trees planted |
| | Percentage of agricultural land with improved irrigation |
| | Number of businesses with insurance for extreme weather events |
| | Percentage of companies assessing risks and opportunities from extreme weather and reduced water availability to their supply chains |
| | Percentage of coastline under marine protection |
| | Number of firebreaks constructed |
| | Energy storage capacity |
| **Outcomes of Adaptation Strategies** | Percentage of climate-resilient roads in the jurisdiction |
| | Number of new major infrastructure projects located in areas at risk |
| | Percentage of water demand being met by existing supply |
| | Number of cubic yards of water conserved |
| | Reduction of flood damage and disaster relief costs in cities due to increased standards for flood protection and improved flood emergency preparedness |
| | Percentage of farmland covered by crop insurance |

*Source: Hammill et al. 2014*

Demonstrating that an adaptation action or suite of actions has minimized vulnerability, reduced risk, and increased adaptive capacity helps to inform future decisions, satisfies taxpayers and external funders, and ensures future stakeholder and constituent buy-in to climate adaptation policies in the future (World Bank Group 2011).

*Adaptation metrics* are defined as a system of measurement for the selection and evaluation of adaptation strategies. Metrics provide a way to compare the effectiveness of options, including cost, and can be used to help establish priorities among adaptation options (CCS 2011). Metrics can be used to measure and track the process of implementing adaptive actions, such as spending on coastal protection, acres of reforestation, or linear miles of elevated roads. Metrics are also needed to measure the effectiveness (outcomes) of adaptation through monitoring and evaluation. This may be difficult to identify, however, as adaption outcomes take time to become identifiable and are often subject to evolving conditions and objectives (Noble et al. 2014). The challenges of monitoring and evaluating adaptation outcomes is further discussed in the sidebar on p. 88.

Metrics for measuring and monitoring success in adaptation can address climate parameters, climate impacts, climate actions, and adaptation results (Hammill et al. 2014). Table 7.1 (p. 86) provides a list of potential metrics.

One framework for tracking adaptation combines the establishment of "upstream" metrics to assess how well risks are being managed by institutions, and "downstream" metrics to track whether the interventions are reducing the vulnerability of affected groups. The upstream metrics focus on assessments of institutional capacity, managerial performance, and integration of climate risk management into planning processes and tracking and feedback processes, while the downstream metrics focus on indicators to track development performance and changes in vulnerability (Brooks et al. 2011).

## CONCLUSION

Adaptation planning will require broad partnerships that include other governments, local communities, nonprofit organizations, academic institutions, and the private sector. The skills and partnerships needed to respond to climate change are the same needed to provide improved quality of life, including better city management, basic service delivery, equity, and good local governance with robust ties across all levels of government.

Although both climate mitigation and adaptation policies will require high levels of investment, it is clear that the costs will be even higher the longer the decision to act is delayed. This is particularly true in rapidly growing urban areas. A decision now to change building codes and practices, to enact policies for increased densities and more compact urban form, and to build efficient public transit systems can save enormously in future energy costs (especially as energy costs are likely to increase faster than the general cost of living increases) while preserving resources and sensitive landscapes. Prompt action can also promote the development of more pleasant cities within which to live, work, and recreate, and more inclusive, better informed, and participatory societies (World Bank Group 2010).

There is a significant transformation underway in the global community's understanding of the costs and benefits associated with investing in climate mitigation and adaptation (Rappaport 2019). A recent report on the economics of climate adaptation found that the overall rate of return on investments in improved resilience is very high, with benefit-cost ratios ranging from 2:1 to 10:1 and in some cases even higher. The report indicates that investing $1.8 trillion globally in five areas (early warning systems, climate-resilient infrastructure, dryland agriculture crop production, global mangrove protection, and water resource resiliency) from 2020 to 2030 could generate $7.1 trillion in total net benefits (Global Commission on Adaptation 2019). Prevention of damages through climate adaptation can deliver a "triple dividend" for greater sustainability that avoids future losses, generates positive economic gains through innovation, and delivers additional social and environmental benefits (Dutch Water Sector 2019). Better awareness of and evidence for all three dividends will make the case for adaptation ever stronger.

Though a multisectoral approach is necessary to effectively address the future impacts of climate change, planners are perhaps best equipped to provide the requisite leadership and ability to influence public policy regarding the built environment. Planners are experts in guiding communities through developing strategies and policies that will improve the vitality, livability, and attractiveness of a community to residents and businesses alike. Planners can act to adjust the trajectory of growth and development and in doing so create more sustainable and resilient communities. Several local planning practices, such as comprehensive planning, hazards mitigation planning, and transportation planning, are a natural fit for enhancing community resilience through strategies and policies that

## MEASURING ADAPTATION

Monitoring and evaluating adaptation can be challenging for the following reasons (CAP and ICLEI 2015):

- **Adaptation is not an objective or an endpoint.** Adaptation is a process of continual adjustment, and there is no clear measure or benchmark that signals that an adaptation measure is "successful." Often adaptation evaluation relies on proxy measures that relate to the achievement of broader societal and environmental aims.
- **Uncertainty is inherent in virtually all monitoring and evaluation processes**. With many climate trends not yet clear, planners need to plan for a range of possible scenarios. For example, uncertainty regarding the rate and extent of sea level rise is critical to adaptation planners in coastal areas, but equally uncertain are issues of population growth and aging infrastructure.
- **Adaptation is evaluated by measuring avoided impacts**. Adaptation efforts are designed to reduce adverse impacts of climate change. In the absence of that impact taking place, it can be challenging to measure how much worse the situation would have been without the intervention.
- **Evaluating adaptation entails tracking towards a "moving target."** In monitoring climate change, natural and socioecological systems undergo continuous change over time and so the use of a fixed baseline may lose some validity. With this consistent variability, baseline data may not always provide a solid reference point.
- **Adaptation requires long time horizons.** Because adaptation activities tend to have long time frames and unclear endpoints that are liable to change over time, it can be difficult to measure them within traditional five-year government planning cycles or political mandates.
- **Adaptation spans multiple scales and sectors.** Adaptation encompasses diverse programming strategies, populations, and locales. While it is predominantly a local process, progress towards it is often examined at much higher levels, and often at a sector scale. It can be very difficult to compare or aggregate results in an effective way because of the eclectic range of sectors, the varying availability of data, and different site contexts.
- **There is no one set of indicators or monitoring and evaluation approaches.** As adaptation is a process rather than an outcome, individual indicators for climate adaptation may not necessarily exist as "good" climate adaptation indicators. In addition, as adaptation cuts across contexts, scales, and sectors, no universal set of indicators will fit these divergent contexts.
- **Assessing the effectiveness and adequacy of adaptation is both complex and challenging.** It demands a practical, replicable approach that provides meaningful, quantifiable information. Recognizing that building resilience is a moving goal in a changing climate, measuring adaptation effectiveness should also be flexible and adaptable to a wide range of contexts and be able to catalyze learning at a variety of spatial and temporal scales (Craft and Fisher 2016).

consider future climate (APA Washington Chapter 2015). The next two chapters describe how planners are helping communities across the country put climate mitigation and adaptation approaches into practice.

CHAPTER 8

# CASE STUDIES IN CLIMATE MITIGATION

This chapter offers a series of case studies of climate mitigation action from communities across the United States, as shown in Figure 8.1 and summarized in Table 8.1 (p. 91). The case studies reflect various types of jurisdictions or entities, scales, and locations, and are ordered by jurisdiction population size, large to small. Key climate mitigation planning documents and resources are linked for each case study.

These case studies predominantly focus on climate mitigation actions to reduce greenhouse gas (GHG) emissions. Chapter 9 offers case studies related to climate adaptation action. As will be apparent, however, climate mitigation and adaptation actions can and do overlap. The intent is to provide recommended practice examples that planners can learn from to take action in their communities.


*Figure 8.1. Climate mitigation case study communities*

**TABLE 8.1. CLIMATE CHANGE MITIGATION CASE STUDIES**

| Project | Entity | Scale | Region | Climate Issues |
|---|---|---|---|---|
| Colorado Climate Action | State of Colorado | State | Mountain West | Decreasing snowpack, earlier snowmelt, persistent drought and water supply issues; increase in megafires and post-fire flood and landslide risks |
| Las Vegas 2050 Master Plan | City of Las Vegas, Nevada | Large city | Arid West | Increasing temperatures, extreme risk for drought, and associated impacts to water supply |
| Jefferson County Partners in Energy Program | Jefferson County Sustainability Commission, Colorado | County | Mountain | Increasing temperatures, increased wildfire risk and longer fire seasons, decreased snowpack, and infrastructure failure |
| Des Moines Climate Action | City of Des Moines, Iowa | Mid-sized city | Plains | Extreme flooding, torrential rain, droughts, derechos, polar vortexes, heat waves, fewer cooling nights |
| Chapel Hill Climate Action and Response Plan | Town of Chapel Hill, North Carolina | Mid-sized city | East Coast | Heavy rain events, more intense hurricanes, coastal and inland flooding, higher and more variable temperatures, increasing drought frequency and duration |
| West Hollywood Climate Action Plan Update | City of West Hollywood, California | Small city | West Coast; coastal | Extreme heat, droughts, flash flood events |
| Whitefish Climate Action Plan | City of Whitefish, Montana | Small city | Mountain Plains | Decreasing snowmelt, wildland-urban interface issues, hotter and drier summers, increasing wildfires and smoke, post-wildfire impacts on water supply |

## COLORADO CLIMATE ACTION

*Anne Miller, AICP, Colorado Resiliency Office Director, Colorado Department of Local Affairs*

As in many Western states, Colorado is feeling the cascading impacts of warming temperatures from earlier snowmelt, persistent drought and water supply issues, and an increase in megafires and post-fire flood and landslide risks. In the last 30 years the temperature in Colorado has increased by 2°F and climate models predict an increase of 2–6°F by 2050.

2020 was a particularly challenging year as Colorado battled the COVID-19 pandemic and experienced record-breaking wildfires—including three of the largest wildfires in state history—and extreme drought conditions. With just over half of Colorado's population living in the wildland-urban interface and growing population pressures, the state faces an urgency to address climate mitigation and adaptation to protect the environment, lives, and livelihoods.

Along with those challenges, however, came promising opportunities to imagine a sustainable and resilient future, leading to a vision of a clean energy economy that benefits all Coloradans. The State of Colorado has stepped up efforts to tackle climate change and work toward this vision, releasing several plans in early 2021 to spur action, including the Greenhouse Gas (GHG) Pollution Reduction Roadmap, Colorado Resiliency Framework update, Just Transition Action Plan, and Climate Equity Framework.

### Greenhouse Gas Pollution Reduction Roadmap

The GHG Roadmap identifies pathways to meet the state's emission reduction targets of 26 percent by 2025, 50 percent by 2030, and 90 percent by 2050 from 2005 levels set out in House Bill 19-1261, Climate Action Plan to Reduce Pollution (Figure 8.2, p. 92). Key actions to achieve these

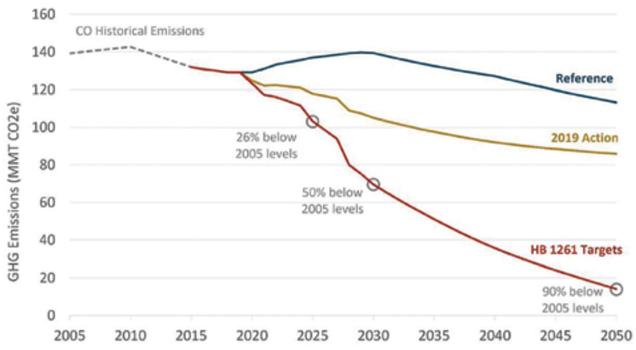



*Figure 8.2. GHG emission projections by scenario (State of Colorado)*

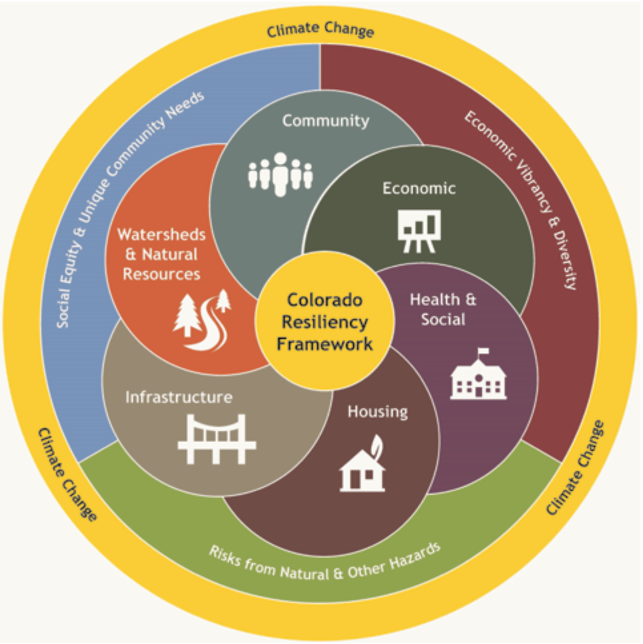



*Figure 8.3. Colorado Resiliency Framework six sectors and four overarching themes (State of Colorado)*

targets and address the largest sources of GHG emissions (transportation, electricity generation, oil and gas development, and buildings) include:

- Continuing the transition away from coal to renewable electricity
- Accelerating the shift to electric cars, trucks, and buses
- Making changes to transportation planning and investment in addition to land-use planning to encourage alternatives to driving
- Increasing building efficiency and electrification
- Reducing methane pollution from oil and gas development as well as from landfills and wastewater

The Roadmap shows that Colorado is on a path to achieve almost half the emissions reductions needed to meet the 2025 and 2030 goals and identifies additional steps the state will take to achieve the targets. Central to the plan is a commitment to implement policies that are responsive to concerns of disproportionately impacted communities and that deliver local air quality benefits.

## Colorado Resiliency Framework

The State of Colorado is also taking leadership on climate resiliency with the 2020 Colorado Resiliency Framework (a five-year update to the 2015 APA award-winning Framework, a first of its kind in the nation). The Framework addresses risks and vulnerabilities across four themes:

- Reduce risk and adapt to changing climate
- Understand risks from natural and other hazards
- Address social equity and unique community needs
- Pursue economic vibrancy and diversity

Taking a holistic, systems approach across six interconnected sectors (Figure 8.3), the Framework lays out six priorities for advancing resiliency in Colorado.

- **Future-ready economy and workforce.** Fortify Colorado's workforce to support a future-ready, regenerative, circular economy.
- **Climate and natural hazard resiliency.** Reduce Colorado's risk from climate change and natural hazards through integrated land-use, ecosystem, and natural resource planning, management, and investment.
- **Building and infrastructure sustainability.** Reimagine and modernize Colorado's built environment to be both climate and hazard resilient and environmentally sustainable.
- **Agriculture and food security.** Cultivate a robust state and local food system, from agriculture to distribution and consumption.
- **Housing attainability.** Increase the supply of attainable housing throughout Colorado, including affordable housing options for workforce populations and those who most experience marginalization.
- **Community capacity.** Empower Colorado communities to improve local resilience, equity, and capacity.

The Resiliency Framework advances plan integration and cross-sector strategies that include implementation of the state's first Just Transition Action Plan to support workers and communities in a just and inclusive transition away from coal. It also promotes equity, including community engagement best practices identified in the Colorado Climate Equity Framework.

Colorado is wasting no time and moving quickly to put these plans into action. Multiple bills are moving forward in the state legislative session and rule-making efforts are underway to advance GHG Roadmap transportation and buildings actions. For example, the Colorado Department of Transportation is leading the charge to develop GHG pollution standards for transportation plans. In addition, Colorado is moving forward on multiple strategies in the Colorado Resiliency Framework, including initiating a new Climate Corps to spur climate action in communities across the state.


*Figure 8.4. Las Vegas and the Colorado River Basin (USGS)*

### Leadership for Bold Climate Action

An all hands-on-deck approach is critical to tackle the climate crisis, starting at the top. New leadership in the Governor's Office and in the state legislature has brought a commitment to bold climate action.

In June 2019, Governor Jared Polis released a roadmap to 100 percent renewable energy by 2040 and signed 11 clean energy bills. The pace of climate action work continues, advanced by a cabinet-level environment and renewables policy group and a climate staff work group, initiated by a handful of staff across multiple state agencies who saw the necessity of cross-agency strategic coordination. In addition, the Colorado Resiliency Working Group (formed in 2015) continues to drive action for Colorado to adapt and thrive no matter what disruption or challenge comes its way.

Leadership, action plans, and taking a "just do it" approach at all levels of government in partnership with the nonprofit and private sectors is what is called for to meet our climate challenges and realize social, environmental, and economic benefits.

## LAS VEGAS CLIMATE ACTION

*Marco N. Velotta, MS, AICP, LEED Green Associate, Planning Department | Long Range Planning, Office of Sustainability*

The City of Las Vegas has championed sustainability since 2005, when Mayor Oscar Goodman signed on to the U.S. Conference of Mayors Climate Protection Agreement. After a series of resolutions, the city—one of the fastest growing in the American West—made a concerted effort to integrate renewable energy production, energy efficiency, water conservation, recycling, green building, and alternative transportation into its plans, codes, and capital projects to mitigate GHG emissions and reduce overall community costs. This was done to address climate opportunities and challenges facing the 2.2 million residents and 45 million annual visitors to the southern Nevada region.

These proactive efforts were also important because of the critical drought that has impacted the Colorado River basin (Figure 8.4) for the past two decades. Given that the Colorado River serves millions of users and irrigates millions of acres—and that Nevada receives only two percent of the flows of the river—climate mitigation and adaption efforts have been a top priority for the city's longevity.

The city's Sustainable Energy Strategy set goals and targets to meet a variety of climate change, renewable energy,

*Figure 8.5. Las Vegas' LEED-certified City Hall (City of Las Vegas)*

*Figure 8.6. Las Vegas's LEED-certified municipal courthouse (Marco Velotta)*

and energy efficiency targets, as well as establish a plan and framework for achieving those goals and target over time. With an infusion in federal funds through the Recovery Act, the city was able to leverage other city, state, and utility funding to install more than six megawatts of solar, construct eight LEED-certified green buildings (Figure 8.5), replace more than 45,000 streetlights with LED lighting, make energy efficiency improvements to its largest facilities, install more than 40 acres of turf with water-conserving landscaping, add more than 500 miles of bike lanes and other bike infrastructure, adopt renewable energy ordinances and a form-based zoning code for downtown Las Vegas, and deploy single-stream recycling citywide at all city facilities, in public rights-of-way, and for all residential customers.

In conjunction with the Southern Nevada Water Authority, the city also adopted a drought ordinance (Las Vegas Municipal Code Title 14, Chapters 8–11) that increased limitations on outdoor irrigation, incentivized the removal of turf, and increased water rates on a tiered pricing system in an effort to conserve water. Due to aggressive state policy, coal-fired power generation was set on track for removal (and successfully phased out) for the state's resource portfolio; Nevada's renewable portfolio standard is now set in the Nevada Constitution at 50 percent renewable by 2030.

These efforts were deployed beginning in 2009 and reduced the city's total energy costs from a peak of $15 million in 2008 to $9.5 million in 2020, reduced annual water consumption by 240 million gallons from 2008 levels, decreased emissions to mid-1950s levels, and increased the recycling rate at city facilities to 50 percent. Savings from the initial investment were used to reinvest in additional projects after repaying debt service on some projects.

With these accomplishments, many of the targets from the Sustainable Energy Strategy were met; however, the city set its sights even higher. In 2017, the city council adopted a strategy for net-zero energy, sustainability, and community resilience. This set in motion a goal to meet 100 percent of the city's municipal retail load with renewable energy, as well as make an assessment of other community sustainability metrics in preparation for the development and adoption of a new comprehensive citywide master plan that had last been adopted in 2000.

The net-zero effort kicked off immediately. The city received an allocation of hydropower from Hoover Dam and partnered with the state's investor-owned electric utility, NV Energy, to execute a renewable energy agreement, fulfilling the goal to receive 100 percent of its electric retail load requirements from renewable sources.

Despite setbacks and major economic impacts from the COVID-19 pandemic, new municipal buildings have continued to be built to LEED standards, including a new municipal courthouse (Figure 8.6) and a replacement fire station. And in late 2020, the city completed its assessment of the natural environment, land use and transportation, energy and climate, water, waste, and quality of life issues and was rated as a LEED Gold-certified city by the U.S. Green Building Council.

Key takeaways from LEED for Cities were incorporated throughout its 2050 Master Plan (Figure 8.7, p. 95), the com-


*Figure 8.7. Las Vegas 2050 Master Plan (City of Las Vegas)*

prehensive 30-year guide to future growth and development that was adopted in May 2021. The plan and corresponding zoning framework emphasize infill and transit-oriented development to create walkable communities, diversify housing stock, reduce vehicle miles traveled, drive even greater water conservation, double down on climate mitigation and adaptation efforts, and address environmental justice concerns. Future outcomes and conditions were intentionally aligned with the assessment to implement the plan and track progress over time.

Overall, this approach is rooted in the traditional planning process—a strong emphasis on goal setting, implementation, and evaluation. Cities large or small can make use of these components when looking for ways to address climate change. Ultimately, leveraging as many tools as possible will be necessary to mitigate and adapt to climate change.

## JEFFERSON COUNTY PARTNERS IN ENERGY PROGRAM

*Conor Merrigan, Sustainability Program Manager, Spirit Environmental, and Member, Jefferson County Sustainability Commission*

Jefferson County, Colorado, is a politically purple community, typically more conservative than more urban Colorado and more liberal than the Western Slope and Eastern Plains. As such, county commissioners have historically trended towards fiscal conservativism and have needed strong convincing to embrace ideas or efforts that lean too strongly towards climate change or sustainability. However, a convergence of synergistic factors led to some planning and implementation efforts that are pushing the county towards a leading role in becoming a more sustainable jurisdiction. One of the most impactful drivers of this shift has been the Partners in Energy program offered by local utility Xcel Energy.

Partners in Energy is a program paid for through demand side management (DSM) fees on customer utility bills that offers energy planning and implementation support for communities within Xcel service territory in whole or in part. The program was proposed, piloted, and is currently managed by sustainability consulting firm Brendle Group, and it consists of a targeted process of developing an Energy Action Plan and providing ongoing support for implementation within a defined timeframe.

Xcel Energy leverages the program to achieve greater DSM and energy efficiency savings to meet goals mandated by the Colorado Public Utilities Corporation and to increase community goodwill throughout its electric and natural gas territories. Plans are customized to each community and involve a systematic process of stakeholder education, engagement, and ultimately direction-taking to develop specific goals and strategies based on data and identified community desires.

### Partnering for Action

In the case of Jefferson County, the original impetus for participation in the program came from the Sustainability Commission, which was established in 2014. The Partners in Energy program was offered at no cost to the county, which helped the county commissioners get on board.

During the roughly six-month planning process, the Xcel Energy team led a group of community stakeholders through a facilitated process to understand where the county stood in terms of its overall demographics and socioeconomic characteristics, as well as its use of Xcel Energy programs, including rebates, direct installs, overall use, and other efforts. The group was carefully curated to include county staff, representatives from businesses, additional utility providers in the area, sustainability coordinators for local municipalities, and nonprofits, among others.

Using data customized for the unincorporated areas of the county, the group was able to see how residents and businesses compared in their use of various energy programs ranging from home energy audits to solar energy installations. This empowered the group to select and take advantage of the various energy programs offered by Xcel Energy, customize communication plans and implementation strategies tied to driving increased participation in particular programs, and target the sectors deemed most important.


*Figure 8.8. Partners in Energy outreach booth, Jefferson County Fair (Jefferson County Sustainability Commission)*

The resulting Energy Action Plan was finalized in 2017. During the planning phase, the stakeholder group was able to concurrently and successfully advocate that the county commissioners include Jefferson County in the recently established Colorado Commercial Property Assessed Clean Energy (Co-PACE) district. Opting in at the county level was a required component for program participation. The program allows private commercial buildings to finance energy improvements with what are effectively property tax liens secured by the credit of the county.

This initial win during the planning process helped to provide momentum and gave the group a clear mandate for at least one strategy of assisting commercial building owners to participate in the program. In addition, the stakeholder group was able to convince the commissioners to hire the county's first sustainability coordinator. That had the synergistic impacts of creating an implementation support mechanism for the broader plan while also giving the county a dedicated resource to implement sustainability initiatives within county government.

With this strong foundation, the county and its implementation partners were able to start implementation efforts for the commercial, residential, and government sectors. Specific residential implementations included tabling at community events (Figure 8.8), focused neighborhood targeting with trusted partners and social media, and customized collateral for the Sustainability Commission to share. Commercial efforts included bringing contractors to offer immediate and convenient assessments and installs, direct outreach to potential Co-PACE participants, and partnership with local municipalities on their programs. And the county government made numerous efforts to investigate energy-saving opportunities and to raise awareness and


*Figure 8.9. Direct outreach to county employees, Jefferson County Courts Building (Jefferson County Sustainability Commission)*

share resources with county staff for personal use (Figure 8.9). Additional efforts are detailed on the county's Sustainability Program webpage.

The success of the program has led to the Implementation Memorandum of Understanding (MOU) between the county and Xcel Energy being extended numerous times, although program focuses have changed as some efforts were deemed more successful or more opportune than others.

## Key Takeaways

Ultimately, the success of this program in Jefferson County was (and is) enabled by several different factors. The county's willingness to engage and the time commitment provided by the volunteer Sustainability Commission, supplemented by the utility-paid efforts from the consultant team, enabled robust participation, and a clear process offered defined milestones and outcomes. The combination of data analysis (and availability) to support decision-making and robust stakeholder engagement led to implementation strategies that had a high degree of buy-in and solid potential for real savings. Xcel Energy made the strategic decision to fund the program and has continued to do so to capture additional savings and build on past successes. The establishment of the Sustainability Commission and key county commissioner support provided the fertile ground for such an effort to take hold. The Co-PACE program at the state level, the supported decision to hire sustainability staff at the county, and the clear reporting and outcomes from all parties all lined up to maintain a program that is still going strong.

For planners elsewhere, a process like this can start with local utilities. If they have mandates to save energy and reduce peak demand, they typically have funding to support some sort of similar effort. Their ability to influence behavior directly is limited, so typically being able to partner with trusted sources allows for more robust participation in programs. Having a conversation with potential stakeholders and a clearly defined process for tracking success will enable any program to endure.

## DES MOINES CLIMATE MITIGATION ACTION

*Allison van Pelt, CC-P, Senior Planner, Des Moines Area MPO*

Like many Midwest cities, Des Moines, Iowa, does not have lingering smog. Except for cold winter days when one can see one's breath, GHG emissions from homes, businesses, and cars go mostly unnoticed. Invisible threats can be a challenge when asking a community to act on anything, especially climate change.

Even without the visibility of local GHG contributions, Des Moines feels the effects of climate change on a nearly annual basis. In the past three decades, the city has experienced major river flooding four times, torrential rain bringing urban flooding in previously unaffected areas, droughts 17 out of the last 20 years, a derecho with 70–100 mile-per-hour winds, polar vortexes, heat waves, fewer cooling nights, and more. These events have shown the community and region that climate change is at its door, and there is a fundamental need to mitigate and adapt.

Recently, Des Moines' goal to mitigate its emissions gained national attention when its city council passed a resolution setting a GHG emission goal of net zero by 2050 and a 24/7 100 percent carbon-free electricity goal by 2035. While the vote was unanimous, it was not an effortless win.

*Figure 8.10. Des Moines Citizen Task Force on Sustainability logo (Anna Lemons)*

### Three Pillars of Leadership

Des Moines is proud to have three main pillars supporting its climate action efforts: a climate-committed mayor, a contemplative city council, and a tenacious citizen-led sustainability task force. Des Moines is now openly and outwardly on the climate action map because of these leaders' individual and collective actions.

Even before declaring "We Are Still In" to the Paris Climate Accord goals and measures after the United States pulled out in 2017, longtime Des Moines mayor T.M. Franklin "Frank" Cownie has been a pillar of sustainability. His involvement, presently and previously, in the Iowa Climate Change Advisory Council (disbanded in 2011), ICLEI's Executive Committee, The Global Covenant of Mayors for Climate & Energy, and Conference of Mayors Climate Change Committee, and his attendance at the United Nations Paris Climate Change Conference, paved the way for the city to become a STAR Community (now LEED for Cities and Communities). His steady and committed hand has guided the community toward the recent carbon-free resolution.

Elected officials can make or break any community-wide initiative. The Des Moines city council is no different. All of its six members are passionate about their work for the city, their constituents, and their professional careers. Though one member is an environmental lawyer, most do not work in environmental fields. They include a restaurateur, a real estate agent, a bike advocate, and former school and zoning board members.

Each realizes the need for climate action; however, they tussle over priority levels and best avenues to achieve better outcomes. Even still, this current council and past councils have been a pillar of action through policy. Without their willingness to listen, question, and evaluate proposals and direct


*Figure 8.11. Climate mitigation milestones (ICLEI-Local Governments for Sustainability USA)*

staff to act, it would not have been possible for Des Moines to arrive at its final carbon-free and net-zero resolution.

The final and most populous pillar is the people. Following the mayor's 2015 trip to the Paris Climate Conference, a group of concerned residents rose to support the mayor and help push the city to commit to climate action. They had two initial requests: one, that the city form a Citizen Taskforce on Sustainability; and two, that the city pledge to lower its GHG emissions to net zero by 2040. The council approved the first request but did not address the second at that time.

Since its establishment in 2016, the Des Moines Citizen Task Force on Sustainability has met bimonthly with businesses, neighborhoods, and elected officials to discuss climate priorities and initiatives (Figure 8.10, p. 97). When a new topic arises, the Task Force reaches out to gain perspective and ideas from cities that have already started work on similar issues. Through these committed citizens' efforts, Des Moines's climate progress is a reality.

## Mitigation Milestones

The International Council for Local Environmental Initiatives (ICLEI) has produced a framework for communities mitigating climate change, termed ICLEI Climate Mitigation Milestones (Figure 8.11). As a member, Des Moines has followed this framework while adding critical pieces for local needs. The milestones are:

1. Conduct an inventory and forecast of local GHG emissions
2. Establish a GHG emissions reduction target
3. Develop a climate action plan for achieving the emissions reduction target
4. Implement the climate action plan
5. Monitor and report on progress

Through the Task Force's efforts, the mayor and council started working toward these milestones. The first entailed partnering with the University of Northern Iowa's Center for Energy and Environmental Education to complete a community-wide GHG emissions inventory in 2017.

The inventory showed commercial energy (33 percent), residential energy (27 percent), transportation (26 percent), and industrial energy (11 percent) make up 99 percent of the GHG emissions in the city. The last percentage point includes solid waste, water, and wastewater. This knowledge empowers the city to focus its efforts and prioritize actions.

In a detour from the ICLEI Milestones, the Task Force recommended the city adopt an Energy and Water Benchmarking Ordinance to measure baselines and track progress made as mitigation efforts move forward. The initial ordinance, adopted in 2019, focused on buildings of more than 25,000 square feet, with the first reporting year cycle in 2020. To fulfill the related work from this ordinance, the city established a Sustainability Program Manager position to manage benchmark reporting, act as a Task Force liaison, and coordinate the integration of sustainability in all city departments.

With dedicated sustainability staff in place, the city moved toward the second milestone: setting emissions reduction goals. Councilmember Josh Mandelbaum, an environmental lawyer and climate advocate, moved quickly to suggest the city commit to a goal of 100 percent carbon-free energy, in addition to setting net-zero reduction goals.

This commitment increased complexities to the resolution development and passage, as the city does not produce its energy—MidAmerican Energy does. While MidAmerican is a privately held company, it has independently committed ongoing investment in significant wind projects and infrastructure across Iowa with the intent of delivering 100 percent renewable energy to its customers through its GreenAdvantage program. MidAmerican reported it produced 61.3 percent of its energy from renewable sources in 2019 and forecast 90 percent renewable production in 2021. This investment by MidAmerican signaled its commitment.

With the help of city staff, the Task Force, and community partners, two opportunities to learn and discuss 100 percent carbon-free feasibility with council members and the public were held. The first was a virtual tour of industrial, commercial, residential, school, and transit organizations in the city and region that have already incorporated renewables in their infrastructure investments. The second was a city council work session with MidAmerican, city staff, and community businesses to discuss in more depth the potential rate increases, changes in efficiencies, intended and unintended consequences, and liabilities.

After hearing from all sides and examining the complexities, council members directed the city manager to draft a resolution. On January 11, 2021, that resolution passed unanimously, marking the second milestone's arrival.

### Moving Forward

Progress is already in the works on the third milestone, the climate action plan. The city allocated funding for a community-wide climate action and adaptation plan within the FY 2022 budget. Inevitably, all three leadership pillars and the ICLEI Climate Mitigation Milestones framework will continue to guide the city and this plan's development.

The last two milestones seek to implement and monitor the prescribed actions, so some of the most challenging work is still ahead. Few climate action plans are enforceable, and the only penalty for not achieving the goals and intended outcomes is further increased climate vulnerability and risk. The work will require social changes, investments, and sometimes sacrifices—but if completed, Des Moines will be more resilient and secure.

As the work rolls out, the mayor will need to continue being a visible and recognized champion, unwavering and committed to giving the city a roadmap for climate action. The council will need to continue contemplating the benefits, costs, impacts, and burdens while making policy and setting precedent. And the Task Force will need to continue its work with neighbors, lifting community needs and stories to the city, putting a face on the impacted lives, and recruiting ground support for the progression toward resilience.

## CHAPEL HILL CLIMATE ACTION AND RESPONSE PLAN

*Teresa Townsend, AICP, Chief Executive Officer, and Ann Steedly, PE, Planning Communities*

The Town of Chapel Hill, North Carolina, with a 2020 population of 61,912 (including University of North Carolina resident students), is located in the region known as the "Triangle," which also includes the cities of Durham and Raleigh. It is the home of the University of North Carolina at Chapel Hill, the nation's first public university.

Chapel Hill has long been a leader in environmental stewardship and carbon footprint reduction. In 2006, it was the first U.S. municipality to commit to a 60 percent reduction in emissions by 2050. In 2017, the Town further committed to uphold the United Nations Paris Agreement through a resolution to meet a 26–28 percent carbon reduction goal. In 2019, the Town Council committed to becoming a 100 percent clean, renewable energy community by 2050 (Figure 8.12) and began a climate action and response planning process with a community-wide focus on mitigating GHGs and making the community more resilient. Town and community goals confirmed during the climate action planning process included the following (Figure 8.13, p. 100):

- 50 percent GHG reductions by 2030
- Net zero GHG emissions by 2050
- 80 percent clean, renewable energy by 2030
- 100 percent clean, renewable energy by 2050


*Figure 8.12. Chapel Hill climate action timeline (Town of Chapel Hill)*

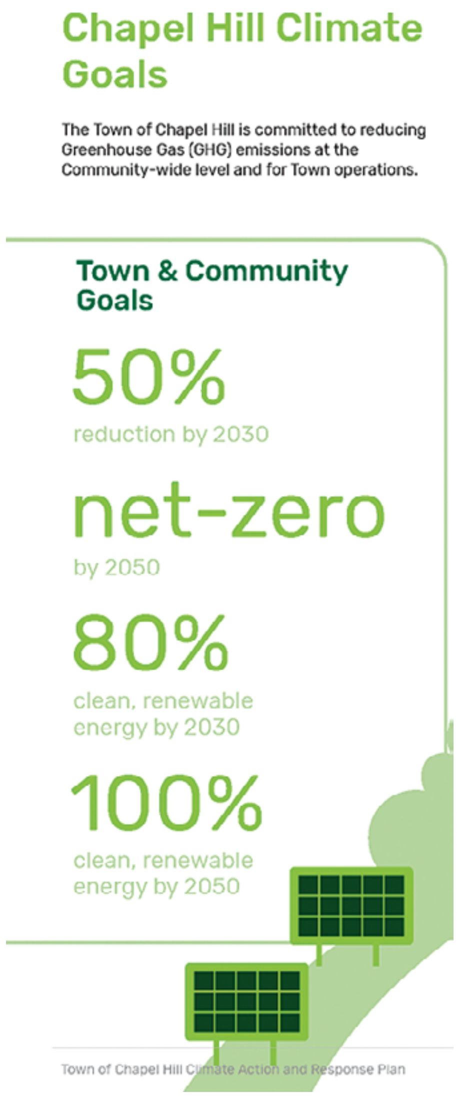



*Figure 8.13. Chapel Hill climate goals (Town of Chapel Hill)*

The Climate Action and Response Plan, which included an update to the town's GHG Inventory and Forecast, was drafted in 2020 and adopted on April 7, 2021. The town also unanimously passed a resolution to declare a climate emergency in conjunction with the plan adoption.

## Regional Significance and Issues

Chapel Hill's climate planning efforts coordinate and align with other climate actions across the state and region. In recent years, North Carolina has been battered with more heavy rain events, more intense hurricanes including Hurricanes Florence and Matthew, and increased coastal and inland flooding.

A regional partnership in the Triangle prepared a resilience assessment in 2018 that explored the threats, vulnerabilities, risks, and assets related to climate change affecting the region. Key stressors the region is facing include the effects of a changing climate—increasing extreme precipitation events, higher and more variable temperatures, and increasing drought frequency and duration—and the challenges of robust regional population growth. The regional assessment and strategies helped to inform the Climate Action and Response Plan, and the plan includes regional solutions and partnership actions.

At the state level, in 2018, North Carolina issued an executive order committing to reducing statewide GHG emissions to 40 percent below 2005 levels by 2025. The state, regional partners, and local governments throughout the southeast region, including Chapel Hill, are working towards "greening the grid," which entails converting the electrical grid to renewable energy sources as a key strategy to address the changing climate. This requires substantial coordination with the major utility providers. Other regional coordination strategies include sustainable transportation and development actions.

## A Structured Plan of Action

The Chapel Hill Climate Action and Response Plan reflects the process and priorities for development of the plan. The community expressed the desire for an actionable, high-impact plan that emphasized the importance of resilience along with mitigation strategies.

Key building blocks for the plan were establishing climate goals, outlining challenges and opportunities, preparing GHG inventories for town and community sources, developing GHG projections under "business as usual" and climate action scenarios, defining equity for the community, focusing on resilience strategies, integrating community engagement and partnerships, and evaluating co-benefits to develop recommended strategies. An implementation timeline and consideration of next steps ensure that recommended actions can quickly build upon the foundations of the plan.

The plan identifies the top 10 actions for both the local government and the community—20 actions overall—and distills them into the following top five sets of actions that will create the greatest impact and momentum for climate action:

1. Green the grid
2. Sustainable transportation

3. Sustainable development
4. Green building retrofits
5. Green infrastructure/resiliency

Evaluations for each of the 20 individual actions include a vision and target, detailed steps to achieve the action, an inventory of existing related Town efforts, key technical concepts, potential community partners, estimated costs, projected emissions reductions, and other community co-benefits of the action.

Actions are organized across four primary sectors or focus areas: buildings and energy; transportation and land use; waste, water, and natural resources; and resiliency. The plan summarizes the data and actions for each area including the existing GHGs, forecast GHGs with and without climate actions, the top actions, and high-level key metrics and measures for each focus area.

- **Buildings and energy.** The majority of Chapel Hill's overall carbon footprint comes from this sector, which represents approximately 69 percent of overall community GHGs. More than 42 percent of these emissions come from the University of North Carolina at Chapel Hill. Top strategies for buildings and energy include adopting an updated Green Building Policy by 2023, completing upgrades to town facilities and encouraging upgrades to other existing buildings with goals of achieving 100 percent net zero emissions in new development by 2030, and converting 15,000 buildings to all electric and having 100 percent of town buildings net zero by 2050.

| ACTION | GHG REDUCTION POTENTIAL (MTCO2e) | LEVEL OF INVESTMENT REQUIRED BY TOWN | TOWN'S AUTHORITY TO ACT | CO-BENEFITS |
|---|---|---|---|---|
| **TRANSPORTATION & LAND USE** | | | | |
| Create a town-wide electric vehicle (EV) charging station network | 107,028 | $$$ $1.7M | Some authority | |
| Expand TDM and plan for mobility on-demand network | 24,119 | $-$$* | Some authority | |
| Create walkable, bikeable, transit-served neighborhoods | 19,905 | $* | Some authority | |
| Increase walking, biking and transit use (mode-shift) | 12,505 | $$$$* | Some authority | |
| Electrify the transit fleet | 4,572 | $$$$ $2.82M | Some authority | |
| Increase transit ridership and implement Bus Rapid Transit (BRT) | 2,305 | $$$ $200M | Some authority | |
| Electrify the municipal fleet | 803 | $$ $480,000 | Full authority | |

*Figure 8.14. Chapel Hill transportation and land-use actions (Town of Chapel Hill)*

- **Transportation and land use.** In Chapel Hill, 26 percent of emissions come from transportation. Top transportation and land-use strategies to reduce emissions listed in the plan include fully implementing the Town's Mobility Plan by 2035; planning for walkable, bikeable, transit-accessible neighborhoods; electrifying Town fleets; and creating a town-wide EV charging network. Targets include achieving 35 percent of commute by walking, biking, or transit by 2035 and 30 percent telework by 2040; opening the town's first bus rapid transit line by 2025 while keeping transit fare free; and converting all Town heavy-duty vehicles to electric by 2050, and buses and other vehicles by 2040 (Figure 8.14).
- **Waste, water, and natural resources.** While only four percent of Chapel Hill's emissions come from this area, there are many community co-benefits to actions that aim to improve management of waste, water, and natural resources. The Town aims to be a zero-waste community by 2045 and to protect water quality, natural, and agricultural resources through a variety of strategies, management practices, incentives, and partnerships.
- **Resiliency.** The Chapel Hill Climate Action and Response Plan approaches this focus area with the same type of thought and evaluation as the GHG sector-based focus areas. With an emphasis on planning for resilience at the regional level and striving to achieve climate equity, the top resiliency actions include strengthening climate/hazard warning systems; enhancing green infrastructure; expanding education, outreach, and awareness; increasing partnerships, funding, and incentives; and broadening community-wide resiliency and recovery capacity. In 2020–21, the Town invested in a flood storage project that doubles as a "climate park" for passive recreation as well.

## Key Takeaways

While each community and climate action plan will be different, there are several lessons learned in Chapel Hill that planners can apply in similar communities:

- **Community partnerships are vital.** Across a wide range of communities, municipal operations contribute a small percentage of the emissions generated by the community. Many climate actions will involve or be led by community partners. Planners must engage community partners in an early and ongoing manner to build these relationships that will be fundamental to delivering climate action. Engaging community partners can also enhance community outreach and equity for climate action.

- **Actionable, high-impact strategies build momentum.** The current climate crisis requires that communities take action quickly. This requires deliberately structuring agency climate action plans with strong, yet achievable, specific targets and actions. By setting climate and sector-specific goals, prioritizing high-impact actions and selecting "top" actions amongst these, detailing the impacts and benefits of climate and resilience actions, committing to specific strategies to implement actions (specific plans, policies and projects), and setting a timeline for action, Chapel Hill's plan is designed to build momentum for implementation.
- **An integrated approach should build on past actions and future plans.** Like many communities, the Town of Chapel Hill had undertaken a number of sustainability and climate-related actions prior to preparing a full climate action plan. In addition, other land-use, mobility, and infrastructure plans for a community will include actions that contribute to climate action or that planners can update moving forward to reflect strategies found in climate action plans. This can enhance the impact of climate actions and reduce excess planning and coordination required.
- **Coordinated and collaborative efforts should be applied through a planning lens.** To achieve the greatest GHG reductions and resilience benefits, land-use, transportation, and other infrastructure planning should be integrated through comprehensive planning. Climate strategies and actions should be complementary and connected across sectors (e.g., sustainable, compact land development works together with transit, bicycle, and pedestrian infrastructure to reduce emissions from the transportation sector).
- **Include and balance mitigation and resilience strategies.** High-impact climate actions are important to prioritize, but resilience strategies are also essential to address the needs of the wider community and vulnerable populations already experiencing the effects of climate change (e.g., flooding events, heat-related effects). Whether preparing a full resilience assessment or plan or including resilience alongside climate action sectors, as was the case for Chapel Hill, planners should make sure that resilience planning and strategies receive a similar emphasis and visibility as climate mitigation actions to deliver sustainable, equitable climate plans.
- **Focus on maximizing other benefits for all community members related to climate action**. With the community partnership-based and integrated approach needed for climate action, planners and the agencies they work with should focus on the co-benefits of climate action such as health, clean environment, green jobs, housing quality and affordability, and environmental justice for all community members, especially vulnerable populations. Addressing wider benefits creates more inclusive climate action plans and broadens community support and participation.

Chapel Hill was an early initiator in taking action to address climate change and through its actions has made significant strides towards reducing the Town's overall carbon footprint. The 2021 Climate Action and Response Plan lays a foundation of strong and connected partnership-led actions that will continue to move the community towards its climate, emissions, and energy goals, while generating other community economic, environmental, and equity benefits. Along with adopting the plan, the Town declared a climate emergency and has encouraged other communities to take action to build the collective local, regional, and national efforts needed to meet the challenges of climate change.

## WEST HOLLYWOOD CLIMATE ACTION PLAN UPDATE

*Robyn Eason, AICP, former Senior Sustainability Planner, City of West Hollywood*

West Hollywood, a 1.9-square-mile city of approximately 35,000 residents, is located in the heart of the Los Angeles region, surrounded by the cities of Los Angeles and Beverly Hills. Incorporated in 1984, the city has been a leader in policies supporting LGBTQ+ issues, social services, and affordable housing. It is home to the Sunset Strip and the West Hollywood Design District and is one of the region's most attractive areas for nightlife and tourism. It is also one of the densest, most walkable cities in California. The city's Long-Range Planning Division has supported the city's sustainability efforts for more than a decade.

The city council adopted the West Hollywood General Plan 2035 and West Hollywood Climate Action Plan in 2011. The General Plan builds upon the City's tradition of progressive policy making, with innovative goals and policies to balance increased density with enhanced mobility, while maintaining quality of life and neighborhood character. The

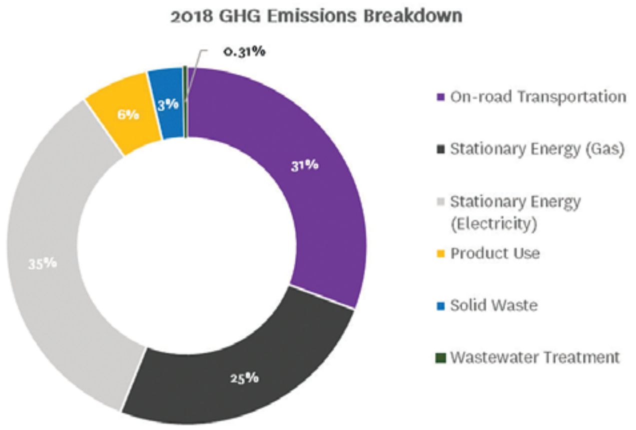



*Figure 8.15. Climate Action & Adaptation Plan 2018 GHG inventory snapshot (City of West Hollywood)*

2011 Climate Action Plan set community-wide and municipal goals for GHG emission reduction in several sectors, including land use and community design, transportation and mobility, energy use and efficiency, waste reduction and recycling, green space, water use and efficiency, and community engagement and leadership. More specifically, it established a citywide GHG emissions reduction goal of 20 to 25 percent below 2008 emissions levels by 2035 and provided a toolbox of implementation actions to strive for this outcome.

Similar to Los Angeles County and other jurisdictions in the region, West Hollywood's largest sources of GHG emissions come from transportation, particularly passenger vehicles, and stationary energy use in buildings and facilities (Figure 8.15). Thus, the measures and actions in the plan that lead to greatest GHG emissions reduction, if implemented, address these two sectors. Examples of such measures include increasing pedestrian and bicycle mode share, expanding locally managed transportation services, supporting efforts to increase and enhance regional transit opportunities, requiring new buildings to meet high energy-performance thresholds, facilitating renewable energy programs, and developing comprehensive outreach programs to promote energy efficiency.

While the city has made significant progress over the past 10 years, reducing its GHG emissions by 31 percent in 2018 and thereby surpassing its 2011 climate mitigation targets, there were some key lessons learned along the way.

- **More consistent data monitoring.** Upon adoption of the 2011 Climate Action Plan, the city did not immediately establish a monitoring tool to measure GHG emissions reduction over time. By following changes to emissions on an annual basis, the city has gained a better understanding of the measures that are most effective in reducing GHG emissions.
- **More verifiable indicators of progress.** Not all of the city's actions included viable indicators of progress. By identifying more quantifiable implementation measures and putting more emphasis on showing progress through annual monitoring of emissions reduction, the city is now better prepared to be more effective at tracking its progress.
- **Better consideration of evolving technologies.** Since plan adoption in 2011, significant advancements have been made in technologies that positively impact GHG emissions (e.g., cleaner vehicles and smart energy and water meters). Future plan updates could benefit from strategies that are more flexible and less prescriptive to accommodate ever-changing trends in automation and new technologies.
- **More measures that fall within city's control or influence.** Several plan actions that were reliant on regional partnerships—the city's utility providers or other third parties—yielded little to no progress over time. Future plan updates should focus on leveraging initiatives currently offered by direct utility providers (rather than creating new programs) and aligning with existing entities with shared environmental goals that can further specific outcomes through localized expertise and additional personnel.

In early 2020, the city embarked on an update to its 2011 Climate Action Plan with the primary focus of carbon neutrality by 2045 (Figure 8.16) and climate adaptation

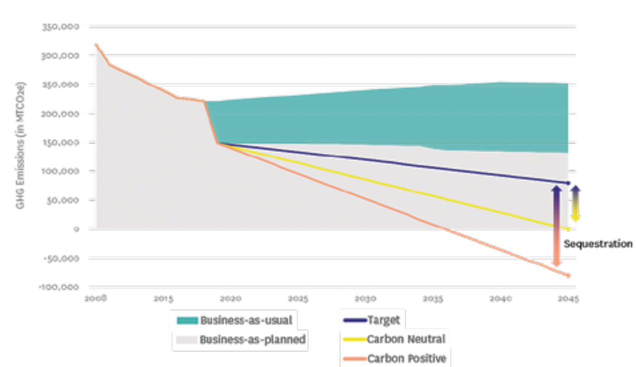



*Figure 8.16. Climate Action & Adaptation Plan carbon neutrality target setting (City of West Hollywood)*

strategies to better prepare for climate-related threats such as extreme heat, drought, and flash flood events. With more than 80 percent of implementation actions from the 2011 plan completed, the climate mitigation pursuits from the past decade established a strong foundation to build upon for the following update. Ongoing efforts supporting electric vehicle charging readiness, green building for new construction, municipal energy efficiency projects, solar energy and battery storage on existing properties, and the procurement of 100 percent renewable energy from the electric grid will carry forward into this new plan.

West Hollywood will apply the lessons learned outlined above and center equity in the process to ensure the perspectives of those acutely impacted by climate change are represented in the plan's outcomes. Statewide mandates and regional goals on waste reduction, transportation electrification (including public transit), and others will also play a significant role in small cities like West Hollywood being able to achieve success with its carbon neutrality goals. Beyond this, the city's major climate focus must continue to be in buildings and on-road transportation, which remain its main sources of emissions still today.

New climate mitigation considerations for the plan update include deep energy retrofits for existing buildings; building electrification codes for new construction; fully electrifying the city's vehicle fleet; increasing pedestrian, bicycle, and electric vehicle infrastructure; and expanding and enhancing the city's urban forest and biodiversity. West Hollywood will also need to consider how it can offset any remaining sources of emissions that cannot be eliminated through mitigation and collaborate with regional and state partners to purchase carbon credits.

Lastly, some key takeaways that planners should consider when moving forward with any kind of climate action planning pursuit include the following:

- **It takes a village.** No planning effort can be completed successfully without the collaboration, feedback, and insights of myriad internal and external stakeholder groups, including, but not limited to, staff members; local, regional, and state climate experts; local leaders; community members (especially those most marginalized); and local businesses. Robust engagement in partnership with community-based organizations helps to mitigate unintended consequences and can lead to a more enriched set of outcomes with equity as a central focus.
- **Research best practices from other jurisdictions.** Planners should learn from other jurisdictions' approaches to aggressively reducing GHG emissions in various sectors and evaluate what is possible for their jurisdictions based on their specific contexts. Many cities share similar climate goals and desire comparable outcomes, even if the pathways to success may differ.
- **Expect the unexpected from technology and innovation.** Even the best climate action plans cannot plan for or predict future advancements in automations and innovations. Ensure the plan is instructive, yet not too inflexible, to account for unexpected technologies that can yield positive climate impacts.
- **Celebrate successes and milestones.** The path toward district-scale climate mitigation can often be quite difficult. It can take years to realize desired outcomes and understand the impacts of implementation measures. It is important to celebrate successes and milestones—no matter how small or big—to show momentum, highlight progress, and recognize all stakeholders involved in implementation.

Applying these and other lessons learned can facilitate significant progress on achieving jurisdictional climate goals, foster regional and subregional collaboration on climate mitigation and adaptation efforts, embrace creativity and new methods in reaching set actions, and promote collective action among city partners and the community.

## WHITEFISH CLIMATE ACTION PLAN

*Kathleen McMahon, FAICP, Owner of Applied Communications, LLC*

The City of Whitefish, Montana, has a year-round population of 8,295, which balloons to more than 30,000 people in the peak summer months. This is due to its location on the shores of Whitefish Lake at the base of Whitefish Mountain Resort (Figure 8.17, p. 105) and its proximity to Glacier National Park. As might be expected, one of Whitefish's largest economic engines is tourism.

While tourism is an economic driver for the community, it also presents serious challenges for sustainable visitation. The surrounding forest is an outdoor recreation dream, but this also means that the entire city is in the wildland-urban interface (WUI). With hotter, drier summers, wildfires are more frequent, more intense, and more dangerous. Wildfire smoke causes health problems, building in the WUI increases risk of property damage, and evacu-

*Figure 8.17. Whitefish, Montana (City of Whitefish)*

ation during wildfire events increase life safety concerns. After a fire, erosion from burnt landscapes are a threat to the city's water supply.

On a regional level, snowpack is declining as the climate warms. This further contributes to drought, which is impacting both habitat and agricultural lands. Shorter winters equal shorter ski seasons, which means less revenue for area resorts and sales tax dollars for communities. Although these are common climate concerns throughout the West, gateway communities near national parks are seeing some of the most dramatic changes. In nearby Glacier National Park, it is predicted that most of the signature glaciers will disappear by 2030. Community members throughout the region want to participate in local solutions to adapt to this climate reality.

## Partnering for Climate Action

In 2017, the City of Whitefish and the Whitefish School District partnered to produce the Climate Action Plan. The resolution initiating the plan states that the goal is to increase the city's efforts to cut GHG emissions, create a clean energy economy, and stand for environmental justice.

The planning process was primarily driven by a citizen committee with support from the City's public works department. The committee was appointed by the mayor and included residents of Whitefish with various professional backgrounds. The City also hired a series of AmeriCorps/Energy Corps interns to assist with drafting the plan. The committee members and interns gathered information on city and school district operations. The City also joined ICLEI to access the ClearPath GHG inventory program to establish a baseline for carbon emissions.

In addition to the committee, a local nonprofit, Climate Smart Glacier Country, provided in-kind technical assistance to help organize community meetings and to compile the final plan. Other key stakeholders included Glacier National Park, state agencies, the electric co-op, hospitality businesses, and various nonprofits. Outreach efforts included public forums, surveys, student engagement, and media coverage (Figure 8.18). Individual interviews with community elders provided witness to the effects of climate change.

The Climate Action Plan includes the goal of Whitefish becoming carbon neutral by 2050. To achieve this target, the plan recognizes that learning, monitoring, and adjusting strategies is an ongoing process that will help the community respond to unexpected disruptions from climate change.

## Focusing on Key Priorities

The plan is organized into six focus areas with a chapter on each that includes baseline data, issues, action items, and recommendations for both local government and individual actions. Each chapter also documents social, economic, and environmental benefits from climate strategies. The focus areas are:

- **City buildings and energy.** About a quarter of the city's carbon footprint from municipal operations is related to energy use to heat and cool buildings and to operate

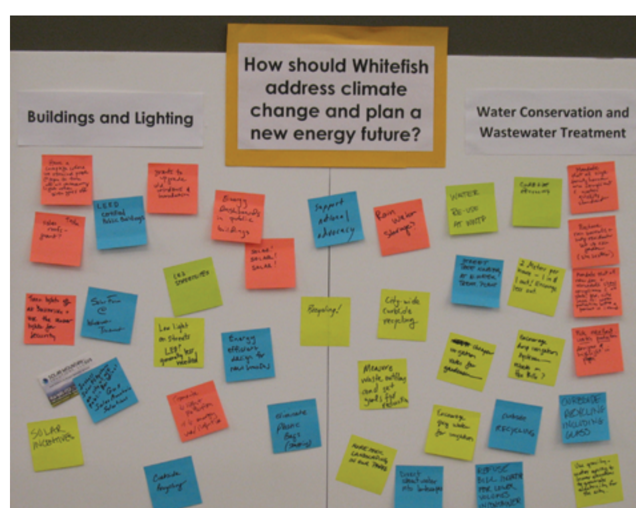



*Figure 8.18. Whitefish Climate Action Plan engagement (City of Whitefish)*

streetlights. Following adoption of the plan, the city installed LED streetlights, resulting in an annual savings of 80 metric tons of carbon dioxide. The plan also includes recommendations from energy audits of city buildings.

- **Transportation and land use.** The plan calls for supporting the expansion of public transit and making Whitefish bike- and pedestrian-friendly. The City is working with the county transit authority to institute a more energy-efficient on-demand system. Fleet management strategies include the purchase of electric vehicles. The City worked with the local electric cooperative to install four electric vehicle charging stations in the downtown parking structure. Land-use strategies include promoting smart growth principles, native landscapes, and green infrastructure.
- **Water and wastewater.** Water and wastewater treatment represent the largest share of energy use in municipal operations. A new wastewater facility currently under construction will require 2.5 times more energy than the existing facility. The new wastewater facility was required by the state Department of Environmental Quality to meet current water quality standards. To offset energy use, the City installed a hydroelectric plant at the water treatment facility and undertook a feasibility study for a solar array at the wastewater treatment plant. Construction of the solar array is pending identification of funding sources such as renewable energy grants. Water conservation and reducing infiltration of sewer lines will also reduce treatment needs with a correlating decrease in energy use.
- **Forest and watersheds.** Since Whitefish is surrounded by forest, an important strategy is to establish Whitefish as a fire-adapted community. Preserving forested land to offset carbon emissions is another critical strategy. Whitefish was successful in working with the Trust for Public Land, Montana Fish, Wildlife, and Parks, and a private property owner (F.H. Stoltze Land and Lumber Company) to establish a conservation easement on 3,022 acres of land. This easement protects the forest from development, which also protects the watershed that is the source of the city's water supply. A preliminary analysis by a forest researcher at Colorado State University indicated that this conservation easement will offset 36,000 tons of carbon dioxide emissions.
- **Consumption, food, and waste.** The community expressed strong support for recycling and waste reduction. Recycling is a challenge for rural communities due to the high cost of transportation to move materials to processing centers. Rural communities also lack economies of scale for cost-effective recycling operations. The climate plan provides parameters for renewing the recycling service contract. Because food waste comprises a large portion of the waste stream, supporting production of local food and composting are other key strategies. In 2020, the city and other partners piloted a "zero waste" farmer's market (Figure 8.19).

*Figure 8.19. The Whitefish "zero waste" farmers market (Kathleen McMahon)*

- **School district.** In addition to recommendations for energy-efficient school buildings, the plan calls for strengthening strategic partnerships between schools and the community. The school district has established the Center for Sustainability and Entrepreneurship (CSE) as an innovation hub to teach both students and adults to build sustainable systems. Currently, the city is developing a series of Climate Action Plan adult education classes in coordination with the school district.

## Lessons Learned for Rural Communities

Small towns have unique challenges in establishing climate action plans. They often must overcome limited funding and staffing, community skepticism, and competing priorities. A strong implementation plan is necessary for successful outcomes. Following are some lessons learned from Whitefish's experience:

- **Foster partnerships.** Partnering with the school district and nonprofits brought staffing resources and technical expertise to the project. The partners also expanded the community outreach effort through their networks.
- **Document co-benefits.** While many community members were ardent supporters of developing a climate plan, there was skepticism among some residents about the necessity of the project as well as concerns about implementation costs. To increase buy-in, the plan documents co-benefits such as cost savings from energy conservation, amenities from green infrastructure, and the health benefits from improved bicycle and pedestrian facilities.
- **Don't stop providing outreach and education.** Outreach and education are ongoing efforts. After the plan was adopted, the city created an "at-a-glance brochure" to provide citizens with an eye-catching overview of the plan. The city's website is updated with informational materials and progress reports. Workshops on firesafe practices, green homes, and recycling and classes at the School District Center for Sustainability and Entrepreneurship provide additional educational opportunities.
- **Plan for implementation.** Although a committee provides ongoing oversight on action items, there are limits to what a volunteer committee can accomplish. The plan proposes hiring a sustainability coordinator to implement recommendations. The challenge is funding the position when there are other competing budget priorities. Some options are a part-time position, hiring an intern, or sharing the position between different departments. A clear job description and identifying new sources of funds are key to creating this position.
- **Coordinate and communicate.** Along with citizen appointees, the climate action committee has representation from public works, planning, parks and recreation, the fire department, and the city council. This allows for coordination between departments and community members. Climate plan recommendations are incorporated in other planning documents to provide consistency and continuity.

Whitefish is already experiencing impacts of climate change and community members are looking to local leaders to develop local solutions. The Climate Action Plan is the first step in this important endeavor to provide a sustainable climate for future generations.

## CONCLUSION

These case studies offer many lessons learned regarding effective climate mitigation action. These examples are just the starting point for further evaluation, however. The documents and resources highlighted in the case studies above can help planners to advance mitigation efforts in their own communities. The next chapter offers case study examples from communities that have focused on climate adaptation action.

CHAPTER 9

# CASE STUDIES IN CLIMATE ADAPTATION

This chapter offers a series of case studies highlighting climate adaptation actions from across the United States, as shown in Figure 9.1 and summarized in Table 9.1 (p. 110). As in Chapter 8, the case studies reflect various types of jurisdictions or entities, scales, and locations. They are presented in order of jurisdiction population size, from large to small. Key climate mitigation planning documents and resources are listed for each case study.

The case studies predominantly focus on climate adaptation actions to reduce risk and vulnerability to climate change impacts. The previous chapter offers case studies related to climate mitigation action. As will be apparent, climate mitigation and adaptation actions can and do overlap. The intent is to provide recommended practice examples that planners can learn from to take action in their communities.


*Figure 9.1. Climate adaptation case study communities*

### TABLE 9.1. CLIMATE ADAPTATION CASE STUDIES

| Project | Community | Scale | Region | Climate Issues |
|---|---|---|---|---|
| North Texas Climate Action Planning | North Central Texas | Region | South | Naturally occurring disasters including fires, drought, flooding, tornadoes, and more |
| Adaptation to Urban Heat in Tucson | City of Tucson and Pima County, Arizona | Region | Desert Southwest | Extreme heat, urban heat island effect |
| Climate Ready Boston Adaptation Plan | City of Boston, Massachusetts | Large city | Northeast | Extreme heat, sea level rise, extreme precipitation and storms; stormwater, coastal, and riverine flooding |
| Alexandria Environmental Action Plan | City of Alexandria, Virginia | Mid-sized city | East Coast | Tidal and localized flooding, rising sea levels, and increased storm activity |
| Monroe County Sustainability and Climate Change Initiative | Monroe County, Florida | County | Southeast | Sea level rise, king tides |

## NORTH TEXAS CLIMATE ACTION PLANNING

*Tamara Cook, AICP, ISSP-SA, LEED Green Associate, former Senior Program Manager of Environment and Development, North Central Texas Council of Governments and Jeff Neal, PTP, Senior Program Manager, Transportation Department, North Central Texas Council of Governments*

North Texas—the 16-county region surrounding Dallas and Fort Worth—is the fourth largest region in the nation (Figure 9.2). Its population is expected to reach almost 12 million by the year 2050. It will face a significant amount of growth in the next several decades, but current infrastructure is not adequate to meet the needs of this growth. A continuation of the development patterns of the past will lead to continued impacts on the region's air, water, land, and natural resources—and threaten overall sustainability and resilience to future impacts of a changing climate.

According to the National Oceanic and Atmospheric Administration (NOAA), Texas led the nation in the number of billion-dollar weather and climate disasters from 1980 to 2020, with 124 total events (Figure 9.3); 11 of those occurred

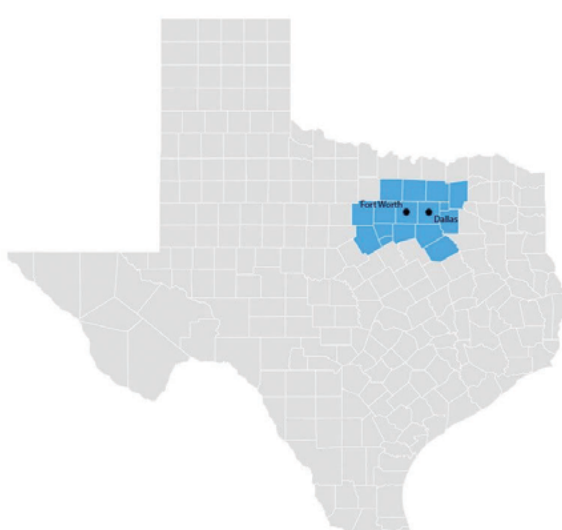



Figure 9.2. North Central Texas 16-County Region (denoted in blue) (NCTCOG)

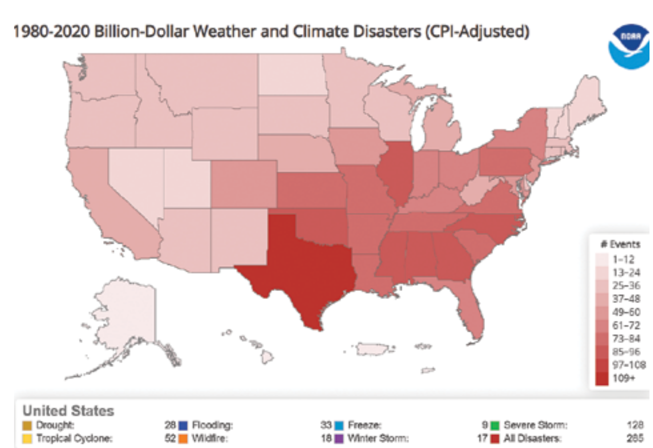



Figure 9.3. Texas led the nation in the number of billion-dollar weather and climate disasters from 1980 to 2020 (NOAA)

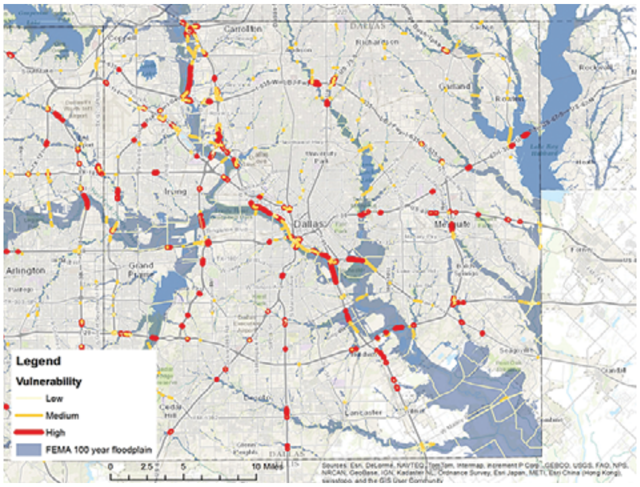



*Figure 9.4. Dallas roadway vulnerability assessment (NCTCOG)*

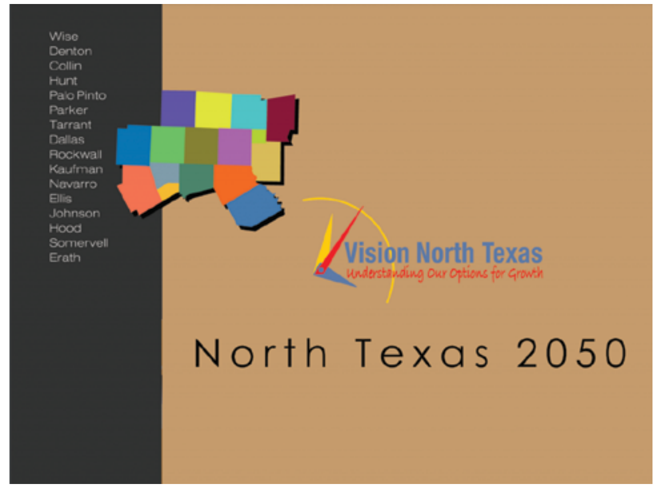



*Figure 9.5. The 2010 Vision North Texas 2050 Plan (NCTCOG)*

in 2020 alone. It is the only state that has been impacted by all seven types of billion-dollar disasters analyzed by NOAA. The North Texas region in particular is at risk of several major naturally occurring disasters, including fires, drought, flooding, and tornadoes.

The lens of climate mitigation and adaptation strategies is important to consider as the region continues to grow and develop additional infrastructure, homes, and businesses. While economic development and the long-term growth of the region is important, balancing growth with proactive planning to reduce emissions and mitigate risks associated with the changing climate is a focus of local government members in North Texas.

To this end, the North Central Texas Council of Governments (NCTCOG) and its Center of Development Excellence have several regional initiatives underway that support climate adaptation. As a voluntary association of, by, and for local governments, NCTCOG is working collaboratively with member governments to advance a range of efforts related to reducing greenhouse gas (GHG) emissions, evaluating future infrastructure risk, and supporting adaptation planning to adjust to the expected future climate of the region.

This large metropolitan area encompasses urban, suburban, and rural communities of all sizes, so a one-size-fits-all approach will not work. But the region has a long history of member governments working together to solve difficult shared challenges, of which a changing climate is certainly one. Local action on climate change is already underway and has been for years. NCTCOG is working collaboratively on several efforts, including implementation of the regional plan North Texas 2050, assessing infrastructure impacts through the Climate Change/Extreme Weather Infrastructure Vulnerability Assessment (Figure 9.4), supporting the Regional Integration of Sustainability Efforts (RISE) Coalition, and conducting a regional GHG inventory and developing a regional emission reduction toolkit.

### North Texas 2050

NCTCOG's adaptation planning work is founded in several regional efforts. Published in 2010, North Texas 2050 (Figure 9.5) was the culmination of several years of regional engagement of diverse stakeholders through a process called Vision North Texas.

North Texas 2050 describes the preferred future envisioned by Vision North Texas participants and is the result of collaboration of experts and input from residents and regional leaders. Region-wide policy recommendations span the regional ecosystem, community character and form, economy, housing, mobility, climate resilience, education, and health. An action package identifies the tools and techniques needed to achieve the vision.

While North Texas 2050 is now more than a decade old, the policy recommendations and action package are still very relevant today. This document established the region's first climate resilience policy and included six recommendations:

- Prepare indicators to measure the region's carbon footprint and monitor change over time
- Develop strategies for evolving regional strength in energy production through alternative energy markets

- Recommend actions to reduce the region's carbon footprint and adapt effectively to the impacts of climate change
- Study regional changes in climate and evaluate strategies to reduce the region's environmental carbon footprint
- Assist cities, towns, and counties in mitigating and adapting to impacts of climate change
- Create and implement educational programs to inform residents and businesses about choices that will reduce the region's carbon footprint

Several efforts have advanced in the region over the past decade that directly support these recommendations. In 2013, for example, NCTCOG was selected as one of 19 state departments of transportation and metropolitan planning organizations nationwide to help the Federal Highway Administration (FHWA) build a "community of practice" pilot program for transportation agencies seeking to increase infrastructure resilience to extreme weather events.

Over the next two years, NCTCOG participated in several peer exchanges arranged for the pilot program, and the interaction among the agencies resulted in a wealth of best practices and examples for each stage of what is now known as the FHWA Climate Change and Extreme Weather Vulnerability Assessment Framework, as well as considerations over a variety of effective adaptation options. This engagement, including an ever-expanding resource portal generated from those activities, gives the pilot teams and other agencies greater abilities to:

- Address climate change and extreme weather risks to infrastructure and vital aspects of the social, economic, and natural environments
- Build capacity among staff to understand, accept, and respond to the challenges of climate change, along with improved data, tools, and best practices to aid in evaluation and communication
- Develop replicable processes to assess areas of vulnerability to effects from multiple climate and manmade stressors, identify critical infrastructure for preservation and/or enhancement, and conduct benefit-cost analyses for determining potential returns on investment, where applicable
- Integrate climate change/extreme weather considerations into decision-making chains relating to engineering design, long-range planning, and asset management

NCTCOG's experience with this pilot study, similar to those of other pilot initiatives, helped to highlight and demonstrate the key resiliency linkages with asset management, economic sustainability, environmental stewardship, and programming accountability.

## Climate Change/Extreme Weather Infrastructure Vulnerability Assessment

Another key effort, the preparation of the Climate Change/Extreme Weather Vulnerability and Risk Assessment for Transportation Infrastructure in Dallas and Tarrant Counties, was a partnership between FHWA, NCTCOG, the University of Texas at Arlington, the City of Dallas, and the Fort Worth Transportation Authority (now known as Trinity Metro).

Developed as a preliminary assessment of critical limited-access roadways, passenger rail, and airport transportation infrastructure vulnerabilities to specific climate stressors such as extreme heat, drought, excessive rainfall, and flash flooding, the study determined a robust likelihood for increased infrastructure damage and service disruptions due to more severe storms and higher precipitation rates, as predicted by downscaled "business-as-usual" climate models, by the end of the 21st century. A strong likelihood of greater heat-related risks to infrastructure asset performance and levels of service was also recognized.

As part of the study's final report, current and planned infrastructure centerline miles or surface areas at the highest-risk locations were identified as target segments for additional future planning and expedited implementation of possible adaptation measures. Local activities such the City of Dallas Pavement Maintenance Plan and the Dallas Area Rapid Transit (DART) Severe Weather Action Plan were elaborated as examples where new resiliency data and tools may not only help highlight and address increasing asset and service performance gaps, but also enable simultaneous linkages to enhanced safety and sustainability both during and between major climatic events.

The study results underscored how, with continuing uncertainties in infrastructure revenues and growth implications over time, creation of an all-inclusive risk-based analysis grounded in resiliency would provide greater transparency and accountability to justify where, when, and why lifecycle-oriented investment choices should be made.

## The RISE Coalition

More recent actions focused on emission reductions and climate adaptation include establishment of the Regional Integration of Sustainability Efforts (RISE) Coalition in 2019. This is a committee of local government members interested in supporting a broad range of sustainability and climate action initiatives in North Texas. The RISE Coalition's purpose is to align regional partner initiatives, leverage regional resources, provide networking opportunities and mentorship, and collaborate as a group on regional sustainability projects and initiatives.

Currently, the RISE Coalition is leading efforts to produce the first GHG inventory for the North Texas region. This inventory will establish baseline 2019 GHG emissions and provide a profile of the region's contributions by sector (transportation, waste, water, and energy). This data and information will be useful in determining what emission reduction strategies are relevant and beneficial for the region and individual cities, counties, special districts, school districts, and others to consider implementing. The RISE Coalition will develop a regional toolkit that includes a comprehensive list of emission reduction strategies for each sector that could be voluntarily adopted or implemented by local governments, the private sector, or other partners.

### Key Takeaways and Next Steps

NCTCOG has initiated several actions as a result of federal, regional, and local policies and planning efforts. North Texas 2050 established a model over 10 years ago that leveraged partnerships and regional input to advance future development and sustainability in North Texas. Since publishing this document, NCTCOG has expanded programs and completed projects focused on climate actions and sustainable development, driven by requests from its local government members to bring greater definition and focus to these efforts that are important to many of them. These include supporting programs for regional air quality, integrated stormwater management, solar energy, and resource conservation; participation in the DOE Clean Cities Initiative; and an economic and environmental benefits project evaluation tool. North Texas 2050 also demonstrated the power of regional collaboration on challenges that impact more than one city or organization, such as reducing GHG emissions and implementing climate actions.

North Texas 2050 was the first regional planning effort that included climate resilience as a focus policy area with accompanying action recommendations. Since this time, momentum at the local government level has grown to have a greater focus on the three-legged stool of sustainability, including a more recent emphasis on equity in planning and implementing climate actions.

The establishment of the RISE Coalition will bring a focus to the regional projects and programs that can be implemented to reduce GHG emissions, develop partnerships and projects to advance regional efforts that are more cost effective and impactful, and produce resources for other government entities that want to expand their sustainability planning efforts. The RISE Coalition is pursuing funding to establish an equity working group, provide a sustainability mentorship program, offer sustainability training for local governments, and develop a template sustainability framework to assist local governments with limited resources in developing sustainability plans.

## ADAPTATION TO URBAN HEAT IN TUCSON

*Ladd Keith, PHD, University of Arizona's School of Landscape Architecture and Planning*

Extreme heat causes more weather-related deaths in the United States than all other weather-related disasters combined, but until recently it has received less focus than other climate risks. In addition to public health, extreme heat also impacts energy and water usage, economic productivity, urban landscapes and ecology, and infrastructure.

Extreme heat is an increasing climate risk due to climate change and the urban heat island (UHI) effect, where the form and function of the built environment increase temperatures in urban areas. While heat planning is in its early days, planners are well positioned to lead adaptation to urban heat by integrating it into existing planning processes and regulatory tools, as described in PAS Report 600, *Planning for Urban Heat Resilience*.

Tucson, Arizona, is one of the fastest-warming cities in the country. Its annual average temperatures have increased nearly 4.5°F since 1970. Temperatures in the desert Southwest are projected to increase as much as 8.6°F by 2100 under the highest GHG emissions scenario, which would mean up to 45 more days each year with temperatures above 90°F. To prepare for and respond to increasing temperatures and their impacts, Tucson has been leading the Southwest in the implementation of a range of urban heat adaptation strategies through innovative plans, ordinances, financing mechanisms, and information sources.

### Planning for Extreme Heat

The City of Tucson adopted the voter-approved Plan Tucson in 2013. This comprehensive plan integrates sustainability principles into social, economic, natural, and built environments chapters. Three of the four plan chapters identify extreme heat as a risk and provide background on heat impacts to public health, historic temperature data, climate change projections for temperatures, and information on the UHI effect. There are urban heat adaptation policies throughout the plan, including civic education on community issues such as urban heat; reducing the UHI effect by minimizing heat generation and retention in the built environment; increasing urban forestry, green infrastructure, and urban agriculture; adding shade provisions to urban design; and enhancing parks and vegetated paths.

In addition to Plan Tucson, the city has also adopted new ordinances with urban heat in mind. The Tucson Complete Streets Policy was developed by the Tucson Department of Transportation, Complete Streets Task Force, and Living Streets Alliance nonprofit and adopted in 2019. The goal of the ordinance is to "foster a vibrant, healthy, equitable, interconnected, accessible, environmentally-sustainable, and more livable city where everyone can move about safely, comfortably, and with dignity," and urban heat adaptation is a focus throughout.

The mitigation of the UHI effect is one of the ordinance's guiding principles, and criteria include increased green infrastructure, increased shade trees, and reduction of heat-trapping impervious pavement in roadway infrastructure projects. The approach of targeting the reduction of urban heat along mobility corridors is critical. Thermally comfortable "cool corridors" that connect activity nodes are more likely to encourage use by transit riders, pedestrians, and bicyclists than their traditionally designed counterparts in the face of increasing extreme heat.

## Funding and Furthering Adaptation Efforts

The Tucson region has established several financing mechanisms to fund urban heat mitigation efforts. In November 2018, voters approved Proposition 407, which will generate $225 million in funding between 2020 and 2028 to improve park amenities and connections. Many of the projects approved as part of the bond package are related to urban heat adaptation, including the addition of splash pads to parks across the city, new playgrounds with shade structures, and new shade structures at those playgrounds that do not have them. In addition to funding the installation of additional tree canopy and vegetation for traditional shared-use paths, the bonds will also enhance the city's greenway system, the park-like vegetated walking and bicycling corridors that often follow the urban waterways known locally as washes.

Another financing mechanism is the Green Stormwater Infrastructure utility service fee, adopted in May 2020. This fee is based on residents' water consumption at the rate of $0.13 per CCF of water usage and is projected to raise up to $3 million a year. Residents enrolled in the city's Low Income Assistance Program are exempt from the new fee.

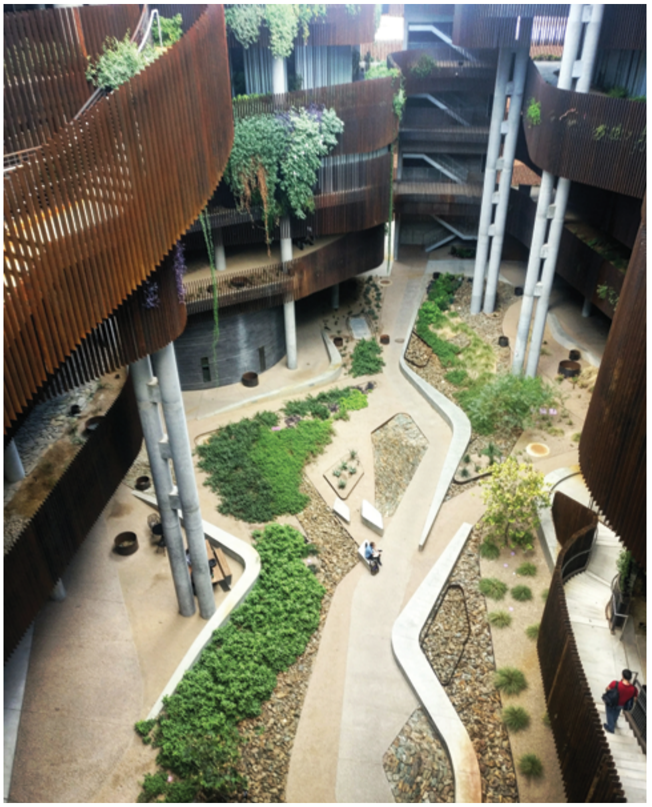


*Figure 9.6. The University of Arizona's ENR2 building mimics a desert slot canyon and features a variety of cooling strategies in its outdoor areas for users (Ladd Keith)*

The generated funds are used to install and maintain desert-adapted green infrastructure across the city, including hundreds of existing green infrastructure projects that previously had no dedicated funding source. In addition to reducing flooding issues, improving stormwater runoff quality, and providing beautification, the program also aims to shade and reduce heat on streets, sidewalks, bikeways, and parking areas. Notably, the increased vegetation strategy to mitigate urban heat in Tucson is explicitly connected to the better usage of the region's rainwater resources, helping conserve other water sources. The funds are prioritized to areas of the city identified as having high heat vulnerability.

The University of Arizona's Environment and Natural Resources 2 (ENR2) building is an example of a heat-adapted building that reduces its contribution to the UHI effect and provides cool outdoor spaces for its users (Figure 9.6).

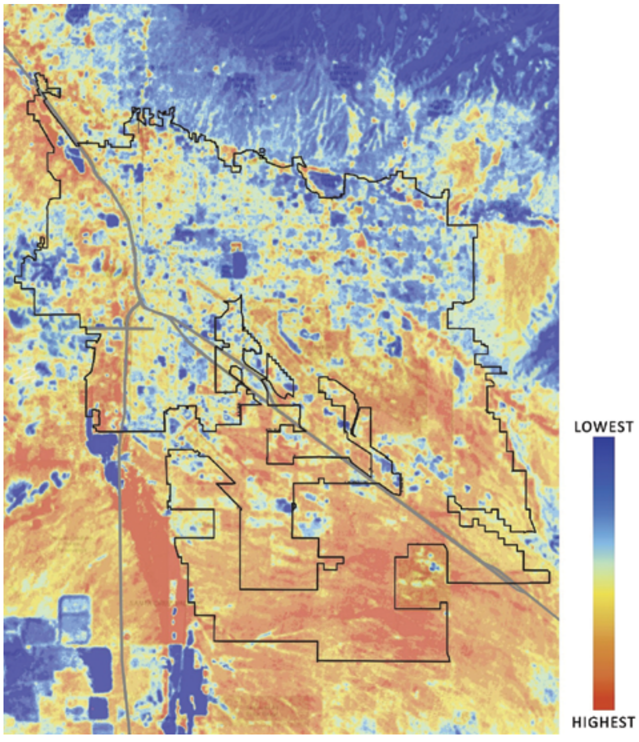



*Figure 9.7. The Pima Association of Governments (PAG)'s publicly accessible Resiliency Planning Maps tool displaying the regional heat severity for Tucson, Arizona (Pima Association of Governments)*

This LEED Platinum-certified building was constructed in 2015 and is home to several of the university's environmental-focused academic programs and initiatives. The building mimics a natural desert slot canyon and integrates vegetation, passive cooling strategies, low-maintenance materials, and other sustainable building techniques that lower its energy requirements and provide cool and shaded outdoor public locations on each level.

In addition to heat-adapted new construction like ENR2, Pima County has a home repair program that assesses hazards in the homes of vulnerable populations in the Tucson region and accompanies other statewide weatherization assistance programs. Through contributions of $3,000 per home, the weatherization program has helped around 400 households per year since 1982. Tucson Electric Power (TEP) also supports sustainability and climate adaptations for homes through its TEP Energy Smart Homes, Trees for You, and Efficient Home programs.

To help inform these urban heat adaptation efforts, the Tucson region's metropolitan planning organization, Pima Association of Governments (PAG), has hosted a publicly accessible mapping tool since 2012. The Resiliency Planning Maps tool includes layers for heat severity, urban tree canopy, cooling centers, and social vulnerability (Figure 9.7). The heat severity map was updated in 2019 and included the heat severity for the hottest months between 2013 and 2015, derived from Landsat satellite imagery. The heat severity layer will be regularly updated to reflect changes in heat severity over time. The public accessibility of the map has led to its use outside of municipal decision-making by several environmental and community nonprofit organizations.

The connection of practitioners, researchers, and stakeholders has also helped advance urban heat adaptation efforts in Tucson. One of the earliest examples is the Urban Heat Island Workshop, first hosted by the City of Tucson and Tucson Water in 2006, bringing stakeholders together to discuss heat impacts, challenges, and solutions. The Low Impact Development (LID) Working Group, initiated in 2011 by the Pima County Regional Flood Control District, has also been an important peer learning network. Its nonprofit, private-sector, and public-sector members have met regularly since then to share best practices in green infrastructure and urban heat mitigation. One of these nonprofits, the Watershed Management Group, has worked on improving the urban desert ecosystem through community-based programs since 2002. Many of these initiatives help increase the native and drought-tolerant vegetation throughout the city with passive rainwater harvesting, mitigating urban heat while also protecting scarce water resources. Finally, the University of Arizona's Extreme Heat Network has helped connect practitioners and researchers within the Tucson region and across the country through a monthly newsletter and events.

## Key Takeaways

While many of the fastest-warming communities are in the desert Southwest, extreme heat is an increasing climate risk to communities across the world. Communities in historically cooler climates are crossing into new climate thresholds, and air conditioning is now needed where it was not before.

Although each community's geography, climate, and built environment is unique, there are several key takeaways for planners from the Tucson region's urban heat adaptation efforts. First, urban heat is a complex climate risk and cannot be solved by a single "silver bullet" adaptation strategy. Tucson is addressing urban heat across levels of government and across plans and regulations. Second, it is important to secure funding sources for adaptation strategies. Tucson has several long-term and stable funding mechanisms in place to


*Figure 9.8. 2013's Climate Ready Boston report (City of Boston)*

aggressively advance urban heat mitigation efforts. Finally, publicly accessible heat information sources help direct urban heat adaptation efforts such as urban forestry and green infrastructure to the areas of the highest need. These efforts are supported by peer learning networks and connections between practitioners and researchers. Tucson's urban heat adaptation efforts provide a framework for how other communities can address extreme heat risk.

## BOSTON CLIMATE READY ADAPTATION PLAN

*Scott Turner, PE, AICP, LEED AP ND, Director of Planning and Associate, Environmental Partners*

Boston has long been a leader in climate adaptation. The city's climate initiatives began in 2007, when Mayor Thomas Menino issued an executive order directing city offices to incorporate climate considerations into all municipal planning, permitting, and review processes. In 2011, the city produced its climate action plan update, which was followed by Climate Ready Boston, a report published in October 2013 (Figure 9.8).

Climate Ready Boston identified initiatives and actions to protect the city from a changing climate, including assessing the consequences of climate change over the next 75 years, determining the vulnerabilities and priorities for city departments, and determining priorities for moving forward. Significant impacts included changes in temperature, increased precipitation, and sea level rise. The report prioritized assessing city-owned buildings, transportation, and water infrastructure; protecting neighborhoods; and incorporating climate-related preparedness criteria in the review of new development projects.

In 2016, under the leadership of Mayor Marty Walsh, the report was updated to include revised climate projections (including extreme temperatures, sea level rise, and extreme precipitation and storms). The 2016 report focused on assessment of hazards including extreme heat, stormwater, and coastal and riverine flooding. It also highlighted eight Boston neighborhoods and areas—Charlestown, Charles River, Dorchester, Downtown, East Boston, Roxbury, South Boston, and the South End—for additional more detailed study. Key initiatives include expanding education and engagement, developing local climate resilience plans, prioritizing flood defense, establishing an infrastructure coordination committee, using green infrastructure solutions on public land, and revising the city's zoning code to support climate-ready buildings and prepare municipal buildings for climate change.

### Key Strategies

Following the release of Climate Ready Boston in 2016, the city has made substantial progress on the key initiatives outlined in the 2016 document.

- *Coastal Resilience Solutions for East Boston and Charlestown* was published in October 2017. This report recommends both short- and long-term interventions such as installing deployable floodwalls, elevating streets, and constructing or elevating new and existing open spaces to reduce risks from the 100-year storms and projected sea level rise.
- *Coastal Resilience Solutions for South Boston* was published in October 2018. This report recommends numerous improvements, including flood-proofing existing buildings, constructing seawalls, raising the existing harborwalk, filling portions of the Fort Point Channel,


*Figure 9.9. Boston's Moakley Park Vision Plan (Stoss Landscape Urbanism)*

constructing a living shoreline, and beach restoration and shoreline protection. Fortifying the Fort Point Channel is the highest priority as it represents a major floodway into South Boston and other parts of the city.

- *Coastal Resilience Solutions for Downtown Boston and North End* was published in September 2020. This report recommends a series of coastal protection systems along Long Wharf, Harbor Towers, Christopher Columbus Park, and Sargent's Wharf, including significant upgrades to Langone Park and Puopolo Playground. This report also recommends raising the existing harborwalk, filling additional land along the shoreline, and protecting existing buildings located along the shoreline.
- *Coastal Resilience Solutions for Dorchester* was published in October 2020. This report contemplates connecting and fortifying a number of existing open spaces, marshes, and parks while protecting critical portions of the city's transportation system, including Morrissey Boulevard and the MBTA Red Line.

All of these efforts included a significant public participation component dedicated to soliciting input from residents from the city and each specific neighborhood. Public engagement for each study included open houses, neighborhood meetings, online surveys, and meetings with key stakeholders to inform recommendations. Each study provides recommendations to providing public access to public waterfront parks, the harborwalk, and other open spaces as well as ensuring that access and connections to these resources are available to all residents of the city.

## Other Planning Efforts

In addition to Climate Ready Boston and the subsequent individual neighborhood studies, the city has proceeded with numerous other planning initiatives and processes that reinforce its commitment to addressing climate change issues.

- Resilient Boston, published in 2017, was undertaken in collaboration with 100 Resilient Cities (100RC) and focuses on racial equality as a necessity for dealing with a number of challenges, including climate change.
- Imagine Boston 2030, published in July 2017, was the first citywide comprehensive plan prepared for the city since 1965. It set five citywide goals, including promoting a healthy environment and preparing for climate change. Consistent with this goal, Imagine Boston sets a target for reducing emissions by 50 percent by 2030, reaching carbon neutrality by 2050, reducing economic loss due to climate-related flooding, and increasing tree canopy coverage.
- Boston Resilient, Historic Buildings Design Guide was published by the Boston Environment Department in August 2018. This document provides a guide for property and historic building owners to reduce energy consumption, create renewable energy, mitigate flood risks, contribute to thermal comfort of building occupants, and adapt to changing conditions.
- Coastal Flood Resilience Design Guidelines was published by the city in September 2019. These guidelines provide property owners and developers tools to ensure their existing and new assets are protected from flood

damage caused by climate change. This guide provides four overarching strategies for building owners: ensuring adaptation strategies are forward looking, requiring that all solutions benefit the public realm, developing strategies that enhance surrounding landscapes, and improving stormwater management and energy efficiency.
- In 2021, the city adopted a Coastal Flood Resilience Zoning Overlay District ordinance. This district applies to all areas projected to experience a one-percent flood with 40 inches of sea level rise, which encompasses a significant area of the city. This zoning bylaw requires all proposed projects located within this district to undergo a resilience review for consistency with the city's Coastal Flood Resilience Design Guidelines.

In addition to these planning processes and reports, the city is currently re-imagining Moakley Park in South Boston as a coastal park that will provide protection from sea level rise and storm surge while offering improved recreational opportunities for all residents (Figure 9.9, p. 117). Design of this park is ongoing and when completed, this project will represent one of the first significant physical improvements designed to provide protection from climate impacts.

The City of Boston continues to be a national leader in preparing for the impacts of climate change.

## ALEXANDRIA ENVIRONMENTAL ACTION PLAN

*Rob Kerns, AICP, Development Division Chief, City of Alexandria*

The City of Alexandria, Virginia, has long been a leader in sustainability. Alexandria's recently adopted Environmental Action Plan 2040 (EAP 2040) for sustainability builds on the city's 2008 Eco-City Charter and the first Environmental Action Plan (EAP 2030) adopted in 2009.

A walk along Alexandria's tree-lined streets reveals elements of sustainability all around: small, local shops and farmers markets, state-of-the-art stormwater tree pits, parks, roads designed to promote biking and walking, and many new green buildings. The city has achieved a per capita GHG emission reduction of 22 percent (2005 base year) by completing or adopting a majority of the 363 actions in the EAP 2030 policy plan. The most significant achievement was closing the coal-fired power plant in 2012 well ahead of the target date. Other achievements are highlighted on Alexandria's Eco-City webpage.

To address the urgent global climate emergency, Alexandria's EAP 2040 sets targets to reduce emissions by 50 percent by 2030 (base year 2005) and to approach net zero or carbon neutral, an 80–100 percent reduction, by 2050. It recognizes that achieving these goals will require local governments, especially urban ones, to be supported by national and state governments in many ways, but especially to significantly push renewable energy for the regional electric grid and improve the efficiency of vehicles. It may also require carbon sequestration actions and negative emissions technologies such as aggressive tree planting and reforestation.

There are 10 sustainability topics covered by EAP 2040, each with an average of two goals and four to six actions in each goal. The 10 topics are climate change; energy; green building; land use and open space; solid waste; water resources; transportation; environmental health; air quality; and implementation, education, and outreach.

### Climate Change Challenges and Approaches

As a tidal riverfront city, Alexandria is particularly vulnerable to the threats of climate change. Its Old Town district is already regularly subject to weather-related localized flooding. EAP 2040 is focused on both climate mitigation and adaptation. Reducing carbon emissions in all sectors is a key mitigation strategy.

Most (96 percent) of the city's GHG emissions are from residential and commercial buildings and transportation. To lower Alexandria's emissions, EAP 2040 recommends aggressive green building policies while acknowledging that current core functions in the city will still require the use of fossil fuels during the transition to electrification.

*Figure 9.10. Robinson Landing promenade adaptation project (Robert Kerns)*

Between 2012 and 2015, the city's transportation emissions decreased due to lower-carbon mobility options of public transportation systems and changes in the grid fuel mix, an encouraging trend. The city is preparing for electric vehicles by requiring new buildings to provide a minimum number of EV charging stations and running the conduit systems in these buildings for easy future expansion. It is also creating a strategy for a public charging infrastructure.

Rising sea levels and increased storm activity will make localized flooding a more significant issue for Alexandria, with resulting impacts on public safety, private property, and businesses. Resiliency planning and adaptation at the waterfront and elsewhere, along with emergency operations, are important actions in EAP 2040. One example of a key adaptation strategy is the city's effort to raise the elevation along the central waterfront to address current and projected flooding events.

The central waterfront flood mitigation project has been underway for the past decade. It began with the Potomac River Waterfront Flood Mitigation Study (FMIP), prepared by engineering and design consultants for the city in 2010 and updated with pricing in 2012. The FMIP identified specific flooding problems and their causes, evaluated strategies to solve these problems, and recommended the most effective adaptation solutions. Of the recommended strategies, the preferred option was to construct a structural bulkhead that would act as a flood barrier for river water levels up to six feet. Additionally, the city is identifying secondary infrastructure and public park amenities that can be incorporated into the project. Robinson Landing, a private development on the city's waterfront, has constructed the first piece of the proposed structural bulkhead and waterfront promenade (Figure 9.10, p. 118).

*Figure 9.11. The Virginia Tech Innovation Campus, with building design inspired by collection of solar energy (Virginia Tech)*

## Raising Standards for Developers

Along with completing EAP 2040 in 2019, the city adopted a new green building policy to implement the goals of the EAP. This policy applies to all development site plans seeking approval in Alexandria and substantially raises the bar on new construction.

All new private projects in the city are required to achieve LEED Silver (or an equivalent level within another certification system) and attain priority performance points in energy, stormwater, and indoor air quality. These performance points push projects to prioritize green building features that are most important for Alexandria's context. Public projects are required to achieve LEED Gold (or equivalent) and new facilities should aim to be net zero. Alexandria approved its first net-zero elementary school in 2020.

Another green building effort underway to implement the EAP is incentivizing larger development tracts with additional density to voluntarily exceed the green building policy requirements and focus on neighborhood-level energy and stormwater systems that can achieve better sustainability performance. An example of this is a sewer-wastewater energy exchange (SWEE) system being installed by the Virginia Tech Innovation Campus in Alexandria (Figure 9.11) to harness the energy from the new neighborhood's sewage flows to power the campus. In addition, EAP 2040 requires larger projects to be carbon neutral by 2030 through ongoing performance monitoring and introduction of new technologies in neighborhood buildings and infrastructure.

## Key Planning Takeaways from EAP 2040

There are several important considerations for planners from Alexandria's EAP planning process.

- **Focus on a smaller number of higher-priority actions.** For this EAP update, city staff made a deliberate decision to pursue a smaller number of higher-level, less-specific actions. This allows the city to prioritize limited resources for fewer actions with higher-level goals when implementing the plan.
- **Harness interconnected co-benefits.** Actions in EAP 2040 are interconnected and provide additive benefits across multiple sectors. The goals, targets, and actions in one section (e.g., reducing single-vehicle commuting in transportation) affect other sectors (e.g., energy, air quality, environmental health, and land use and open space). This is especially important in cities because they generally benefit from the proximity of community amenities, homes, and jobs. These synergies connect the

impacts of EAP 2040 across topics and the results are captured in the monitoring and tracking of implementation progress.

- **Track metrics.** The EAP 2040 update prioritized tracking and metrics to better understand how effective actions are in terms of better sustainability performance. This will help community members see the tangible results of actions. It will also inform future revisions to approaches and prioritizing future investment for maximum benefits. Overall, it will show how well Alexandria is doing with addressing climate change.

The goals and targets of EAP 2040 seek to significantly exceed regulatory minimums, achieve carbon neutrality by 2050, and provide better tracking and performance. This will require all in the city to take action, make sustainable choices, do their fair share, and work together to be successful.

## MONROE COUNTY SUSTAINABILITY AND CLIMATE CHANGE INITIATIVE

*Erin L. Deady, PA, AICP, LEED AP, Erin L. Deady Law Firm, and Rhonda Haag, Chief Resiliency Officer for Monroe County, Florida*

Monroe County, Florida, is an island chain more than 100 miles long in the Florida Keys and is the United States' most southern county. The county has been working for more than a decade on becoming more resilient and climate ready, primarily through its GreenKeys! planning process.


*Figure 9.12. October king tide road flooding in Key Largo, Florida (Erin Deady)*

The county is designated as one of only a few Areas of Critical State Concern within the Florida Statutes due to its sensitive habitat, hurricane evacuation needs, and critical marine ecosystems. Along with Miami Dade, Broward, and Palm Beach Counties, it is part of the Southeast Florida Regional Climate Change Compact, an entity that works to improve resilience across the entire south Florida region through the sharing of data and science and through the development of unified sea level rise projections.

### GreenKeys! and King Tides

In 2013, Monroe County embarked on a planning process to begin identifying its vulnerabilities to climate change. The GreenKeys! planning process took place over the course of two years and culminated in the GreenKeys! Sustainability Action Plan, along with a five-year work plan and a vulnerability assessment. The vulnerability assessment from the plan serves as the county's first such assessment and modeling exercise for sea level-based climate impacts.

Following the completion of the GreenKeys! plan, the increasing depth, severity, and duration of October king tides throughout the Florida Keys have played an increasingly pivotal role in helping the community understand what the primary future impacts of climate change and sea level rise will be. A king tide is an exceptionally high tide that typically occurs during a new or full moon, when the moon is closest to the Earth in its orbit, or during specific seasons around the country.

In 2015 and 2016, the king tides were particularly high, resulting in prolonged saltwater on many neighborhood roads. This has helped shape one of the most critical priorities in the Keys' adaptation planning process—impacts to roads and the need for flood mitigation projects. Without a functional road system, people will not be able to get to work or pick their kids up from school and tourism will be impacted. Because of this, planning for roads has been a high priority for the county.

Based on recommendations in its GreenKeys! plan, the county has collected highly accurate elevation data upon which to base its further planning efforts. The county has also launched a specific planning process for road elevation, stormwater, and flood mitigation. The process will prioritize road elevation projects, identify necessary stormwater and flood mitigation features, develop conceptual designs, and provide timeframes and preliminary cost estimates to help the county implement these types of capital improvements.

These efforts are being planned based on sea level rise scenarios developed by the Southeast Florida Regional

Climate Change Compact and projected king tide elevations based on data from the National Oceanic and Atmospheric Administration (NOAA). The county is estimating the cost of reconstructing the most vulnerable 25 percent of the roads to higher elevations with stormwater features by 2045 to be approximately $2 billion.

In addition to developing the GreenKeys! Sustainability Action Plan in 2016 and updating it in 2018, Monroe County has also undertaken the following activities:

- Adding a new energy and climate element to its comprehensive plan (2016)
- Implementing road elevation pilot projects in two communities (2015–present) with the final report including a design methodology for road elevation
- Obtaining two site-specific adaptation planning grants for a county park and an assisted living facility (2018 and 2019), two important facilities within the county
- Obtaining two state grants to assist in developing draft resiliency-based comprehensive plan amendments (2019 and 2020) that will culminate in the county's upcoming Evaluation and Appraisal report process
- Securing mobile Lidar elevation data throughout the entire county (2019) to provide better elevation data for roads and other vulnerability work
- Securing a NOAA grant to create stormwater management system data and a watershed management plan—a Community Rating System (CRS) activity
- Achieving a class rating of 3 through FEMA's CRS program (2021)
- Enhancing interagency and community participation to harmonize resiliency and floodplain management planning initiatives and activities

In 2021, the county concluded an update of its previous vulnerability assessment work. This was funded by a grant from the State of Florida and included new updated sea level rise projections from the Compact as well as new social vulnerability analysis. This work continues Monroe County's efforts to become a more resilient community and will serve as a basis for an update to the five-year work plan and support upcoming grant applications to the State of Florida's new Resilient Florida program.

## Key Takeaways

There are several key takeaways from Monroe County's resiliency planning efforts that can be helpful to other communities.

- **Start planning now for tomorrow and plan further out.** The legal issues, policy response, and citizen engagement for flooding and sea level rise are only becoming more imminent and complex. Some worry that sharing too much information can scare the public. Others feel strongly that communicating the future risks is the key to transparently informing people about what is to come. Using flood events to help increase awareness, such as encouraging the submission of photos, has been key to engaging the community in these discussions. Planners must look beyond the typical 10- or 20-year planning horizon to the 25- or 50-year lifespan of assets and infrastructure, which is where the appreciable impacts of climate change will really be seen. Thinking longer-term now will help make sure the right investments are made for the future.
- **Understand your data (or lack thereof) and collect it.** To embark on a sea level rise planning process, good data is critical. An initial assessment using GIS to map locations of infrastructure, services, and other local government assets is pivotal. If structure data is not available in GIS formats and elevations (above and below ground) are not known, it is very difficult to model what future flood risk looks like. Investing in good data and GIS improvements is important to assist with modeling efforts for future adaptation of structures, roads, and stormwater outfalls.
- **Look for opportunities to harmonize planning efforts.** Monroe County was fortunate to be able to coordinate its floodplain, CRS, grant, and modeling efforts to produce a sea level rise, CRS-compliant watershed management plan. CRS ratings establish insurance premium reductions on National Flood Insurance Program policies—the better the rating, the bigger the discounts. Monroe County's Class 3 rating translates to a 30 percent reduction for policyholders. The FEMA requirement that CRS watershed management plans project sea level rise out to 2100 might convince reticent communities to undertake these modeling processes. Doing that upfront work can create efficiencies across initiatives.
- **Prioritize public involvement and communications.** There is no amount of public involvement and communication that is enough when talking about future flood risk and people's investments in their homes and businesses. Local governments should clearly communicate what they are responsible for maintaining (i.e., public assets and infrastructure) and what private-property owners will be responsible for (i.e., site level fill, seawalls, buffering, and onsite stormwater retention). People need

> to understand that there is no governmental obligation or available funding to help every individual property owner adapt to sea level rise, and they will have to make individual choices about their property or business investments and future quality of life. Policies should address local government design criteria for infrastructure and future development as well as what individual property owners will be encouraged or permitted to do to adapt their properties. Discussions about funding strategies, special assessments, grant funds, and how the community will pay for climate adaptation are crucial early in the process.

Monroe County is an excellent case study demonstrating a couple of key elements of climate resiliency planning. First, this is not a "one and done" proposition for communities—data changes and gets updated periodically and this will influence local government decision-making. Second, transparency is key in using data and establishing a technical basis for planning, policy, and funding decisions. Finally, communication with the community is crucial. The public doesn't necessarily have to agree with specific sea level rise projections, but they do need to understand why the local government is taking the approach it is taking and its basis for decision-making.

## CONCLUSION

Planners' roles in advancing climate action will require proactive and sustained efforts. As these case studies have highlighted, it will require a dual approach focused on both mitigating GHG emissions and adapting to a changing climate. It will require planners from all levels of government to take leadership on forming partnerships for both planning and post-plan implementation. It will also require planners to be flexible and adaptive in their approaches and methods, be responsive to changing conditions, and proactive in taking advantage of opportunities as they arise.

The final chapter wraps up this report by focusing on how planners get to action. It overviews principles that planners need to consider when planning for climate mitigation and adaptation, provides an overarching climate planning framework, and introduces key climate implementation tools already developed to help planners get to action faster.

CHAPTER 10

# TAKING CLIMATE ACTION

As highlighted throughout this PAS Report, addressing the climate crisis necessitates immediate and sustained action. This is because climate change and its associated impacts will continue to worsen even after human-caused global greenhouse gas (GHG) emissions are mitigated.

Although climate change will affect all living and nonliving things across the Earth, it will disproportionately affect urban areas, where over 70 percent of the world's population is expected to live by 2050.

This concluding chapter provides a blueprint for planners to initiate action in their communities across the country. It overviews principles that planners need to consider when planning for climate mitigation and adaptation, provides a climate planning framework, and introduces key climate implementation tools already developed to help planners get to action faster.

## A PLANNER'S ROLE IN CLIMATE ACTION

The changing climate is, and will continue to be, impacting local communities and overall livability. From sea level rise to catastrophic flooding to the urban heat island effect, these impacts are worsening and will increasingly affect our most vulnerable populations. As introduced in Chapter 1, planners are particularly qualified to take a leadership role in addressing these climate impacts, and it truly will be the defining challenge of our generation and generations to come.

As stated in both the AICP Code of Ethics and Professional Conduct and the American Planning Association's Ethical Principles in Planning, planners' primary obligation is to serve the public interest. Planners aspire to have "special concern for the long-range consequences of past and present actions," endeavor to "conserve and preserve the integrity and heritage of the natural and built environment," and "use principles of sustainability and resilience as guiding influences in our work" (APA 2021). The climate crisis provides no better example of where these three issues intersect. Planners are also the only professionals whose focus is the scale of entire cities.

Although climate mitigation success is measured at the global scale, action needs to be local. Climate adaptation is hyperlocal. This places planners at the forefront of the climate response. Planners are key players in the processes leading the growth and redevelopment of cities, and they will play critical roles in scaling up local climate action.

## PRINCIPLES FOR CLIMATE ACTION

Unlike traditional planning and development actions that can be easily implemented as part of siloed responses, implementation for climate mitigation and adaptation action will require fundamental shifts in governance, community growth and redevelopment, and essential services.

As such, there are several guiding principles that need to be considered as part of any planner-initiated climate action. These include:

- **Set ambitious, yet achievable goals.** Global net zero emissions must be reached by mid-century to keep the 1.5°C of warming target, as set out in the 2015 Paris Agreement, in reach. A recent study by Meerow and Woodruff (2020) suggests that even when communities develop climate mitigation, adaptation, or resilience plans, they are often lacking in ambition or quality. Inherently, the extent, scale, and timeframe of climate action necessitates a bold and ambitious vision, yet one that allows for measured progress of implementation.
- **Maximize the toolbox.** Planning for climate change can be accomplished in numerous ways, and the climate

crisis requires planners to be proactive in maximizing the toolbox of climate-friendly approaches and solutions. As such, a policy framework could be established as part of an overarching comprehensive plan or other long-range plan (e.g., a hazard mitigation or emergency preparedness plan, special area plan, or others), or as part of recovery and redevelopment efforts stemming from a post-disaster response. Strong leadership could also achieve positive climate outcomes by promoting climate considerations in routine new infrastructure projects and upgrades, or as part of updates to regulations, changes in city operations, investment in capacity building, and in other processes planners are usually involved in.

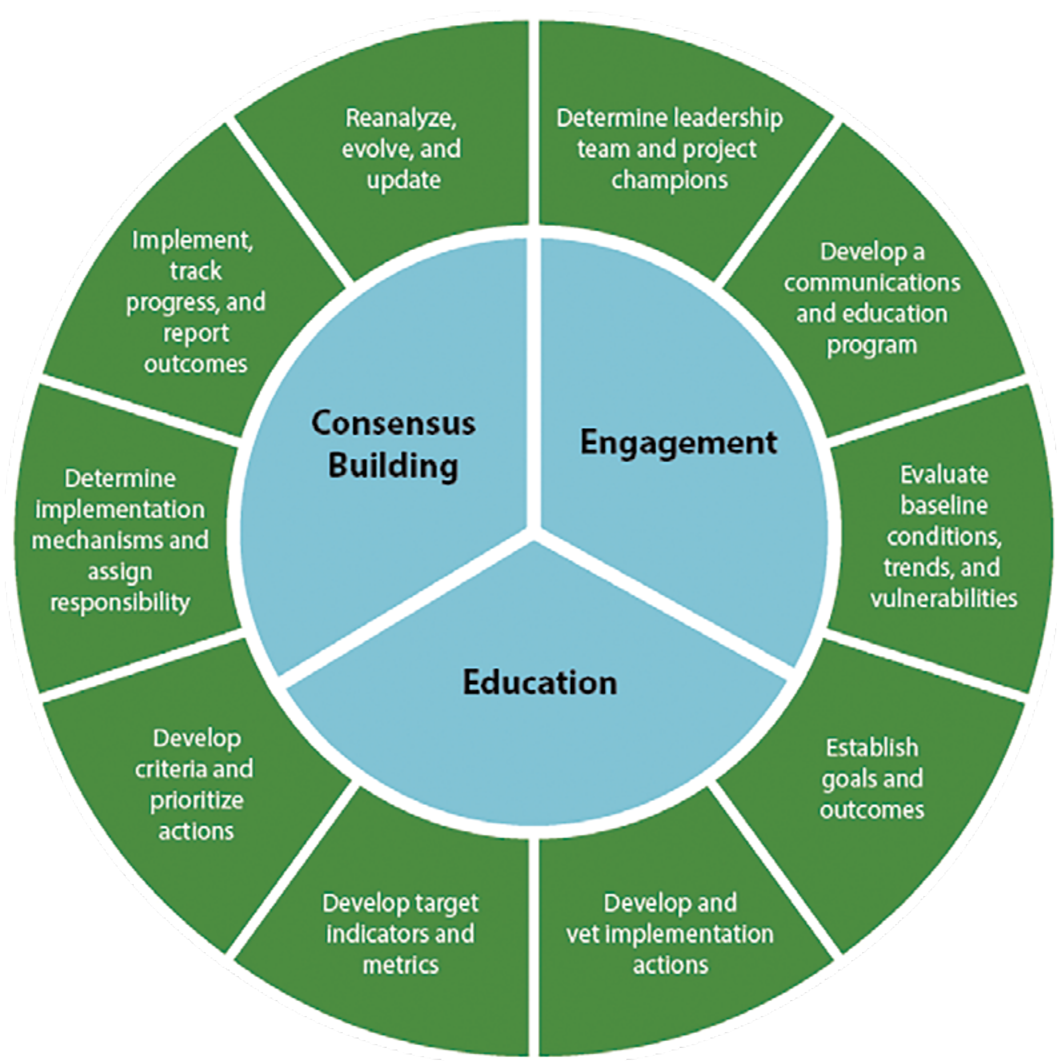
- **Engage, educate, and foster equitable outcomes.** The climate emergency is and will continue to be the most critical long-term and complex crisis facing society today and for generations to come. The science is clear and alarming. But the associated climate dialogue and debate is still oftentimes shrouded in skepticism and misinformation. A positive climate response will require enormous amounts of public engagement and consensus building, which starts with climate education—about the crisis, the local impacts today and tomorrow, and viable options for moving forward. Since climate impacts do not affect everyone equally, planners and policy makers must foster equity outcomes especially for those vulnerable communities who will be impacted the most and who traditionally do not have a seat at the proverbial table.
- **Build interdisciplinary partnerships and cross-sector collaboration.** Thus far, our response to the climate emergency has all too often been piecemeal, siloed, and not commensurate with the need. Facing this challenge will require collaborative leadership supported by an interdisciplinary team of partners and cross-sector collaborators all working together to address climate change and its associated impacts. Only with strong partnerships can there be enough resources to effectively and adequately respond to a rapidly changing climate.
- **Address vulnerabilities and uncertainties.** The scientific community is overwhelmingly in agreement that climate change is occurring and is caused primarily by human GHG emissions. But science is the application of knowledge and understanding based on evidence. Climate science, particularly as it relates to future GHG emissions, is based on predictive models of human and natural behavior. While the scientific evidence is overwhelmingly clear as it relates to the impacts of GHG emissions today, it is less precise farther out in the future, and we can only make assumptions as to future global efforts and success in reducing GHG emissions. As such, planning for climate resilience must acknowledge these uncertainties while addressing existing and likely vulnerabilities. Because new buildings and infrastructure typically last decades or longer, and because of the rapid and accelerating speed of the changing climate, it will not be enough to just address present-day impacts without thinking about the future.
- **Use whole-systems thinking.** Building a climate-resilient future will require a whole-systems thinking approach to planning and community development. Global warming and worsening climate conditions are a direct byproduct of how we have built our cities and live our lives. It is a complex, but explicitly linked, interconnected feedback system and relationship. The solutions to fix the climate emergency will require us to similarly respond with a focus on systems. This involves both an understanding of the negative climate inputs (the link between the built environment and GHG emissions) and the myriad of possibilities to change course, both directly (e.g., lowering carbon emissions through the purchase of renewable energy credits) and indirectly (e.g., capitalizing on a road retrofit to plant carbon-sequestering trees).
- **Plan and design for resilient and sustainable outcomes.** Planning and designing for community resilience must include both resilience and sustainability outcomes. The challenges are too great and the resources too scarce to be focused on short-term solutions that are unable to be maintained over the long term. This dual focus acknowledges that there are inherent differences between the two, yet both are important. A sustainability outcome would be to protect and preserve the natural flood carrying capacity of floodplain corridors through an urban area. A resilience outcome would be to design structures to be flood resistant, or even better, to not locate them there at all.
- **Develop diverse, flexible cross-sector strategies.** The impacts of climate change are interrelated and all encompassing—affecting all populations, resources, systems (both natural and, increasingly, manmade), and sectors. Responses that consider only a single climate sector or resource increase the inherent risk that they will affect or exacerbate issues in other sectors or populations. The need for flexibility stems from the uncertainty regarding future climate impacts. As such, planning for climate resilience requires a focus on diverse, flexible cross-sector strategies.
- **Prioritize for multibenefit outcomes.** Mitigating and adapting to climate change will involve and impact our

ecological, social, economic, institutional, infrastructure, and urban systems. The extent of the response needed will exceed our capacity to achieve the necessary outcomes. As such, planners must make every attempt to maximize the value of every project through a focus on multibenefit outcomes—e.g., an urban drainage park that protects against flooding, reduces ambient air temperatures and the urban heat island effect, improves biodiversity, and provides recreation opportunities.

- **Integrate implementation and monitoring into the planning process.** Planning is often said to be much easier than implementation. Despite the development of many climate action plans and policies, implementation has not yet resulted in significant reductions in GHG emissions or adaptation to long-term future impacts. To ensure successful outcomes, implementation must be a focus of the planning process. This means that plans need to include realistic and actionable strategies, measurable outcomes, a clear timeline, plausible funding sources and mechanisms, and a responsible champion for each action. In addition, all plans should include a built-in accountability framework for post-adoption action and measuring and tracking success and failures over time.

Planning will play a crucial role in advancing climate action. The application of these planning principles provides

*Figure 10.1. A climate planning framework*



planners with the necessary foundation to succeed in an ever-changing and uncertain environment.

## A CLIMATE PLANNING FRAMEWORK

Implementing the principles for climate action listed above requires planners to advance climate planning now. This requires planning for climate mitigation and adaptation as described in this report to advance a climate-resilient future. It is imperative that planners move forward with the sense of urgency that responding to the climate crisis requires.

Planning for a climate-resilient future requires a few key considerations that are particularly important for climate-related outcomes (Figure 10.1). All efforts must be people-centric and rooted in the following three foundational elements:

- **Engagement.** Engagement is a foundational component of the climate planning framework. The scale and extent of impacts warrant a comprehensive engagement program throughout all steps of the planning process. In particular, it requires planners to ensure engagement and representation from a broad spectrum of the community (including youth) and the most vulnerable or disadvantaged populations. As part of the development of the engagement program, it is critical to evaluate key community groups and stakeholders. This evaluation should include identification of key stakeholders and their levels of engagement. To ensure quicker and more effective implementation, it also requires involving those who will implement the climate planning recommendations, including community elected and appointed officials, the private sector (e.g., developers, energy partners, etc.), and other partners.
- **Education.** Education is another foundational component of the climate planning framework. Planners must ensure all stakeholders understand the near- and longer-term impacts of their decision-making, including the critical tradeoffs that will be needed among the many competing priorities.
- **Consensus building.** The third foundational component of the climate planning framework involves consensus building. This requires planners to become expert facilitators who are skilled in building consensus among stakeholders, both present and not present, who bring various viewpoints and disparate priorities.

Engagement, education, and consensus building must be an overarching focus throughout the process. Once these foundational considerations are met, a climate planning framework that integrates mitigation and adaptation approaches to create more climate-resilient communities should include the following steps.

### Determine Leadership Team and Project Champions

Planning for climate action requires a strong, interdisciplinary leadership team and designated champions who will be outward-facing stewards of the project. The mobilization of all resources needed for planning for a changing climate requires an interdisciplinary leadership team that represents every facet of community growth and development. This ensures that all the necessary baseline information can be appropriately collected and strengthens the chances of successful outcomes because actions will be subsequently implemented through multiple departments, programs, and initiatives overseen by this leadership team. The leadership team should include an experienced and respected chair who is able to manage both people and outcomes.

Project champions are also critical. They are those people within an organization or community who take on the burden of ensuring everyone is on board and sharing in the ultimate success of the project. This means that they need to be authoritative both within the group and the overall community. Project champions greatly increase the chances of a successful process and are critical to post-project implementation outcomes by continuing to advocate for implementation long after the project is complete.

### Develop a Communications and Education Program

Communicating with and educating leadership, stakeholders, and the public is an important part of any planning process—and a critical part of a process that involves climate change. This is because the changing climate impacts all facets of the built environment, from governmental operations to how we live our daily lives. It requires proactive action to prevent current and longer-term impacts, many of which cannot be readily seen (e.g., the gradual increase in temperatures over time) or will occur decades down the road—and success is only measured based on the global response. And the changing climate is only one of many global disrupters affecting our communities. This necessitates a strong communications and education program that starts with project initiation and continues through project implementation. The communication and education program must emphasize that impacts, and associated extent and costs to adapt, will exponentially worsen the less successful efforts are at mitigation.

### Evaluate Baseline Conditions, Trends, and Vulnerabilities

Planning for climate change needs to be specific to the local region and community. It needs to include an analysis of the current and future ecological and socioeconomic climatic trends, and it needs to consider how changing conditions will impact the environment, businesses, institutions (including governmental operations), and local vulnerable populations. It needs to be objective and data driven so that baseline metrics can be developed and tracked over time as actions are implemented.

Historical trends are important in that they help to explain changing local climate conditions. They are also important because people trust what they know and experience, more so than something that is modeled or predicted. But projections are extremely important too. They provide a snapshot of future potential conditions based on various mitigation success rates, and they create the basis to communicate changes in scale and extent of impacts as the climate continues to warm further over time. It is the communication of these impacts that can moivate people to proactively mobilize for action.

### Establish Goals and Outcomes

Once a baseline assessment is complete, the true extent of existing and future impacts should be apparent. This provides the starting point for stakeholder discussions regarding how to address them. This is probably one of the most critical components of the process. Developing project goals and outcomes for climate mitigation and adaptation require educated and informed stakeholders who have a full understanding of all the interrelated issues that affect community growth and development.

Goals are important to establish a future target worth striving for. But for goals to be achievable, they must be specific and include identifiable, measurable outcomes that accurately describe what will happen if the goal is achieved.

### Develop and Vet Implementation Actions

Once goals and outcomes to achieve more climate-resilient communities are defined, actions can be developed to achieve those goals. The development of actions requires a critical focus on implementation—but this is where many plans and projects fall short. Implementation needs to be front and center during the development of the action itself. Also, the speed, scale, and extent of impacts stemming from a changing climate necessitates a "climate in all actions" focus, with particular attention to cross-sector strategies that address multiple community issues simultaneously. The chapters on climate mitigation and adaptation in this report offer a wide range of considerations, strategies, and approaches for planners to consider for mitigation and adaptation action in their communities.

One important consideration noted throughout this report is that the climate will continue to change for the next several decades or centuries, even if the global community rapidly achieves net-zero carbon emissions. This means that local communities must be prepared for the continuation and worsening of impacts that are already being felt today. Therefore, adaptation actions need to be scalable over time (e.g., the installation of a two-foot sea wall to address today's sea levels that is designed to accommodate an additional four feet to address future conditions). This requires planners to focus on high-impact strategies that can move the bar quickly, but they must also develop a better understanding and communication of the economic benefits, and conversely, impacts of implementing climate solutions.

### Develop Target Indicators and Metrics

It is important to identify specific, quantifiable target indicators and metrics. These should be derived from the baseline conditions identified at the beginning of the process. This allows for a comparison between base and future conditions and provides for objective evaluation of a project's success. Chapter 7 offers a list of climate action-related metrics.

The determination of indicators or metrics should account for changing conditions (e.g., population size). An example is per capita number of solar panel installations, rather than total number of installations. This provides for an objective evaluation of success whether the community grows or shrinks, or whether growth is fast or slow.

Additionally, consideration should be given to the availability and ability of staff to collect and track data over time. This means that the indicators and metrics should be developed using commonly available sources of information (e.g., the number of permits for solar installations against annual population estimates) to ease tracking and updating over time.

### Develop Criteria and Prioritize Actions

Two fundamental truths must be considered when determining priorities: competing needs will be significant and

## APA RESOURCES FOR ADVANCING CLIMATE POLICY

Advancing climate policy requires planners to use all tools in the toolbox and to act with unprecedented speed across all scales and sectors of government. This means that planners must maximize use of existing tools at the same time as developing new ones. In addition to this PAS Report, planners can look to the APA resources described below to help advance climate action. Additional APA climate-related resources are listed in Appendix B of this report.

### Climate Change Policy Guide

This APA policy guide, adopted in 2020, is intended to help planners formulate position statements, legislative recommendations, and other policy-based actions, and to recommend program funding at the federal and state government levels. It also provides planners with a comprehensive starting point of resources for advancing effective policy at the local level.

The policy guide is organized around six principles established by APA's Comprehensive Plan Standards for Sustaining Places (Godschalk and Rouse 2015)—livable built environment, harmony with nature, resilient economy, interwoven equity, healthy communities, and responsible regionalism—as well as an additional organizational priority, federal and state policy action. This promotes development of climate policy that is comprehensive and interdisciplinary in nature—a necessity due to the interrelated nature of how cities and communities grow and change over time—and reflects the importance that federal and state policy plays in all local action.

The guide explains the importance of each principle (plus federal and state considerations) and offers more specific policy statements and individual strategies to further define each principle, creating both a comprehensive policy toolkit and preliminary next steps for climate action. Although the policy statements provide planners with a comprehensive starting point for advancing climate policy, it is the additional associated strategies that makes this resource a strong tool for advancing climate action.

### Climate Change Research KnowledgeBase Collection

The Climate Change KnowledgeBase collection, published in May 2022, brings together more than 300 APA and non-APA resources on planning for climate mitigation and adaptation. Resources range from reports, articles, and blog posts, to clearinghouses, toolkits, and guides, and include model and sample policies, plans, and regulations relating to climate change. The database can be searched and results filtered by various geographic and demographic characteristics.

### SCD Climate Action Resources

APA's Sustainable Communities Division (SCD) has developed resources for planners to use to advance climate action at the local level. This growing list of resources can be found on the division's website. Key documents include the following:

- **Climate Data Collection Process Guide.** This resource provides planners with guidance on accessible data collections and data calculation methodologies for climate action. It includes a list of data resources available for communities across the United States to use in the development of a climate action plan or greenhouse gas (GHG) inventory.
- **Climate Development Review Checklist.** This document is an example development review checklist to help identify how climate considerations can be better integrated into the development review process. It is a valuable tool for expressing the community's GHG reduction, climate, or energy goals to developers and builders. The checklist helps to identify whether proposed development projects can meet (or adapt over time to) the community's near and long-term energy and climate goals.
- **Climate Ordinance Summary.** This searchable database includes both model and adopted ordinance language to advance climate action as part of private land development. It allows filtering by jurisdiction type, population size, and sector (e.g., land use, renewable energy, etc.) and offers summaries, example language, and links to existing climate ordinances across the country. It can be used by planners to benchmark their community's climate-related regulatory provisions against other comparable communities and to initiate regulatory updates.

available resources will be limited. Important discussions are needed during the process to identify how to make the difficult decisions regarding what gets done first and next. The process should identify criteria to adjust the priority order of action implementation as conditions change, new information is derived, or as other community issues or emergencies arise. It should also consider how to respond to changes in available funding, which could speed up or slow down various implementation actions.

### Determine Implementation Mechanisms and Assign Responsibility

A project cannot be successful unless it is implemented. Therefore, implementation must be a critical component of the overall climate action planning process. Successful implementation requires the consideration of five critical questions:

- What is the action specifically trying to achieve?
- Who will take the lead to initiate and manage it?
- How much will it cost?
- What is the source of funding to pay for it?
- When should it start?

As there will almost always be more need than available resources, the development of criteria helps to make the prioritization process more objective.

Implementation can be difficult, particularly if the recommendations were not founded in a strong engagement process or the realities of the local market. The identification of a strong leadership team—and, particularly, the outward-facing champions—can strengthen implementation success outcomes.

### Track Progress and Report Outcomes

Continue the communications and education program by keeping the implementation outcomes front and center. This requires the tracking of progress and reporting of outcomes through periodic (at least annual) updates and celebration of successful achievements through local news channels, social media, and community workshops and special events. Particular attention should be given to ongoing status updates of the identified target indicators or metrics. Physical projects should also include the inclusion of an on-site sign connecting the project to the implementation of the overall program.

### Reanalyze, Evolve, and Update

The results of a planning process, no matter the time horizon, will soon be outdated by changing climate conditions, innovative technologies, and community priorities. As such, a climate action planning process should include a specific and definable timeframe to undertake an update that reanalyzes trends, vulnerabilities, and changing community preferences.

Each planning process should also include an analysis of implementation success itself. How successful was implementation of the actions? If implementation of any particular action was less than expected, why was that? Which actions did not get implemented, and why? These are critical questions to ask so that the next update process is more informed and effective.

## INTEGRATING CLIMATE THROUGHOUT PLANNING PRACTICE

Planners have many opportunities to use this PAS Report and the other climate action resources described in the sidebar on p. 129 in their day-to-day practices to advance a "climate in all policies" approach to the following planning activities:

- **Comprehensive/long-range planning.** The comprehensive or general plan is the document that provides the strategic directions for the future growth and development of a community. It presents a community-supported vision, supported by goals, objectives, and actions, to guide all local decision-making. As such, the Climate Change Policy Guide in association with this PAS Report provides an organizational framework and supporting background narrative for framing a community's overarching climate response—from proactive climate mitigation to the equitable protection of vulnerable communities. Information from the policy guide and PAS Report can be directly used to frame vision statements, goals, and objectives. The individual strategies in the Policy Guide help to further identify a comprehensive starting point for detailing specific actions that can be implemented as part of subsequent annual budget development, operational changes, capital improvement programming, and other governmental processes. Additionally, Appendix C of this PAS Report provides a series of strategies that can help planners advance climate mitigation and adaptation solutions as part of their overall long-range plans.
- **Regulatory updates.** Implementing regulations is an essential component of an effective climate response. This is particularly true considering that most changes in the built environment occur on private land. As such,

planners can use this PAS Report, the Policy Guide, and the APA SCD Ordinance Climate Summary to identify the types of regulations needed and review example regulatory language as the starting point for drafting new regulations in their communities.

- **Development review.** Development approvals can play a critical role in affecting positive change in communities. In some jurisdictions, the vision, guiding principles, goals, objectives, and element-based policies of the comprehensive plan are used as part of decision-making during rezonings and other development-related processes. In other jurisdictions, conformance with the comprehensive plan is required for all items placed on the agenda of a planning board or commission. It is also common to develop special decision-making criteria directly within the administrative section of the regulations. As such, this PAS Report and the policies identified in the Policy Guide can be used to develop decision-making criteria pertinent to development review so that climate-related considerations are made part of every development. Additional opportunities for infusing climate considerations into the development approval process are identified in the APA SCD Climate Development Review Checklist.
- **Programs and initiatives.** Planners also are involved in various special programs and initiatives, from livable center studies to planning for innovation districts. Each of these opportunities can be used to advance climate-friendly outcomes as well. Resources such as the APA SCD Climate Data Collection Guide can be used to ensure climate-related considerations are a foundational element of all new programs and initiatives.

## A PLANNER'S COMMITMENT

Our 150-year experiment running a global economy based on fossil fuel emissions has led to a rapidly changing climate, one that will increasingly impact our local communities and overall quality of life. Planners must take action and it needs to be quick. This necessitates the question: What can I do about it?

As highlighted throughout this PAS Report, there are many avenues for infusing climate considerations into all aspects of the growth and redevelopment of our cities. Every planner has a role to play. But not all planners will have the same opportunities or will be able to proceed in the same ways, as different opinions, biases, and political realities will affect a planner's ability to effect change. The key is to do as much as possible within the context of the opportunities available. There are, however, a few key things all planners can do to better integrate climate action as part of their daily practice.

- **Get educated.** The list of climate-related resources is growing exponentially every day. From written reports, plans, and blog posts to TED Talks, YouTube videos, and podcasts, there is a wide range of resources that planners can turn to learn more about climate change and its associated impacts on our communities. APA has committed to educating planners about issues related to climate change as part of its new Certification Maintenance (CM) special topic mandatory credit requirement for Sustainability and Resilience, which went into effect in January 2022. Getting educated could involve taking college-level courses, pursuing climate-related certifications (such as the Association of Climate Change Officers Certified Climate Professional credential), reading reports, or watching webinars. Or it could simply include following topics related to climate change on social media, which provides a key opportunity to keep the latest resources front and center. One caveat is that the science and response to climate change is evolving rapidly, so certain resources, such as projections, can quickly become outdated.
- **Talk about it.** As identified by renowned climate scientist Katharine Hayhoe of the Nature Conservancy in her TED Talk on the subject, one of the most important things a person can do to fight climate change is to talk about it. You don't need to be an expert in climate science; you just must be willing to talk about it and be open and honest about what you do know and what you are concerned about. A little talk from every individual aggregates into millions and billions of conversations across the globe—and this is what will be needed to gain momentum towards action. This is already occurring in politics and in the mainstream media. It needs to occur in our daily conversations regarding federal, state, and local governmental operations. In this regard, climate change must be mainstreamed into all conversations related to the growth and development of our cities and communities.
- **Network.** Networking provides the opportunity to collaborate with other like-minded and motivated individuals, groups, or organizations. It can be as simple as following individuals or groups on social media, or as committed as joining and volunteering for a project or initiative that advances the climate conversation. There are many organizations that provide networking opportunities related

to climate change, including APA's Sustainable Communities Division, the Association of Climate Change Officers, the Association of Adaptation Professionals, the Urban Sustainability Director's Network, and the U.S. Green Building Council, among others. Networking also provides a great opportunity to advance the planning profession through climate-related research, planning education, and the development of collaborative approaches to respond to the climate emergency.

- **Promote policy and take action.** Policy can take many forms, from long-range planning to new regulations, programs, and initiatives. This means that planners have numerous opportunities to advance climate policy in all actions. It just requires the wherewithal to do so and the motivation to overcome the inertia of "how we have always done things." As many planners work within a governmental structure, they are subject to local political preferences and cultural norms. This can sometimes influence the way a planner is able to talk about climate change, let alone act. In these situations, planners must become expert in advancing climate-resilient outcomes without triggering negative responses to key words and phrases, working within their designated framework and areas of expertise to effect change. Such tactics may include promoting the economic benefits of certain actions rather than focusing on the ecological benefits.

## THE TIME IS NOW

The climate is changing rapidly, and the rate of change is accelerating. Despite a worsening crisis, there are increasing signs that the decades-long call to climate action may finally be gaining momentum. Getting to action fast must be a planner's imperative. Only a comprehensive transformation to the growth and redevelopment of our cities can provide enough scale to adequately respond.

This transformation necessitates action that results in fundamental changes to our built environment, economies, and social norms. It will require a comprehensive, visionary, and forward- and systems-thinking response based on strong, informed community engagement and facilitation, consensus building and prioritization, and equitable outcomes. This means that planners are uniquely qualified to take a leadership role in building a climate-resilient future. The question is, will we? For the sake of ourselves and our communities, the answer must be a resounding yes.

## APPENDIX A: GLOSSARY OF TERMS

**adaptation:** Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished:

- **anticipatory adaptation:** Adaptation that takes place before impacts of climate change are observed. Also referred to as *proactive adaptation*.
- **autonomous adaptation:** Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as *spontaneous adaptation*.
- **planned adaptation:** Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.
- **private adaptation:** Adaptation that is initiated and implemented by individuals, households, or private companies, usually in the actor's rational self-interest.
- **public adaptation:** Adaptation that is initiated and implemented by governments at all levels, usually directed at collective needs.
- **reactive adaptation:** Adaptation that takes place after impacts of climate change have been observed. (IPCC 2001)

**adaptation, climate:** The process of adjustment to actual or expected climate change and its effects. It includes reducing the vulnerability of people, places, and ecosystems to the impacts of climate change. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. A community that decides to plan for and design a stormwater system based on future precipitation projections is practicing climate adaptation. (IPCC 2014a; DeAngelis, Briel, and Lauer 2019)

**adaptation, sustainable:** Adaptation that contributes to sustainable development pathways, including both social justice and environmental integrity. It begins with the understanding that adaptation is a process, rather than a prescriptive list of actions and measures that address specific climate change impacts. (Eriksen et al. 2011)

**adaptation, uncertainty-based:** There are generally four types of uncertainty-based climate adaptation actions:

- **no-regrets adaptation:** Adaptation actions that can be justified under current climate conditions but make even more sense when considering potential impacts resulting from climate change.
- l**ow-regrets adaptation:** Adaptation actions that are specifically designed to address climate-induced vulnerabilities. These actions would not be implemented if the climate was not changing.
- **adaptive management:** A process by which management decisions can be regularly revisited based on receipt of new information (e.g., monitoring changes in conditions, new science, or other information).
- **risk management:** A process by which risks are identified, assessed, agreed upon, and then managed as appropriate. (CCS 2011)

**adaptation metrics:** A system of measurement for the selection and evaluation of adaptation strategies. Metrics provide a way to compare the effectiveness of options, including cost, and can be used to help establish priorities among adaptation options. (CCS 2011)

**adaptive capacity:** The potential or ability of a system, region, or community to adapt to the effects or impacts of climate change (IPCC 2014). As it relates to infrastructure planning, adaptive capacity refers to the inherent ability of a piece of infrastructure or an infrastructure system to adapt to the impacts of climate change without needing larger-scale modifications. A bridge or structure that is designed to be easily elevated or requires no elevation to accommodate sea level rise can be said to have adaptive capacity. (San Francisco 2015; DeAngelis, Briel, and Lauer 2019)

**anthropogenic:** Environmental change caused or influenced by people, either directly or indirectly. (USGS 2015)

**carbon capture and storage (CCS):** The process of capturing carbon dioxide and injecting it into geologic formations underground for long-term storage. (USGCRP 2018)

**carbon footprint:** The amount of carbon released into the atmosphere due to burning of fossil fuels. Collectively reducing the societal carbon footprint is seen as a way to slow or reverse global warming. (Schwab 2013)

**climate:** The statistical average of observed weather for any given scale. Climatological knowledge based on past observations anticipates what conditions might be like at a particular place and time. (Schwab 2013)

**climate change:** A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (Schwab 2013)

**climate-resilient community:** A community that is adequately prepared to survive, recover, adapt, and thrive in the face of future climate-related shocks and stressors—not just for extreme weather events, but for a full spectrum of ecological, sociocultural, and economic issues.

**climate variability:** The natural fluctuation of climate (monthly, seasonally, annually, and even by decades, centuries, and millennia) in relation to a long-term average value. (Schwab 2013)

**ecosystem services:** The direct and indirect contributions of ecosystems to human well-being. (Millennium Ecosystem Assessment 2003)

**food security:** Having a sufficient quantity and quality of food available in the right place at the right time.

**food access:** Having adequate resources and the social right to produce or purchase suitable foods for a healthy diet. Stability of access is achieved when the food supply remains uninterrupted.

**green infrastructure:** Interventions to preserve the functionality of existing green landscapes (including parks, urban forest canopy, wetlands, or green belts). It can reduce impacts to an urban environment through phytoremediation and water-management techniques and by introducing productive landscapes. Section 502 of the Clean Water Act defines green infrastructure as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." (IPCC 2014; U.S. EPA 2022d)

**greenhouse gas (GHG):** Gaseous constituent of the atmosphere, natural or anthropogenic, that absorbs and emits radiation of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and clouds. The main greenhouse gases are water vapor, carbon dioxide, nitrous oxide, methane, and ozone. (Schwab 2013)

**hazard:** Any real or potential condition that can cause damage, loss, or harm to people, infrastructure, equipment, natural resources, or property. (Thompson et al. 2016)

**mitigation, climate:** A human intervention to reduce the sources or enhance the sinks of greenhouse gas emissions to limit future warming. Examples of climate mitigation include investing in zero- or low-emission energy sources, such as wind turbines. (IPCC 2014)

**permafrost:** A layer of soil or rock, at some depth beneath the surface, in which the temperature has been continuously below 0°C for at least several years; it exists where summer heating fails to reach the base of the layer of frozen ground. (NSIDC 2022)

**policy:** A specific statement of principle or of guiding actions that implies clear commitment but is not mandatory. A general direction that a governmental agency sets to follow in order to meet its goals and objectives before undertaking an action program. (Davidson and Dolnick 2004)

**resilience:** The capacity of individuals, communities, and systems to survive, adapt, and grow in the face of stress and shocks, and even transform when conditions require it. (ResilienceTools.org 2022)

**resilience lens:** An analytical framework to evaluate options and ensure city actions achieve multiple positive outcomes while mitigating negative consequences. (ResilienceTools.org 2022)

**risk:** A measure of the probability and consequence of uncertain future events. It is a reflection of the likelihood or probability of a shock or stress combined with the consequences of that shock or stress. (Thompson et al. 2016)

**shock:** An acute natural or human-made event or phenomenon threatening major loss of life, damage to assets, and a city's ability to function and provide basic services, particularly for poor or vulnerable populations. (ResilienceTools.org 2022)

**stress:** A chronic (ongoing or cyclical) natural or human-made event or phenomenon that renders a city less able to function and provide basic services, particularly for poor or vulnerable populations. (ResilienceTools.org 2022)

**strategies, nonstructural:** Approaches such as policy changes; modifications to zoning, subdivision, and other land-use-based development regulations (e.g., green building requirements, more stringent floodplain management regulations, elevated structure requirements, or reduced parking requirements); property buy-outs and relocations; early warning systems; improved transportation demand management; better ecosystem and resource management; new human and social capital and staff capacity (e.g., similar to the 100RC's Chief Resilience Officers); the building of community support and climate champions; and the mainstreaming of mitigation and adaptation strategies as part of existing institutional processes.

**strategies, structural:** Approaches such as green buildings and low-impact development (e.g., zero carbon emission buildings and the use of green infrastructure); urban forests; greater amounts of open space in urban downtowns and throughout the entire community; roadway surface composition changes that resist breaking down during extreme heat temperatures; improved mass transit; sea walls; and reclaiming floodplains to reduce flood risk.

**vulnerability:** The propensity or predisposition to be adversely affected. The concept of vulnerability as it relates to climate change has evolved to include larger societal issues such as inequality and poverty. The vulnerability of an infrastructure system to future flooding can be measured by assessing the system's exposure, sensitivity, and adaptive capacity. (IPCC 2014; Bharwani 2011; San Francisco 2015; DeAngelis, Briel, and Lauer 2019)

**weather:** The state of the atmosphere, mainly with respect to its effects upon life and human activities; distinguished from climate by focusing on short-term (minutes to about 15 days) variations of the atmosphere state. (NSIDC 2022)

## APPENDIX B: APA CLIMATE POLICY RESOURCES

The American Planning Association (APA) has been a proactive contributor to the discussion of climate change, beginning with a 2008 policy guide on planning and climate and a 2010 PAS Report on energy and climate. Since then, references to climate change have been increasing throughout APA's resources, creating a comprehensive compilation of literature for planners to become educated participants in the climate discussion.

This PAS Report and APA's 2020 Climate Change Policy Guide provide planners with the next level of resources to better prepare them to take future leadership roles in addressing the climate emergency, but there are many additional APA resources related to climate change.

### PAS REPORTS

The APA's Planning Advisory Service (PAS) has been providing planners with information and best practice strategies since 1949. Since the publication of PAS Report 558, many PAS Reports reference or include sections on or related to climate change, including the following:

- PAS Report 600, *Planning for Urban Heat Resilience* (2022), provides holistic guidance to help practitioners address urban heat—a threat being rapidly exacerbated by climate change—in the communities they serve. It provides an in-depth overview of the contributors to urban heat and equity implications, and it lays out an urban heat resilience framework and collection of strategies to help planners mitigate and adapt to heat across a variety of plans, policies, and actions.
- PAS Report 596, *Planning for Infrastructure Resilience* (2019), focuses primarily on the connection between climate change and flood hazard risk as it relates to sea level rise, coastal storms and storm surge, tidal flooding and inundation, and extreme precipitation. It highlights the critical need for improved infrastructure risk and vulnerability assessments; local plan integration; capital improvement plans and planning; standards, guidelines, and regulations for infrastructure resilience; and resilient infrastructure finance.
- PAS Report 588, *Planners and Water* (2017), focuses on the concept of One Water, a postindustrial paradigm to replace the highly engineered and siloed water systems of our industrial past, and highlights climate change as a leading challenge for the U.S. water future.
- PAS Report 586, *Emerging Trends in Regional Planning* (2017), addresses regional planning efforts around climate change, acknowledging that the impacts of climate change on both the natural and built environments occur at—and will require action at—regional and megaregional scales.
- PAS Report 581, *Coastal Zone Management* (2016), shows that coastal areas—our most populous areas and economic centers—are highly susceptible to climate impacts (sea level rise, storm surge, and flooding), and identifies the near- and long-term needs for adaptation and resilience planning for coastal cities.
- PAS Report 558, *Planning for a New Energy and Climate Future* (2010), provides an overview of why climate change is occurring, describes how our default development patterns and built environment are exacerbating the increase in GHG emissions, and provides best practice examples of climate-supportive energy responses.

In addition, the following PAS Reports provide context-specific information to help planners address climate change:

- PAS Report 594, *Planning the Wildland-Urban Interface* (2019)
- PAS Report 584, *Subdivision Design and Flood Hazard Areas* (2016)
- PAS Report 582, *Local Planning Agency Management* (2016)
- PAS Report 578, *Sustaining Places: Best Practices for Comprehensive Plans* (2015)

- PAS Report 575, *Planning for Solar Energy* (2014)
- PAS Report 576, *Planning for Post-Disaster Recovery: Next Generation* (2014)
- PAS Report 574, *Planning and Drought* (2013)
- PAS Report 571, *Green Infrastructure: A Landscape Approach* (2013)
- PAS Report 570, *The Rules That Shape Urban Form* (2012)
- PAS Report 569, *Planning and Broadband: Infrastructure, Policy, and Sustainability* (2012)
- PAS Report 566, *Planning for Wind Energy* (2012)
- PAS Report 567, *Sustaining Places: The Role of the Comprehensive Plan* (2012)
- PAS Report 565, *Assessing Sustainability: A Guide for Local Governments* (2011)
- PAS Report 563, *Urban Agriculture: Growing Healthy, Sustainable Communities* (2011)
- PAS Report 560, *Hazard Mitigation: Integrating Best Practices into Planning* (2010)
- PAS Report 559, *Complete Streets: Best Policy and Implementation Practices* (2010)
- PAS Report 555, *Planning the Urban Forest: Ecology, Economy, and Community Development* (2009)
- PAS Report 554, *A Planners Guide to Community and Regional Food Planning* (2008)

## APA POLICY GUIDES

APA's policy guides represent the organization's official position on critical planning issues. They can be used by planners in advocating for quality planning that leads to great communities. In addition to the Climate Change Policy Guide (2020) described in Chapter 10, four other policy guides highlight climate issues:

- The Surface Transportation Policy Guide (2019) calls for public transportation policy to assess and respond to future risks related to climate change by establishing stronger data partnerships to assess the impacts of climate change, developing a sustainable energy and transportation agenda (including cleaner vehicle standards), raising the gas tax to combat the impacts of climate change, and increasing funding support for transit to reduce transportation's share of greenhouse gas emissions.
- The Planning for Equity Policy Guide (2019) argues that climate change and resilience solutions should consider "equity in all policies and practice," and it strongly connects climate mitigation and adaptation with potential impacts on disadvantaged populations and vulnerable communities.
- The Healthy Communities Policy Guide (2017) calls for planners to create policies and design guidelines to address climate change and recommends that hazard mitigation and climate data and projections be included in all future plans.
- The Energy Policy Guide (2012) describes the energy sector's contribution to greenhouse gas emissions and calls for transforming our current energy system into a sustainable, clean energy future and reducing overall emissions through such approaches as improved conservation and efficiency.

Other APA Policy Guides with connections to climate change include the following:

- Hazard Mitigation Policy Guide (2020)
- Housing Policy Guide (2019)
- Water Policy Guide (2016)
- Freight Policy Guide (2016)
- Food Planning Policy Guide (2007)

## ADDITIONAL APA RESOURCES

Additional articles, stories, and resources on climate change from other PAS publications, APA's *Planning* magazine, the APA blog, and APA Learn may be found by searching the APA website.

## APPENDIX C: CLIMATE MITIGATION AND ADAPTATION STRATEGIES

Planners can draw on a wide range of strategies and practices to help their communities mitigate climate change by reducing the emission of greenhouse gases (GHGs) and adapt the natural and built environments to the current and future impacts of climate change. The ultimate goals are to keep global warming from increasing to minimize the associated climate impacts on the natural and built environments, and to prepare communities to withstand climate-related shocks and stressors and survive and thrive on a changing Earth.

The following tables list a selection of mitigation and adaptation strategies both structural (i.e., changes to the built environment) and nonstructural (i.e., policies and regulations) across eight sectors: energy, transportation, land use, infrastructure, buildings, waste management, natural systems, and public health.

**ENERGY**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Energy generation | General decarbonization | Reduce emissions through diversifying energy portfolio | S | Expand district heating and cooling systems and switch to use of industrial waste heat and renewable energy technologies.[12]<br>Implement distributed energy/co-generation systems.[5]<br>Where feasible, require all new buildings be constructed to allow for easy, cost-effective future installation of solar energy systems. "Solar-ready" features include roof orientation of between 20 to 55 degrees from horizontal with sufficient south-sloped surface and installation of electrical conduit to accept solar electric system wiring.[13] |
| MITIGATION | Energy generation | General decarbonization | Reduce emissions through diversifying energy portfolio | N | Develop and use climate-protective tax incentives and other financial tools to promote implementation of renewable energy technologies.[2]<br>Promote local clean energy regulations and incentives.[2]<br>Promote adoption of mandatory building codes.[2] |
| MITIGATION | Energy transmission | General decarbonization | Avoid energy loss | S | Decentralize energy generation and transmission,[2] using shorter transmission lines and small distribution areas.[15] |
| MITIGATION | Energy use | General decarbonization | Reduce emissions through minimizing energy use | N | Require the installation of alternative energy systems (e.g., electric vehicle charging stations, residential electric vehicle hook-ups, etc.). [2]<br>Promote or require the use of green building design and programs (e.g., LEED, Energy Star, etc.) to reduce energy and water consumption. [2]<br>Advance the use of GHG emissions reduction analyses in all long-range planning efforts. [2] |

**ENERGY**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| ADAPTATION | Energy generation | All climate impacts | Protect energy generation infrastructure | N | Identify and map key energy infrastructure points of production and transmission that may be affected by climate impacts.[8] |
| | Energy generation | Inland flooding | Protect generation infrastructure | S | Assess location vulnerabilities of new generation facilities and site new facilities out of floodprone areas. [8] |
| | Energy transmission | Increased storm events | Protect transmission infrastructure | S | Bury transmission cables/infrastructure. [8] |
| | Energy use | All climate impacts | Manage energy resources through redundancy | S | Develop energy management plans for key facilities. Provide backup power sources for those systems and evaluate options to reduce power consumption by upgrading to more efficient equipment. Utilities can develop plans to produce energy, reduce use, and work toward net-zero goals.[16]<br>Identify redundancies and re-routing potential in energy infrastructure for emergency switching should primary systems go down.[8] |

**LAND USE**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Agriculture | General decarbonization | Carbon sequestration | S | Adopt practices such as terracing, contour stripping, and growing cover crops.[7] |
| | Agriculture | General decarbonization | Reduce production of high-carbon food items | S | Reduce production of carbon-intensive food products (i.e., meat and dairy from ruminants.[7]<br>Optimize health and reproductive capacity of herds.[7]<br>Improve pasture management practices include managing stocking rates, timing and rotation of livestock, introduction of grass species or legumes with higher productivity, and application of biochar, compost, fertilizer, or irrigation to increase productivity.[7] |
| | Agriculture | General decarbonization | Increase production and consumption of high-protein vegetables | S | Increase agricultural product yield by improving timing, rate, and method of nutrient/fertilizer application.[7]<br>Intensify agricultural production.[7] |
| | Agriculture | General decarbonization | Encourage emissions reductions | N | Provide agricultural subsidies to encourage and reward mitigation practices.[7] |
| | Agriculture | General decarbonization | Increase amount of carbon sequestered in soils | N/S | Promote the benefits of sustainable agroforestry.[15]<br>Increase agroforestry practices (i.e., windbreaks, riparian buffers, silvopasturing).[7] |

## LAND USE

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Agriculture | General decarbonization | Reduce emissions from stored manure | S | Mandate the installation and use of methane digestors and compost facilities.[7] |
| | Agriculture | General decarbonization | Reduction in VMT through localized agricultural production | S | Promote urban agriculture.[21] |
| | Urban settlement patterns | General decarbonization | Carbon sequestration | S | Use green infrastructure best practices.[2] |
| | Urban settlement patterns | Reduced precipitation (drought) | Increased wildfires | N | Assess threat of increased wildfires.[8] |
| | Urban settlement patterns | General decarbonization | Promote VMT reductions through increasing residential densities, reducing sprawl, and implementing transit-oriented development (TOD) best practices | N | Incorporate urban design principles that promote higher residential densities in attractive forms with easily accessible parks and recreation opportunities nearby.[4]<br>Encourage the development of accessory dwelling units in urban areas.4<br>Increase densities in urban core areas to support public transit.[13]<br>Identify transit centers appropriate for mixed-use development, and promote transit-oriented, mixed-use development within these targeted areas, including providing expanded zoning for multifamily housing, density bonus programs, and minimum pedestrian and bicycle connectivity standards.[13]<br>Locate medium- to high-density residential development near activity centers that can be served efficiently by public transit and alternative transportation modes.[13]<br>Create zoning that allows TOD by right, develop subarea plans that encourage TOD, and create TOD design guidelines.[2]<br>Establish an urban growth boundary (UGB) with related ordinances or programs to limit suburban sprawl. Restrict urban development beyond the UGB and streamline entitlement processes within the UGB for consistent projects.[13] |
| | Urban settlement patterns | General decarbonization | Improve carbon sequestration | N | Incorporate policies to plant trees in medians and preserve open space for cooling and stormwater management.[4] |
| | Urban settlement patterns | General decarbonization | Increase residential densities and reduce sprawl | N | Encourage high-density, mixed-use infill development and creative use of brownfield, underused, or marginal properties within the urban core.[13] |

## LAND USE

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Urban settlement patterns | General decarbonization | Promote mixed-use development | N | Facilitate the inclusion of complementary land uses not already present in local zoning districts, such as supermarkets, parks, schools in neighborhoods, and residential uses in business districts, to reduce VMT and promote cycling and walking to these uses.[13]<br>Revise zoning ordinances to allow local-serving businesses, such as childcare centers, restaurants, banks, family medical offices, drug stores, and other similar services to locate near employment centers to minimize midday vehicle use.[13] |
| ADAPTATION | Agriculture | All climate impacts | Decline in agricultural productivity | | Promote intensive agriculture in controlled environments and conditions (e.g., greenhouses).[1] |
| | Agriculture | All climate impacts | Reduce existing stressors of crops and livestock | S | Reduce the impacts of pests and pathogens on crops.[22]<br>Reduce competition from weedy and invasive species.[22]<br>Maintain livestock health and performance.[22] |
| | Agriculture | Reduced precipitation (drought) | Reduce risks from warmer and drier conditions | S | Identify alternate crops that respond well to hotter temperatures and dryer weather.[1]<br>Reduce water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted.[1]<br>Modify land topography to reduce runoff, improve water uptake, and reduce wind erosion.[1]<br>Support alternative irrigation techniques (e.g., subsurface drip irrigation) to reduce water use and encourage use of climate-sensitive water supplies.[14]<br>Manage crops and livestock to cope with warmer and drier conditions.[22] |
| | Agriculture | Sea level rise | Decline in agricultural productivity | S | Modify land use and agricultural practices, including aquaculture and saline-resistant crops.[1] |
| | Forestry | All climate impacts | Deforestation leading to reduced carbon sequestration | S | Introduce species that are expected to be adapted to future conditions (i.e., plant swamp white oak to replace ash lost to decline resulting from emerald ash borer).[6]<br>Promptly revegetate with native species after disturbance.[6] |
| | Forestry | Increased temperatures | Increased susceptibility to invasive species, pests, and pathogens | N | Research alternative methods for addressing new forest pests and invasive species through improved management techniques and/or biological controls.[6] |
| | Forestry | Increased temperatures | Increased susceptibility to invasive species, pests, and pathogens | S | Restrict harvest and transportation of logs near stands heavily infested with known pests or pathogens.[6]<br>Thin to reduce the density of a pest's host species to discourage infestation.[6]<br>Create a diverse mix of forest or community types, age classes, and stand structures to reduce the availability of host species for pests and pathogens.[6] |

**LAND USE**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| ADAPTATION | Forestry | Increased temperatures | Increased likelihood of wildfires | N | Develop, adopt, and implement integrated plans for mitigating wildfire impacts in wildland-urban interface (WUI) areas.[14]<br>Encourage compliance with statutory requirements for vegetation management around structures and promote fuel breaks to slow fire spread in WUI areas.[14]<br>Design homes, neighborhoods, and streets to minimize vulnerability to fire hazards in WUI areas.[14] |
| | Forestry | Increased temperatures | Increased likelihood of wildfires | S | Restore fire in forests to reduce surface fuel and promote fire- and heat-tolerant species.[6]<br>Establish fuel breaks to slow the spread of catastrophic fire.[6]<br>Alter forest structure or composition to reduce risk or severity of wildfire (i.e., plant fire-resistant species, such as hardwoods, in buffer zones between more flammable conifers to slow the movement of wildfires).[6] |
| | Urban settlement patterns | All climate impacts | Increase public awareness | N | Establish a climate adaptation public outreach and education program.[14]<br>Build collaborative relationships between regional entities and neighboring communities to promote complementary adaptation strategy development and regional approaches.[14]<br>Establish an ongoing monitoring program to track local and regional climate impacts and adaptation strategy effectiveness.[14]<br>Increase participation of low-income, immigrant, non-English-speaking, racially and ethnically diverse, and special needs residents in climate action planning and implementation.[14] |
| | Urban settlement patterns | Increased temperatures | Heat events in densely populated urban areas | N | Review and update heat response plans based on climate (heat events) projections.[3]<br>Develop and adopt an urban forestry plan.[3]<br>Encourage density near transit without significantly modifying land surfaces to avoid exacerbating urban heat island effects (e.g., repurposing vacant or underutilized buildings near transit for affordable housing).[4] |
| | Urban settlement patterns | Increased temperatures | Heat events in densely populated urban areas | S | Increase urban forest canopy to manage the urban heat island effect. |
| | Urban settlement patterns | Reduced precipitation (drought) | Increased wildfires | N | Assess threat of increased wildfires.[8] |

## LAND USE

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| ADAPTATION | Urban settlement patterns | All climate impacts | Reduce vulnerability | N | Develop new criteria for "climate safe" communities and developments.[8]<br>Require that local government coastal land-use plans include a strategic plan for responding to sea level rise and other climate risks.[1]<br>Discourage building in areas that are currently or are projected to be more vulnerable to climate-related impacts. Make it easier to build in safer areas to help relieve pressure to develop in more vulnerable areas.[18]<br>Guide future development out of areas vulnerable to sea level rise and associated hazards.[8]<br>Incorporate adaptation strategies into comprehensive land-use planning.[8]<br>Promote vocational, educational, and other local training programs in climate-readiness initiatives to foster employment opportunities in growing the green housing and renewable energy industries.[2] |
| | Urban settlement patterns | All climate impacts | Prepare for managed retreat | N | Survey currently inhabited vulnerable areas and develop relocation plans and contingency measures in the event of emergencies.[8]<br>Investigate potential and limitations of eminent domain, vesting, grandfathering, and amortizing strategies to support retreat activities.[8]<br>Conduct a vulnerability assessment for cultural resources such as museums and historical sites.[8]<br>Update real estate transaction disclosure requirements for hazards related to climate change.[8]<br>End permitting of new home construction in areas vulnerable to sea level rise and associated hazards.[8]<br>Buyout unused properties in areas vulnerable to sea level rise and associated hazards.[8]<br>Enact law that authorizes the state to secure rolling property easements as sea level rises.[8]<br>Use transfer of development rights for the rebuilding of structures damaged or destroyed due to flooding in high-risk areas.[14] |
| | Urban settlement patterns | Sea level rise | Anticipate and plan for sea level rise | N | Create visualization tools for sea level rise and associated hazards.[8]<br>Develop adaptive management plans to address the long-term impacts of sea level rise.[14]<br>Require accounting for sea level rise in all applications for new development in shoreline areas.[14] |
| | Urban settlement patterns | Sea level rise | Protect assets | S | Investigate consequences of installation of hard structural options (e.g., dikes, levees, floodwalls, and saltwater intrusion barriers).[1]<br>Protect shorelines with soft structural options such as dune and wetland restoration and creation, tree and other plantings, and periodic beach nourishment.[1] |
| | Urban settlement patterns | Inland flooding | Protection of environmental systems and settlement patterns | N | Regularly update floodplain maps.[8]<br>Implement National Flood Insurance Program activities to minimize and avoid development in flood hazard areas.[14]<br>Redefine riverine flood hazard zones to match projected expansion of flooding frequency and extent.[16]<br>Increase shoreline setbacks.[16] |

**INFRASTRUCTURE**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | All | General decarbonization | Demand management | | Reduce demand and improve efficiency by increasing public awareness of impacts on water supplies.[5]<br>Promote use of reclaimed wastewater.[5] |
| ADAPTATION | Water | All climate impacts | Promote the use of green infrastructure systems | N | Invest in green infrastructure, watershed management, and ecosystem planning to improve natural stormwater function. |
| | Water | All climate impacts | Maintain water quality and availability | N | Integrate climate change scenarios into water supply systems.[16]<br>Establish mutual aid agreements with neighboring utilities. Beyond the establishment of water trading in times of water shortages or service disruptions, these agreements involve the sharing of personnel and resources in emergencies (e.g., natural disasters).[16]<br>Update drought contingency plans to include the use of alternate water supplies and the adoption of water use restrictions for households, businesses, and other water users.[16]<br>Assess, monitor, and create plans to address threats of saltwater intrusion into water supplies.[8] |
| | Water | All climate impacts | Maintain water quality and availability | S | Expand and diversify water supplies (e.g., new groundwater sources and reservoirs).[8]<br>Promote use of water reuse and recycling.[5]<br>Increase water use efficiency and water recycling in residential and commercial buildings.[8]<br>Employ water conservation techniques such as reuse of wastewater from tertiary treatment plants, cisterns, and rain barrels.[8]<br>Expand use of water markets to reallocate water to highly valued uses.[8]<br>Implement tiered pricing to reduce water consumption and demand.[14]<br>Increase “above-the-dam” regional natural water storage systems.[14]<br>Manage water supply through water reuse, recycling, rainwater harvesting, desalination, etc.[16]<br>Pursue methods to protect potable water supply from saltwater intrusion.[8] |
| | Water | Drought | Demand management | N | Increase public awareness of impacts on water supplies.[16]<br>Promote use of reclaimed wastewater.[16] |
| | Stormwater | Inland flooding | Ensure adequate capacities | S | Develop adaptive stormwater management practices (e.g., remove impervious surface, replace undersized culverts).[16] |
| | Stormwater | Inland flooding | Increase stormwater detention/ retention | S | Use underground storage systems to detain runoff in underground receptacles (e.g., culverts, engineered stormwater detention vaults, or perforated pipes).[16]<br>Use stormwater tree trenches to store and filter stormwater runoff.[16] |
| | Stormwater | Inland flooding | Increase system efficiency | N | Evaluate and improve capacity of stormwater infrastructure for high-intensity rainfall events.[8]<br>Conduct an assessment to identify stormwater outfalls most likely to be flooded.[11] |

**INFRASTRUCTURE**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| ADAPTATION | Stormwater | Inland flooding | Promote the use of green infrastructure systems | N | Publicize a list of "certified" or "qualified" green infrastructure contractors and engineers.[16]<br>Adopt more stringent policies such as stormwater fees and requirements for developers to manage water onsite to the maximum extent feasible.[16]<br>Offer incentives for engineers or contractors to use green infrastructure designs, rather than relying on pipe-based systems.[16] |
| | Stormwater | Inland flooding | Promote the use of green infrastructure systems | S | Manage stormwater onsite with green infrastructure and low-impact development techniques.[8] |
| | Stormwater | Inland flooding | Protect water and sewage treatment facilities located close to rivers or coast | S | Increase permeable surfaces and wetlands to increase natural infiltration of rainwater and reduce stormwater runoff.[10]<br>Prioritize low-impact development practices in areas where storm sewers may be impaired by high water due to inland flooding or sea level rise.[14]<br>Restore existing flood control and riparian corridors. Convert concrete-lined channels to soft-bottomed waterways, install landscaping on embankments to slow flood waters, provide natural planting to encourage biodiversity, and build retention basins for percolation into aquifers.[11] |
| | Infrastructure protection | All climate impacts | Ensure long-term utility function | N | Map locations of infrastructure vulnerable to floods, storm surges, extreme thermal or precipitation events, wildfire, etc.[8]<br>Incorporate sea level rise into planning for new infrastructure.[16] |
| | Infrastructure protection | Extreme weather events | Protect infrastructure | N | Adopt insurance mechanisms and other financial instruments to insulate utilities from financial losses due to extreme weather events, helping to maintain financial sustainability of utility operations.[16]<br>Conduct climate impact assessments for community infrastructure.[14] |
| | Infrastructure protection | Inland flooding, Sea level rise | Protect infrastructure | N | Review construction standards for piers and wharves for wave strength resistance.[8]<br>Require developers and local governments to incorporate climate change into design and decision-making processes.[16]<br>Initiate surveillance and monitoring of sea-level rise related to storm-surge early warning systems and ensure adequate response and evacuation plans.[8]<br>Limit infrastructure investments in hazard-affected coastal areas.[8] |
| | Infrastructure protection | Sea level rise | Protect infrastructure | S | Increase the number and height of flood barriers, levees, and dams.[8]<br>Use beach nourishment to protect infrastructure in coastal areas.[8]<br>Design industrial systems to reduce vulnerability to future sea level rise and associated hazards.[8]<br>Retreat from highest risk barrier islands and low-lying lands, removing infrastructure that may exacerbate flooding and natural processes.[8]<br>Implement ecosystem-based protection, such as mangroves, for coastline regeneration and disaster risk reduction.[10]<br>Relocate facilities (e.g., treatment plants and pump stations) to higher elevations to reduce risks from coastal flooding and coastal erosion or wetland loss.[16] |

**BUILDINGS AND HOUSING**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Design and siting | General decarbonization | Increase density | N | Remove barriers to the development of accessory dwelling units in existing residential neighborhoods.[13]<br>Encourage diverse and affordable housing options.[2] |
| | Construction standards | General decarbonization | Reduce emissions through improved building standards | N | Adopt a green building ordinance that requires new development and redevelopment projects for both residential and commercial buildings to incorporate sufficient high-performance green building methods and techniques to qualify for the equivalent of a USGBC LEED certification rating.[13]<br>Provide incentives for application of green building best practices.[13]<br>Adopt a national building energy performance rating system.[2]<br>Set carbon-neutral building standards for new construction.[20]<br>Promote local building insulation and weatherization programs.[2] |
| | Building performance | General decarbonization | Reduce emissions through increased building performance | S | Promote the installation of heat pumps, solar cells, and heat storage technology.[20]<br>Provide incentives for the installation of central cooling and heating and the use of energy-efficient lighting and appliances.[20]<br>Mainstream sustainable building policies and practices within urban and rural planning.[20]<br>Seal windows and doors, stop thermal bridges through insulation, install double-glazed doors, and invest in heat pumps.[20]<br>Regulate temperature by adding verandas, green roofs, high-inertia walls, and bio-based insulation made from renewable or recyclable materials.[20]<br>Switch to LED lighting and high-efficiency appliances, especially air conditioners.[20]<br>Require new development and redevelopment projects to include smart cities technologies that have proven climate benefits.[2] |
| | Building performance | General decarbonization | Reduce emissions through increased energy efficiency | N | Require or encourage third-party certification for public and private building renovations and new construction to promote awareness and visibility of efficiency strategies while also encouraging higher certification levels.[17]<br>Adopt an energy benchmarking ordinance for public and private buildings greater than 50,000 square feet to allow prospective and current building owners to compare the energy use of buildings of similar sizes. Data transparency can create an incentive for implementing energy efficiency upgrades in buildings with higher energy use.[17]<br>Provide tax credits for buildings that implement energy efficiency measures.[17]<br>Reduce permitting fees and simplify permitting processes for energy efficiency upgrades.[17]<br>Require energy efficiency in rental licensing.[17]<br>Adopt the most energy-efficient building code allowed by state law.[17]<br>Mandate that all applicable zoning standards related to efficiency apply to all types of dwellings and establishments.[17]<br>Address gaps in utility assistance programs by financially assisting underserved communities and by providing energy efficiency education and upgrades.[17] |

**BUILDINGS AND HOUSING**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Adaptive reuse | General decarbonization | Reduce emissions through adaptive reuse of buildings | S | Reuse existing infrastructure and buildings to take advantage of previous investments and the energy already used to build them.[18]<br>Reuse and recycle existing building materials.[18] |
| ADAPTATION | Design and siting | All climate impacts | Design buildings with adaptation and resilience in mind | S | Use modular buildings, as they can more easily be moved, renovated, and deconstructed as community or tenant needs and climate-related impacts change. Use exposed mechanical fasteners, moveable walls and ramps, and standard-sized modular building components and assemblies, and disentangle utilities from the structure.[18]<br>Design buildings for passive survivability (remaining habitable if they lose external power for an extended period) to help ensure that if the power goes out, the building will stay at a safe temperature. Passive survivability techniques such as better insulation and operable windows also save energy and money on energy bills.[18] |
| | Design and siting | Increased temperatures | Improve internal cooling temperatures | S | Increase urban forest canopy to manage the urban heat island effect. |
| | Design and siting | Inland flooding | Reduce risk of damage to buildings | N | Discourage development within floodplain. |
| | Design and siting | Sea level rise | Regulate building in hazardous areas | N | Institute new hazard-resistant building codes and design standards to reduce vulnerability of structures to future sea level rise and associated hazards.[8] |
| | Design and siting | Sea level rise | Regulate building in hazardous areas | S | Significantly increase estuarine buffers and oceanfront development setbacks.[8]<br>Raise shoreline structures.[8] |
| | Construction standards | Increased storm events | Improve resilience to extreme weather | N | Review state building and design codes to promote resiliency and mitigate storm and flood damage.[8]<br>Strengthen building codes and increase building inspection frequency.[8]<br>Create incentives for individuals and businesses to reduce risk of losses due to climate through building design codes.[8]<br>Use "blue roofs" to hold precipitation after a storm event and discharge it at a controlled rate.[16] |
| | Building performance | Increased temperatures | Improve internal cooling temperatures | S | Install green roofs to reduce summer heat, provide winter insulation, and reduce stormwater runoff.[10]<br>Implement energy efficiency retrofits to residential buildings to improve the structural thermal energy performance and reduce energy demand for spatial heating and cooling.[12] |

**WASTE MANAGEMENT**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Waste reduction | General decarbonization | Reduce emissions from food waste | S | Reduce postharvest food lost and consumer waste of food across the supply chain.[7]<br>Facilitate increased donation of unsold goods.[7]<br>Reduce amount of waste produced and taken to final disposal site.[7]<br>Repurpose extra-ripe foods in-store.[20]<br>Set up processes for surplus food rescue to transfer healthy, uneaten food to services who can distribute it to those in need.[20]<br>Develop city-level food storage infrastructure.[21]<br>Promote the expansion of composting and waste-to-energy generation.[2,20]<br>Capture landfill gas to reduce GHG emissions.[5] |
| | Waste reduction | General decarbonization | Reduce emissions through discouraging food waste | N | Inform consumers and producers about food choices and how to reduce food loss waste across the supply chain.[20]<br>Align national diet recommendations with climate goals.[20]<br>Review packaging, provide clear storage and freezing guidance, eliminate "display until" dates, and clarify best before/use-by dates.[20]<br>Provide incentives for more sustainable packaging.[5]<br>Promote adoption of corporate commitments to halve food loss and waste by 2030.[20] |
| | Life-cycle assessment | General decarbonization | Promote life-cycle thinking | N | Support development of a federal program to encourage use of low-/no-carbon products and encourage their reuse.[2]<br>Support life-cycle materials management.[2] |
| ADAPTATION | Waste management | All climate impacts | Manage waste disposal | N | Adopt pre-incident waste management plans to prepare for increased waste disposal needs following natural disasters.[25] |
| | Infrastructure protection | Sea level rise, inland flooding | Protect waste management infrastructure | N | Ensure that waste can be collected from floodprone areas.[2] |
| | Infrastructure protection | Sea level rise, inland flooding | Protect waste management infrastructure | S | Relocate waste disposal sites threatened by sea level rise or inland flooding.[2] |

**NATURAL SYSTEMS**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| **MITIGATION** | Ecosystem services | General decarbonization | Protect ecosystem services and natural habitats | N | Promote ecological thinking and nature-based solutions.[2]<br>Promote landscape connectivity.[6]<br>Preserve large, contiguous areas of open space to better protect ecosystems that might be under pressure from the changing climate.[6]<br>Use purchase of development rights or conservation easements to protect climate-vulnerable habitats.[14] |
| **ADAPTATION** | Ecosystem services | All climate impacts | Enhance ecological functions | S | Use ecosystem services.[2]<br>Protect, restore, and enhance green and blue infrastructure.[5]<br>Increase ecosystem redundancy across the landscape.[6]<br>Maintain or restore riparian areas to reduce erosion and nutrient loading into adjacent water bodies.[6] |
| | Ecosystem services | Reduced flooding | Reduce flood risk and vulnerability and improve water quality | S | Increase the use of sponge parks to increase recreational space while mitigating increased flood risk.[23]<br>Restore disturbed floodplains to improve flood carrying capacity.[23]<br>Increase the use of neighborhood-scale green infrastructure and low-impact development solutions (e.g., rain gardens, green roofs, vegetated swales, rainwater harvesting, permeable pavement, and increased tree canopy).[23] |
| | Ecosystem services | Reduced precipitation (drought) | Manage water resources | N | Promote aquifer protection, storage, and recharge.[2] |
| | Ecological protection | All climate impacts | Biodiversity preservation | S | Protect and restore the carrying capacity of natural ecosystems (e.g., restoration, rewilding, etc.).[2]<br>Maintain and create habitat corridors through reforestation or restoration.[6]<br>Connect landscapes with corridors to enable migration.[16]<br>Collaborate with agencies managing public lands to identify, develop, or maintain corridors and linkages between undeveloped areas.[14]<br>Eliminate invasive species that compete with native species for moisture, nutrients, and light.[6] |
| | Ecological protection | Sea level rise | Maintain and restore wetlands | N | Preserve open space along water bodies to absorb flood waters and reduce flooding in developed areas.[18]<br>Allow coastal wetlands to migrate inland (e.g., through setbacks, density restrictions, land purchases).[16]<br>Incorporate wetland protection into infrastructure planning (e.g., transportation planning, sewer utilities).[16] |
| | Ecological protection | Sea level rise | Maintain and restore wetlands | S | Promote wetland accretion by introducing sediment.[16]<br>Create marshes by planting the appropriate species (typically grasses, sedges, or rushes) in the existing substrate.[16] |
| | Ecological protection | Sea level rise | Protect shorelines | N | Prohibit hard shore protection.[16] |

**NATURAL SYSTEMS**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| ADAPTATION | Ecological protection | Sea level rise | Protect shorelines | S | Remove hard protection or other barriers to tidal and riverine flow (e.g., riverine and tidal dike removals).[16]<br>Preserve and restore the structural complexity and biodiversity of vegetation in tidal marshes, seagrass meadows, and mangroves.[16]<br>Identify and protect ecologically significant ("critical") areas such as nursery grounds, spawning grounds, and areas of high species diversity.[16]<br>Establish rolling easements that "roll" upland as sea level rise and coastal erosion cause coastline encroachment.[16, 24]<br>Replace shoreline armoring with living shorelines through beach nourishment, planting vegetation, etc.[16]<br>Trap or add sand through beach nourishment (the addition of sand to a shoreline to enhance or create a beach area).[16]<br>Create dunes along backshores of beaches by planting dune grasses and using sand fencing to induce settling of wind-blown sands.[16]<br>Use natural breakwaters of oysters (or install other natural breakwaters) to dissipate wave action and protect shorelines.[16]<br>Install rock sills and other artificial breakwaters in front of tidal marshes along energetic estuarine shores.[16]<br>Protect shorelines with breakwaters (structures placed offshore to reduce wave action).[16] |

**PUBLIC HEALTH**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| MITIGATION | Public education | General decarbonization | Improve health outcomes through climate action | N | Promote the use of use healthy habits, community participation and activation, and other opportunities to improve overall social cohesion as part of climate mitigation action.[2]<br>Build relationships between planners and public health officials to promote a cross-sectoral approach to climate mitigation action.[2]<br>Support policies that link public health to planning to address climate mitigation action.[2] |

**PUBLIC HEALTH**

| | Subsector | Climate Impact/ Vulnerability | Objective | Structural/ Nonstructural | Strategies |
|---|---|---|---|---|---|
| ADAPTATION | Public education | All climate impacts | Reduce potential risk and injury to at-risk populations | N | Promote the use of health impact assessments and other tools to address the potential impacts of health, equity, and climate change on vulnerable communities.[2]<br>Support the development of emergency response and evacuation plans to reduce the loss of life and property from disasters.[2]<br>Address the social and mental health needs of dislocated populations following disasters.[2]<br>Link climate adaptation strategies with social equity and public health strategies.[14]<br>Reduce exposure to toxins and pollutants that increase vulnerability to health impacts from climate change, for example, outdoor and indoor air pollutants that contribute to cardiovascular and respiratory conditions such as asthma.[2]<br>Focus planning and intervention programs on neighborhoods that currently experience social or environmental injustice or bear a disproportionate burden of potential public health impacts.[14] |
| | Public education | Increased temperatures | Reduce health impacts resulting from increased temperatures | N | Undertake public relations campaigns to encourage residents to carry water with them to avoid heat stroke.[21] |
| | Equitable distribution | All climate impacts | Increase equitable distribution of resources | N | Promote localized food production in disadvantaged areas to improve access to, and reduce the cost of, food for residents.[2]<br>Address vulnerability of key supply chains.[5] |

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## with these related PAS resources.


**Planning for Urban Heat Resilience**
(PAS Report 600)

Heat is the deadliest U.S. weather-related hazard, and climate change makes it a growing threat to all communities. Read this report to learn how planners can enhance equitable urban heat resilience with heat mitigation and management strategies.


**Planning for Infrastructure Resilience**
(PAS Report 596)

Climate change is causing more frequent and intense storm events and rising sea levels, putting communities at higher risk of flooding and cascading impacts. Read this report for guidance on addressing new climate realities in planning processes to create more resilient infrastructure.


**Planning the Wildland-Urban Interface**
(PAS Report 594)

More than one-third of the U.S. population lives in the wildland-urban interface (WUI), where climate change is making wildfires bigger, more destructive, and more deadly. Read this report for a holistic planning framework to address wildfire challenges in plans, policies, and regulations.


**Hazard Mitigation: Integrating Best Practices into Planning**
(PAS Report 560)

Every year, communities face natural hazards that threaten lives and cause millions of dollars in property damage. Well-crafted plans, policies, and land-use regulations can help mitigate those impacts. Read this report for guidance on integrating hazard mitigation into local planning processes.

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American Planning Association
205 N. Michigan Ave., Suite 1200
Chicago, IL 60601-5927

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