Governing for Resilience: A new epoch in U.S. environmental policy?

Duran Fiack, Lehman College, City University of New York

Western Political Science Association

Panel 4.04 Resilience and Sustainability Governance

April 1, 2021

Abstract

The evolution of U.S. environmental policy has occurred through a series of three overlapping epochs, with each distinguished by differences in problem definition and policy objectives, implementation philosophies, points of intervention, policy tools, data and informational needs, political and institutional contexts, and key events and public actions. In the third environmental epoch, policy efforts have primarily been framed within the context of sustainability and focus on applying comprehensive, bottom-up policy and planning initiatives. Despite its practical approach for addressing crosscutting environmental issues, the 'sustainable communities' paradigm has fallen short of facilitating a transformation in which U.S. society subsists within the Earth system's ecological limits. As a result of the sustainability epoch's policy failures, environmental policy practitioners have increasingly applied the concept of resilience to frame policy discussions. This study draws from resilience theory and applies the environmental epoch framework to conceptualize the emergence of the fourth epoch in U.S. environmental politics and policy, Governing for Resilience. An examination of the features that distinguish an environmental epoch that centers on resilience contributes to theory and provides practical insight for policymakers by identifying opportunities to prepare for ongoing and unprecedented environmental challenges.

Keywords: resilience, environmental policy, Anthropocene, climate adaptation

Table of Contents

Introduction

For the last thirty years, the concept of sustainability has served as the dominant frame through which ecological issues are discussed, understood, and addressed. However, global progress towards achieving environmental sustainability has been modest, and society has been approaching planetary ecological limits with increasing speed, in some cases having already surpassed them (IPBES 2019; IPCC 2014b, 2018; Steffen et al. 2015). Since the mid-20th century, unprecedented growth in population, affluence, and global trade has led to rapid urbanization, the expansion of industrial agricultural practices, the exploitation and redistribution of plant and animal species, increased pollution, and exponential growth in fossil fuel consumption (IPBES 2019; Roser and Ortiz-Ospina 2017; Schaffartzik et al. 2014). These growth patterns have produced a net loss of terrestrial habitat, ocean ecosystem alteration, increased species extinction rates, a decline in biodiversity, diminished air and freshwater quality, and atmospheric changes (IPBES 2019; IPCC 2014b, 2018). The rapid rate of global environmental change documented by the scientific community has produced compelling evidence that the Earth has entered a new geologic era, the Anthropocene, in which human activity has been the dominant influence on the planetary system (Steffen, Crutzen, and McNeill 2007).

In this new era, the crosscutting effects of global climate change pose one of the most significant global commons problems for society and the environment. Global temperatures have increased by approximately 1° Celsius (C) since the Industrial Revolution, and, in the absence of aggressive mitigation measures, temperatures are likely to increase by at least 1.5° C by midcentury and at 2° C by the end of the century (IPCC 2014b, 2018). The projected changes in global climatic conditions will alter the characteristics of natural systems and weather patterns, producing irreversible and, in some cases, abrupt, catastrophic system feedbacks. The observed increase in global temperatures has already contributed to the melting of sea ice and glaciers and increased thermal expansion rates, producing sea level rise and increased tidal flooding occurrences (IPCC 2018). Climate change will also influence the frequency and magnitude of singular extreme weather events, such as heavy rainfall, heatwaves and droughts, hurricanes, tornadoes, winter storms, and forest fires (IPCC 2018). Additionally, the occurrence of compound effects, such as reduced air and water quality and the crossing of tipping points or thresholds in a wide array of ecological systems, may amplify the impacts of these events on natural systems, society, and the economy.

The crosscutting and complex environmental problems of the Anthropocene, and their effect on the functioning of **social-ecological systems (SES)**[1], require policymakers to undertake a new approach to environmental governance (Benson and Craig 2014; Griggs et al. 2013; Liu et al. 2007). In the U.S., the practice of environmental policy has undergone several periods of evolution to respond to changes in our scientific understanding of the causes and consequences of environmental problems. Mazmanian and Kraft (2009b) articulate these periods by applying a conceptual framework to identify three distinct and overlapping Environmental Epochs in U.S. environmental politics and policy. Their analysis of the evolution of U.S. environmental policy from the 1970s to the 2000s presents a conceptual framework comprised of seven dimensions concerning the context and application of environmental policy, including:

1. key events and public actions;
2. environmental problem definition and policy objectives;
3. the predominant political and institutional contexts;
4. policy implementation philosophy;
5. points of intervention;
6. policy approach and tools; and
7. information and data management needs (Mazmanian and Kraft 2009b)

[1] Although the academic community has not developed a unifying definition of SES, the concept's applications generally describe SES as the interdependency and mutual interactions between ecological and social systems at various scales (Colding and Barthel 2019).

Each epoch is distinguished by focusing events and societal trends that reframe and redefine the way environmental problems are understood. Such events provide a foundation for the establishment of policy goals, which, when coupled with the prevailing political climate and existing environmental institutions, influence the design and selection of implementation strategies and policy instruments, creating the requisites for specific information and data management needs (Mazmanian and Kraft 2009b).

As a result of the apparent policy failures of the sustainability epoch and growing concerns regarding the anticipated environmental challenges of the Anthropocene, environmental policy practitioners have increasingly applied the concept of resilience to frame policy discussions (Benson and Garmestani 2011; Normandin et al. 2019; Redman 2014; Meerow, Newell, and Stults 2016; Woodruff et al. 2018). Rooted in engineering and ecological theory, the earliest definitions of resilience describe a complex ecological system's capacity to endure or return to a stable condition after being exposed to external stressors and shocks while preserving its structure and function (Holling 1973). Contemporary perspectives on resilience have evolved to consider the interplay between complex SES at various scales in which change occurs under uncertain and unpredictable conditions producing new and evolving steady states (Berkes and Folke 1998; Berkes, Colding, and Folke 2003; Folke 2006; Gunderson and Holling 2002; Walker et al. 2002; Walker and Salt 2006, 2012). The notion of system persistence and recovery described by each perspective on resilience, and their respective implications for adaptation and transformational change, fit well with the predicted behavior of an anthropogenically disrupted planet characterized by irreversible, nonstationary, and nonlinear change (Adger and Hodbod 2014).

This study draws from the environmental epoch framework and resilience theory to conceptualize the emergence of the fourth epoch in U.S. environmental policy, *Governing for Resilience*. An examination of the key features that distinguish an environmental epoch that centers on resilience contributes to theory concerning the evolution of issue framing, management strategies, and policy tools within the context of U.S. environmental policy and provides insight for policymakers by identifying new opportunities to prepare for the unprecedented environmental changes that are likely to occur in the Anthropocene.

Background

The Three Epochs of U.S. Environmental Policy

Mazmanian and Kraft's (2009b) Environmental Epoch framework provides a practical approach for assessing whether and how environmental policy and politics have begun to evolve to address the environmental challenges that characterize the Anthropocene. During the first environmental epoch, *Regulating for Environmental Protection* (1970-1990), proponents of regulation capitalized on the growing concern amongst the general public regarding national environmental quality and a favorable political climate to establish significant federal regulation on pollution sources (Mazmanian and Kraft 2009b; Mazmanian and Nijaki 2012). During this period, environmental policy solutions primarily relied upon top-down, command-and-control regulations that emphasized the establishment of pollution reduction goals to protect public health and the environment and remedial actions designed to address "point source" pollution problems.

The second environmental epoch (1980s-2000s) was characterized by a push for efficiency-based regulatory reform and flexibility. Primarily driven by the neo-liberal economic principles of the Reagan administration, the rise of Republican party influence on Capitol Hill, and the grievances of industry interests regarding the costs of regulation, the application of cost-benefit analyses, and the use of performance standards and market-based mechanisms became a preferred solution over technology mandates. Additionally, many regulatory oversight and enforcement responsibilities were decentralized and shifted to the state and local levels (Mazmanian and Nijaki 2012).

The contemporary environmental epoch, *Toward Sustainable Communities* (1990-Present), developed alongside the emergence of sustainable development onto the international community's policy agenda and the realization that unresolved environmental issues of past epochs will require a new

paradigm of governance and management strategies. In the U.S., the influence of this international environmental governance agenda, along with the declining policy capacity of the federal government, and the emergence of complex, multifaceted environmental problems led to the development of innovative policy solutions by state and local governments that characterize the third epoch of U.S. environmental policy and politics (Table 1; Klyza and Sousa 2008; Mazmanian and Kraft 2009b; Mazmanian and Nijaki 2012; Rabe 2004).

In keeping with the conventional view of sustainable development, the policy tools applied during the sustainability epoch seek to maintain environmental quality while promoting economic growth and supporting diverse social needs. The implementation philosophy mainly focuses at the individual and community level and the establishment of preventative and comprehensive interventions through the implementation of flexible, voluntary, and incentive-based methods of policy implementation (Hempel 1998; Kraft 2014; Maser 1997; Mazmanian and Kraft 2009a; Weber 2003; Wondolleck and Yaffee 2000). The policymaking process supports cooperation across the public, nonprofit, and private sectors by applying collaborative decision-making processes, public-private partnerships, and public education campaigns (Durant et al. 2004; Press and Mazmanian 2006). In practice, this approach requires civic leaders and public and private stakeholders to recognize the interdependence of communities in both economic and ecological terms and relies on citizens to draw connections between civic engagement and quality of life (Hempel 2012).

Table 1. Toward Sustainable Communities (1990–Present). (adapted from Mazmanian and Kraft 2009b)

Dimension	Characteristics
Key Events and Public Actions	• Brundtland report, Our Common Future Earth Summit (UNCED) • Montreal Protocol on CFCs • Kyoto Protocol • Intergovernmental Panel on Climate Change, series of reports • Hurricane Katrina
Predominant Political/ Institutional Context	• public/private partnerships • local/regional collaborations • community capacity building and consensus building • mechanisms created to enforce "collective" decisions
Problem Identification and Policy Objectives	• bringing into harmony human and natural systems on a sustainable basis • balance long-term societal and natural system needs through system design and management • rediscovery of/emphasis on resource conservation • halt diminution of biodiversity • embrace an eco-centric ethic
Policy Approaches and "Tools"	• comprehensive future visioning • regional planning based on sustainability guidelines, • Total Quality Environmental Management (TQEM) and life-cycle- design practice in industry • various experiments with new approaches
Points of Intervention	• societal level needs assessment and goal prioritization • industry-level attention to product design, materials selection, and environmental strategic planning • individual behavior and life-style choices

Implementation Philosophy	• develop new mechanisms and institutions that balance the needs of human and natural systems, both within the U.S. and around the globe • focus on outcomes and performance
Information and Data Management Needs	• sustainability criteria and indicators • eco-human support system thresholds • region/community/global interaction effects (e.g., regarding carbon dioxide emissions and depletion of ozone layer) • utilization of ecological footprint analysis • use of material and energy "flow- through" inventories and accounting • computer modeling of human- natural systems interactions

The sustainable communities approach to environmental governance is frequently applied by developing comprehensive, local-level sustainability plans and has been applied to address specific areas such as urban growth, water management, agriculture, energy, and climate change (Hempel 2009, 2012; Portney 2013; Mazmanian and Kraft 2009a).

In theory, a bottom-up approach to environmental governance based on sustainability principles that focus on local level initiatives designed to protect environmental quality while promoting economic growth and development and enhancing social equity is a practical strategy for designing solutions to mitigate the political conflicts and cross-cutting environmental issues left unresolved by prior environmental epochs. However, policy practitioners and sustainability scholars have frequently debated the effectiveness of sustainability as a model of environmental governance due to the term's wide range of interpretations and normative connotation (i.e., the sustainability of what and for whom), the political challenges of designing policies that support environmental, economic, and equity improvements simultaneously, and the challenge of identifying appropriate metrics for measuring progress (Campbell 1996; Hempel 2009, 2012). Additionally, in practice, the *sustainable communities* model of environmental governance has fallen short of facilitating a transformation in which U.S. society subsists within the Earth system's ecological limits. Efforts to improve environmental quality during each of the environmental policy epochs identified by Mazmanian and Kraft (2009b) have produced improvements in critical areas such as air and water quality, biodiversity protection, and solid and hazardous waste management (Kraft 2018). However, air quality problems in urban areas, from contaminants such as ozone and particulate matter, continue to threaten human health. At the same time, nonpoint source water pollution remains a significant threat to the nation's surface and groundwater resources, and the populations of some plant and animal species have declined to precarious levels (Kraft 2018).

The long-term stressors and short-term shocks associated with global climate change will likely amplify contemporary air, water, and biodiversity problems, creating a unique set of challenges for policymakers. Long-term environmental stressors from increasing temperatures will shift the range of endemic and invasive species, altering terrestrial and aquatic ecosystems (USGCRP 2018). Rising sea levels will further alter the characteristics of coastal ecosystems and water quality in coastal aquifers. In contrast, rising temperatures and changes in the frequency and intensity of snow and precipitation events will alter the pattern and quality of surface water flows. In urban areas, projected increases in the frequency and intensity of precipitation may overwhelm urban stormwater infrastructure, contributing to increased occurrences of nonpoint source water pollution. Simultaneously, more frequent heatwaves will exacerbate existing air quality problems and challenge energy system capacity (USGCRP 2018).

Resilience Theory

Past epochs of U.S. environmental policy have primarily focused on policy approaches designed to address environmental stressors by mitigating environmental pollution sources (Mazmanian and Kraft

2009b). In the Anthropocene, planetary problems such as climate change result from anthropogenic disturbances to Earth system cycles that may be irreversible in some cases. The multi-scalar, cross-sector, and compounding impacts of such large-scale system disturbances can produce cascade effects that result in SES disturbances at lower levels (IPCC 2014b, 2018; USGCRP 2017). While efforts to mitigate the anthropogenic drivers of such disturbances may slow the rate of system change, once critical thresholds are past, SES must learn to respond to the uncertain and unpredictable changes to environmental conditions that result from the alteration of Earth system cycles. As our scientific understanding of the nature of these complex systems and critical thresholds has improved, environmental scientists, policymakers, and planners have increasingly applied the concept of resilience to frame policy discussions, establish policy goals, and develop strategies to preserve and protect environmental quality and human health.

The earliest conceptualization of resilience within the context of environmental disruptions is often referred to as ecological resilience (ER) and was introduced by Holling (1973), who defined resilience as the capacity of a complex ecological system to reorganize in order to endure or adapt to uncertain disruptions while preserving its structure and function (Davoudi 2012; Walker et al. 2006; Walker and Salt 2006, 2012). Based upon the perspective that ecological systems may experience multiple stable states as a result of regime shifts in response to system shocks, the concept was introduced as an alternative to the single stable state perspective of previous conceptualizations of resilience and offered an approach to address the unpredictability and uncertainty of system change (Gunderson 2000; Gunderson and Holling 2002; Holling 1996).

In the late 1990s, the ER concept expanded to include the complex interactions between human and natural systems (Adger 2000; Berkes and Folke 1998; Folke et al. 2002; Walker et al. 2002; Walker and Salt, 2006, 2012). Referred to as social-ecological resilience (SER), the new perspective incorporated concepts such as adaptive capacity and transformative capacity to account for the unique reorganizational capabilities of institutions, social systems, and individuals (Berkes, Colding and Folke 2003; Walker et al. 2004). In contrast, to ER which emphasizes a return to a preexisting or a new stable state following a system disruption, the SER perspective views SES as complex systems characterized by constant change and states of non-equilibrium, uncertainty, unpredictability, and nonlinearity (Carpenter, Westley, and Turner 2005). Thus, in contrast to the ER perspective, SER is achieved through an iterative process of incremental adaptation and transformative change to small- and medium-scale level systems in response to evolving conditions at larger scales (Coaffee 2013; Davoudi 2012; Prior and Hagmann 2013).

More recently, Gunderson and Holling (2002) expanded upon the SER perspective with the *Panarchy* framework to account for the interconnectedness and interactions between SES with various adaptive cycles that exist within nested scales and operate at different speeds and timeframes. At the broadest scale, slow, long-term processes, such as global climate change, establish the conditions within which smaller-scale systems, such as a city or watershed, function under faster cycles of change. Smaller-scale systems can also influence the conditions of larger-scale systems where a localized shock, such as coastal flooding in an urban center, can produce impacts that affect the stability of larger-scale systems, such as a state-level economy or regional transportation system. In such cases, responses from the broader system, such as state-level policy institutions, may mobilize resources to return the smaller system to a preexisting or new equilibrium state.

Increased awareness of the interdependency of SES coupled with the uncertain and nonlinear environmental changes that can occur due to surpassing Earth system thresholds has led policymakers and planners to increasingly employ the concept of resilience to recover from and prepare for social, economic, and environmental disturbances. The growing interest in applying resilience-based principles has created a demand to identify actionable policies to support SES adaptive and transformative capacity (Chandler and Coaffee 2016). In response, scholars have identified a variety of principles to support the design of policies that can be applied to support the resilience of systems (Barnett 2001; Biggs et al. 2012; Tyler & Moench 2012; Wardekker et al. 2010; Sharifi and Yamagata, 2016; de Bruijn et al. 2017). Wardekker et al. (2020) provide a comprehensive framework of 10 resilience principles, based upon a review of the literature, that can be applied to design and evaluate plans and policy options to support

resilience (Table 2). Each principle is grouped into one of four resilience goals: planning and preparedness, absorption of disturbances, recovery from disturbances, and adaptability and change. The points of intervention for principles identified to support adaptive capacity and recovery from system disturbances can be applied to support the resilience of natural, social, economic, infrastructure systems. At the same time, those associated with planning and adaptability focus more explicitly on resilience strategies to support governance and management systems. Collectively, the range of principles identified by Wardekker et al. (2020) provides a suite of potential strategies that policymakers can employ to support SES resilience at various levels of governance.

Table 2. Resilience principles (adapted from Wilk et al. 2020).

Goal	**Principle**	**Operationalization**
Plan/Prepare:	Anticipation & Foresight	Building knowledge about disturbance, exposure, vulnerability Monitoring of slow variables Information management & sharing Capacity to learn
	Preparedness & Planning	Public awareness, risk communication, education & training Response & emergency management
	Homeostasis	Preservation and restoration of regulating ecosystem services Integrated planning, coordination and collaboration Clearly defined responsibilities of actors and institutions Inclusiveness & equity standards Quick notification of disturbances
Absorb:	Robustness & Buffering	Robustness through infrastructure Creating buffer capacities Impact and risk reducing planning and planning practice
	Diversity	Functional and response diversity Spatial diversity of critical functions Actor and stakeholder diversity Institutional diversity, multi-level governance systems and linkages
	Redundancy	Overlapping functions and roles Functional redundancy in important functions and services Spare capacities and back-up resources
Recover:	Flatness	Institutional decentralization and autonomy Broad participation and stakeholder engagement and inclusiveness Room for autonomous change
	High-flux	Availability of an access to resources Social and institutional networks Flexibility in response / resourcefulness Managing connectivity of critical sectors, infrastructure and natural habitats
Adapt:	Learning	Institutional learning capacity and reflectivity Experimentation and innovation

Flexibility	Institutional flexibility
	Flexibility in spatial planning
	Flexibly in measures

The Anthropocene's emergent environmental problems are driven mainly by system feedbacks caused by the crossing of Earth system thresholds. Climate change is the most pervasive of these issues, as the direct and compounding effects of a changing climate can cause the exceedance of critical thresholds in lower-level systems, producing cascade effects with potentially catastrophic and irreversible consequences for SES. The history of environmental policymaking in the U.S. provides ample evidence that policymakers at each level of governance are capable of reaching agreements on solutions to address significant environmental challenges. While mitigation will continue to be a fundamental aspect of environmental policy, the scientific complexity of many contemporary environmental issues combined with the diffuse and crosscutting characteristics of their causes and effects has made the development of policy solutions to regulate pollution politically challenging (Kraft 2021). The concept of resilience and the application of resilience-based principles to frame and develop environmental policy and planning strategies offer a promising approach to account for the uncertainties and nonlinear changes associated with environmental conditions that have become increasingly likely to occur in the Anthropocene.

While the concepts of sustainability and resilience share several similar and overlapping characteristics, scholars have proposed that the shift to a model of environmental governance that centers on resilience would imply a realignment of policy objectives that are distinct from those established under an approach based on environmental sustainability (Benson and Craig 2014; Hunt 2009; Lew et al. 2016; Lizarralde et al. 2015; Redman 2014). Although resilience is viewed, in some cases, as a critical component of SES sustainability (Ahern 2013; Anderies et al. 2013; Blackmore and Plant 2008), and policy and planning initiatives, such as energy efficiency and green infrastructure programs, can simultaneously support resilience and sustainability objectives, there are instances in which efforts to enhance resilience can conflict with sustainability principles. For example, the construction of grey, rather than green, infrastructure to support the resilience of coastal communities to coastal storms and flooding may result in the loss of coastal ecosystems and biodiversity. Additionally, initiatives to enhance resilience may occur independently from those that support environmental sustainability (Portney and Hannibal 2021). For example, the development of public health and education campaigns in urban communities to inform healthcare professionals and residents about the effects of increased low air quality days, which are likely to become more frequent due to climate change, supports the adaptive capacity of vulnerable populations. However, efforts to address such impacts through stricter regulations on localized sources of air pollution may be more compatible with environmental sustainability goals.

Perhaps the most significant divergence between the concepts of sustainability and resilience are their assumptions about system stationarity and equilibrium (Benson and Craig 2014; Carpenter et al. 2001). Traditionally, resilience has been characterized as the amount of change a system can undergo following a disturbance and still retain the same function and structure, a view that is compatible with the concept of sustainability. However, more contemporary perspectives on resilience have embraced the idea that SES can experience multiple stable states as a result of regime shifts and that such systems undergo constant change and states of non-equilibrium that occur under conditions of uncertainty, unpredictability, and nonlinear change (Carpenter, Westley, and Turner 2005; Gunderson 2000; Gunderson and Holling 2002; Holling 1996). This perspective is less compatible with the popular conceptualization of sustainability and emphasizes the ability of SES to support and develop the capacity for learning, adaptation, and transformation to recover from system disturbances (Berkes, Colding and Folke 2003; Carpenter et al. 2001; Coaffee 2013; Davoudi 2012; Prior and Hagmann 2013; Walker et al. 2004). Therefore, in contrast to sustainability, resilience thinking embraces the dynamics and complexities of SES and emphasizes adaptive capacity and adaptive management rather than stationarity (Benson and Craig 2014).

This study applies the environmental epochs framework developed by Mazmanian and Kraft (2009b) to examine whether and how policymakers and planners at the federal, state, and local levels in

the U.S. apply the concept of resilience to address the effects of climate change, and whether such a trend lends evidence to the emergence of a new epoch in environmental policy and politics. Although the concept of resilience has important applications in a number of environmental policy areas, the widespread, cross-sector, and crosscutting effects of climate change have important implications for a diverse array of existing environmental challenges. Therefore, it is likely that policy efforts concerning climate resilience are reflective of such efforts in more focused aspects of environmental policy.

Methods

In the U.S., adaptation has served as the primary policy approach to support the resilience of SES to environmental change, and these efforts have primarily focused on addressing the effects of climate change. This study defines adaptation as the decision-making process and strategies undertaken to maintain or improve SES capacity to recover from long-term stressors and short-term shocks without undergoing significant changes in function, structure, or feedbacks (Nelson, Adger, and Brown 2007). Therefore, adaptation is the operationalization of resilience and refers to the procedures and policies established to manage system resilience by increasing adaptive capacity through the allocation of resources and processes that work to support response and recovery to maintain the function of a system when exposed to long- and short-term disruptions (Walker et al. 2004). Policy initiatives to support climate adaptation have generally occurred through the development of climate adaptation plans which assess the observed or predicted climate change impacts to SES, identify vulnerabilities across a range of sectors, and include actions to moderate harm that target vulnerable systems (Measham et al. 2011; Preston, Westaway, and Yuen 2011).

In order to assess the emergence of a new environmental epoch in environmental policy in which resilience serves as the guiding principle of decision-making processes and policy strategies, the study begins with a review of key events and public actions that have contributed to the emergence of climate adaptation and resilience as an approach for enhancing system resilience. The study continues with a review of the institutional structure and characteristics of climate adaptation plans and policies at the federal, state, and local levels. The Environmental Epochs framework is applied to structure the analysis and primarily centers on plan content that focused on addressing environmental quality concerns related to public health and natural systems protection. The analysis also includes the identification of specific resilience principles to adaptation planning and policy initiatives to illustrate the resilience approach (i.e., return to a stable state, advance to a new stable state, new stable state at various scales) that is applied to enhance the ability of SES to recover from the effects of long-term stressors and short-term shocks.

The sources of materials reviewed for this study include government documents and scientific reports. The purpose of this study is to identify the key features that distinguish an environmental epoch that centers on resilience from past eras of environmental policy. Therefore, the adaptation activities included in this study do not represent a comprehensive depiction of such initiatives throughout the U.S.

Results

Key Events and Public Actions

Similar to sustainability, initiatives established by global governance institutions and networks have also contributed to the emergence of resilience and adaptation as an applied policy and planning strategy. International initiatives have primarily been supported through multilateral resolutions and agreements facilitated by various United Nations (U.N.) organizations, and have primarily been framed within the context of climate change risks and as a supplement to sustainable development efforts (Table 3). For example, climate adaptation and resilience garnered unprecedented attention in the 2015 Paris Agreement; an international treaty focused on addressing climate change negotiated at the 21st Conference of the Parties to the U.N. Framework Convention on Climate Change. Although the predecessor to the Paris Agreement, the 1997 Kyoto Protocol, supported adaptation by establishing an

international adaptation fund to finance adaptation projects and programs in developing countries, the treaty centered primarily on climate change mitigation (Kyoto Protocol 1997). In contrast, the Paris Agreement placed climate adaptation alongside mitigation as a critical component of the global response to climate change. Article 7 of the agreement establishes adaptation as a long-term global goal to enhance adaptive capacity, strengthen resilience, and reduce vulnerability to climate change and includes resilience directives for agreement signatories, including the development, implementation, monitoring, and evaluation of adaptation plans and initiatives (Conference of the Parties 2015).

Various nonprofit, private sector, and philanthropic organizations that provide technical consulting, training, and information services to support capacity building, knowledge sharing, and local government efforts to implement urban resilience strategies have supported the diffusion of these efforts. Among the more prominent of these organizations are C40 Cities and the International Council for Local Environmental Initiatives– Local Governments for Sustainability, each of which have established initiatives that focus explicitly on supporting urban climate change resilience (C40 Cities 2020; ICLEI 2019). More recently, the Rockefeller Foundation's 100 Resilient Cities program, now known as the Global Resilient Cities Network, was created to help cities develop resilience strategies to prepare for a range of disruptive events (GRCN 2020).

Table 3. International initiatives that include resilience-based initiatives.

Organization	Year	Event	Description
UN Office for Disaster Risk Reduction	1994	Yokohama Strategy and Plan of Action for a Safer World	Focus on disaster and climate risk mitigation within the context of sustainability at the local level
	2010	Making Cities Resilient (MCR) Campaign	Support local governments to address risks and build urban resilience
	2015	Sendai Framework for Disaster Risk Reduction 2015–2030	Outlines seven targets and four priorities for action to prevent new and reduce existing disaster risks
UN Framework Convention on Climate Change	2011	Durban Adaptation Charter	Commits signatory local governments to climate action in their jurisdiction to assist communities to respond to and cope with climate change risks
	2015	Paris Agreement	Includes long-term climate adaptation goals that focus on enhancing adaptive capacity, increasing resilience, and limiting vulnerability
	2017	Conference of the Parties to the UNFCCC	Sought to address the challenges of urban resilience and climate adaptation
World Urban Forum	2014	Medellin Collaboration for Urban Resilience	Comprised of a conglomeration of international governance, nonprofit, and philanthropic organizations to promote resilient and sustainable growth in cities
UN General Assembly	2015	2030 Agenda for Sustainable	Includes 17 Sustainable Development Goals (SDG) that include the concept of resilience both explicitly

		Development	and implicitly in a range of SDG targets
United Nations Conference on Housing and Sustainable Urban Development	2017	New Urban Agenda	Resilience is a key theme and signatories commit to strengthening resilience in cities to reduce the risk and the impact of disasters

Sources: ICLEI 2019.

In the U.S., as the international agenda on climate adaptation and resilience began to unfold, a series of events captured the attention of policymakers and the general public concerning the potential effects of a changing climate. In August 2005, the devastating effects of Hurricane Katrina and Hurricane Rita, two of the most powerful and costly storms on record, captured the public's attention (Knab, Rhome, and Brown 2011; NOAA 2018). Most of the losses were caused by Hurricane Katrina and experienced by Louisiana, where low-lying communities were inundated with water, the causes of which have primarily been attributed to a flood management infrastructure that was inadequate for absorbing the shocks of such powerful extreme weather events (Rogers et al. 2015).

A year after Hurricane Katrina captured the public's attention concerning the potential effects of extreme weather events that may be strengthened by climate change, awareness of the climate change issue grew with the release of a documentary film entitled *An Inconvenient Truth*. In the film, former Vice President Al Gore presented the scientific basis for climate change, discussed the scientific consensus on the issue, and the existing and future effects and stresses that are likely to occur due to climatic changes (Guggenheim 2006).

Perhaps the most significant event related to climate resilience came in 2007 with the release of the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment report. Established in 1988 by the World Meteorological Association and the U.N. Environment Program, the IPCC relies upon the work of thousands of scientists to assess the scientific literature and provide a comprehensive summary of knowledge concerning the drivers, impacts, and future risks of climate change, and how adaptation and mitigation can reduce those risks (IPCC 2014a). The IPCC's Fourth Assessment report concluded that most of the observed increases in global average temperatures since the mid-20th century are due to human activities and that warming and sea level rise would continue for centuries even if greenhouse (GHG) emissions were stabilized.

Another important event that underscored the relevance of resilience, and the limitations of mitigation and environmental sustainability, as a guiding principle of environmental policy was the failed attempt by U.S. policymakers to enact a federal cap and trade program. In 2009 newly elected President Barack Obama had just taken office with a strong environmental and climate change policy agenda and a Democratic majority in both chambers of Congress. Two years prior, Congressional members had begun to work with advocacy groups such as the U.S. Climate Action Partnership (USCAP), a coalition of more than two dozen big business CEOs and environmental organizations, to develop a cap and trade bill to reduce carbon dioxide (CO2) emissions (Skocpol 2013). In January 2009, USCAP leaders released their plan, and House Representatives Henry Waxman (D-CA) and Ed Markey (D-MA) introduced the American Clean Energy and Security Act (ACESA), a federal cap and trade program that received support from both environmental and business interests (American Clean Energy and Security Act of 2009; Skocpol 2013). In June 2009, the House of Representatives passed the ACESA by a slim majority (219-212), mainly along party lines, with only eight Republicans voting in favor and 44 Democrats voting against the bill. However, oppositional lobbying efforts, led by the fossil fuel industry and conservative think tanks, media outlets, and contrarian scientists, were amplified by Tea Party-led advocacy campaign leading up to the 2010 midterm elections that produced a Republican wave in which the party regained

control of the House (Dunlap and Jacques 2013; Elsasser and Dunlap 2013; Skocpol 2013). Although the Senate remained in Democratic control, Republicans gained six seats which, along with the lobbying efforts of the fossil fuel industry and conservative interest groups, ensured that the chamber would not acquire the 60 votes needed to end a filibuster successfully (Skocpol 2013). Consequently, the bill was not brought before the Senate for a vote, closing the brief window of opportunity to enact a national policy on climate change mitigation.

The failed attempt by Congress to enact a cap and trade program occurred at a time when partisan polarization on environmental policy amongst political elites and the general public had been steadily growing (Dunlap, MCright, and Yarosh 2016; McCright, Xiao, and Dunlap 2014). Following the 2008 Presidential election, polarization surged, in part, due to Tea Party-led anti-Obama backlash, funded by conservative elites (Bradbury and Jacobson 2011; Williamson, Skocpol, and Coggin 2011). At the same time, alliances had formed between the fossil fuel industry, resource-based corporations and associations, and conservative organizations, think tanks and foundations to prevent climate policy discussions from gaining political momentum (Dunlap and McCright 2011; Layzer 2007, 2014). The coalitions sought to stymie such efforts by establishing counter-claims that questioned the scientific validity of anthropogenic climate change and emphasized the potential economic implications of policy action on American's way of life (Dunlap and McCright 2011; Jaques, Dunlap, and Freeman 2008; Layzer 2007, 2014; McCright and Dunlap 2000, 2003). This concerted effort contributed to an increase in partisan polarization and, along with a growing tendency to associate party identification with social identity, established political party affiliation as a critical indicator of climate change concern and policy beliefs (Dunlap, McCright, and Yarosh 2016; Mason 2015; Dunlap and McCright 2008; McCright, Dunlap, and Xiao 2014). In general, Republicans are more skeptical of the findings of climate scientists, less concerned about climate change threats, and are opposed to the regulation of GHG emissions; while Democrats tend to express more trust in climate science, greater concern regarding the effects of climate change, and more support for policy efforts to reduce emissions (Dunlap and McCright 2008; Dunlap, McCright, and Yarosh 2016).

Climate Resilience at the Federal Level

Political and Institutional Context

In the U.S., the culmination of the events discussed above set the stage for the emergence of climate adaptation to reduce SES vulnerability and increase resiliency to the unavoidable climate change shocks and stressors. In 2009, the same year that Congress introduced the ACESA, and just two years after the release of the IPCC's 2007 climate change assessment report, the issue of climate change resilience climbed to the top of the federal government's political agenda following. President Obama issued Executive Order 13514 establishing an Interagency Climate Change Adaptation Task Force (ICCATF) to assess federal-level climate adaptation activities and prepare recommendations on how existing policies, programs, and planning efforts can be modified to reinforce the emergent national strategy on climate change adaptation (Exec. Order No. 13514, 2009).

In November 2013, a year after Hurricane Sandy devastated parts of New York City and the northeast, President Obama released the *President's Climate Action Plan* (CAP), which contained a section on climate adaptation, including proposed actions to support climate resilience (EOP 2013). As part of the White House CAP, President Obama issued Executive Order 13653. The order replaced the ICCATF with an intergovernmental State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience (Task Force on Climate Preparedness and Resilience) to provide recommendations for a federal government response to communities that are experiencing the effects of climate change. Executive Order 13653 also directed agencies to develop adaptation plans for federal facilities and resources and assess how land- and water-related policies and programs can be modified to make the nation's aquatic and terrestrial ecosystems, and the communities and economies that depend on them, more resilient to climatic changes (Exec. Order No. 13653, 2013). The mandate led the Task Force on Climate Preparedness and Resilience to convene a Climate and Natural Resources Working Group (CNRWG).

In addition to the CAP, the ICCATF, the Task Force on Climate Preparedness and Resilience, and the CNRWG each produced a report for the White House that provided recommendations to enhance the resilience of the nation's built, social, economic, and natural systems to climatic changes (Table 4).

Table 4. Federal reports on climate adaptation and resilience.

Prepared By	Initiated	Completed	Report	Initiated by
Interagency Climate Change Adaptation Task Force	2009	2010	Progress Report of the Interagency Climate Change Adaptation Task Force	Federal Leadership in Environmental, Energy, and Economic Performance (Executive Order 13514)
Executive Office of the White House	2012	2013	President's Climate Action Plan	President's Office
State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience	2013	2014	President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience: Recommendations to the President	Preparing the United States for the Impacts of Climate Change (Executive Order 13653)
Climate and Natural Resources Working Group	2013	2014	Priority Agenda Enhancing the Climate Resilience of America's Natural Resources	Section 3 of Executive Order 13653

Each effort to support the national agenda on climate resilience employed a unique institutional approach to support the development of climate adaptation strategies. While the development of the CAP was prepared primarily by the Council on Environmental Quality (CEQ) within the Executive Office of the President, the ICCATF was co-chaired by representatives from the CEQ, the National Oceanic and Atmospheric Administration, and the Office of Science and Technology Policy and included formal members from the Executive Office of the President and a wide range of federal Departments (EOP 2013; CEQ 2010). The task force also established nine thematic, cross-sector workgroups comprised of representatives from various federal departments that focused on broad and specific areas such as adaptation science, international resilience, urban areas, water resources, health, and natural systems (CEQ 2010). Given the CNRWG's focus on natural resources, the group consisted of a collection of representatives from the CEQ and eight federal departments that oversee policies and programs concerning natural resources management (CCPR 2014). In contrast to the federal focus of the ICCATF and the CNRWG, the structure of the Task Force on Climate Preparedness and Resilience, while co-chaired by representatives from the CEQ and the White House Office of Intergovernmental Affairs, focused exclusively on formal input from state and local governments. Membership included a collection of 26 governors, mayors, supervisors, and commissioners, as well as a representative from tribal governments (Task Force on Climate Preparedness and Resilience 2014).

Each effort supported the inclusion of stakeholder engagement to varying degrees. The CAP and the CNRWG report development processes did not include formal opportunities for input from public and private organizations, while the ICCATF integrated formal stakeholder engagement by hosting a series of public workshops in various locations throughout the country (EOP 2013; CCPR 2014; CEQ 2010). The Task Force on Climate Preparedness and Resilience integrated opportunities for informal input from a wide range of external stakeholders, including nonprofit organizations, think tanks, academic institutions, and the private sector. Additionally, nearly all of the task force's workgroups hosted multiple, sector-specific meetings to garner input from key stakeholder groups with expertise in their respective areas (Task Force on Climate Preparedness and Resilience 2014).

Problem Identification

The U.S. Global Change Research Program's (USGCRP) National Climate Assessment (NCA) supported the process of problem identification for each of these federal-level efforts. Established by President George H.W. Bush in 1989 and codified by the Congress in the Global Change Research Act (GCRA) of 1990, the USGCRP is an interagency research body comprised of 13 federal agencies and led by the National Oceanic and Atmospheric Administration. The organization is responsible for developing and coordinating a comprehensive and integrated research program to understand, assess, predict, and respond to human-induced and natural processes of global change (GCRA 1990). Among other things, the GCRA requires the USGCRP to prepare and submit a quadrennial climate change assessment to the President and the Congress that details the observed and projected effects of climate change in the U.S. Referred to as the National Climate Assessment (NCA), the document serves as the primary product of the USGCRP's reporting requirements. The NCA is conducted with the support of hundreds of technical experts and relies upon integrated data, scientific studies, and climate models produced by the USGCRP, the IPCC, and other climate science organizations. Climate scientists use the data and models to provide projections and scenarios based upon assumptions concerning the anthropogenic and natural factors that influence GHG emissions to provide information concerning current and medium- to long-term climate conditions in the U.S. (USGCRP 2018).

The USGCRP's second NCA, released in 2009, supported the development of the ICCATF's 2010 report while the third NCA, released in 2014, informed the work conducted by the Task Force on Climate Preparedness and Resilience and the CNRWG (CCPR 2014; CEQ 2010; Task Force on Climate Preparedness and Resilience 2014). The NCA served as a decision-making tool for each task force by supporting the identification of vulnerable systems based upon their level of exposure and sensitivity to the stressors and shocks associated with climate change impacts. Each report identified rising temperatures, sea level rise, flooding, and droughts as critical problems to be addressed to support climate resilience. Heat waves, ecological impacts, more frequent and intense storms, changes in the timing and distribution of water supplies, and impacts to the agriculture sector were also frequently identified as critical problems (CCPR 2014; CEQ 2010; Task Force on Climate Preparedness and Resilience 2014). The reports completed by the ICCATF and the Task Force on Climate Preparedness and Resilience identified public health impacts and the disproportionate effects of climate change on vulnerable communities as vital concerns. However, the CAP and the report produced by the Task Force on Climate Preparedness and Resilience were the only two to identify air pollution and water quality impacts. Other problems identified to varying degrees across the reports included wildfires, reduced permafrost, coastal erosion, insect outbreaks, ocean impacts (e.g., acidification), and energy supply impacts (CCPR 2014; CEQ 2010; EOP 2013; Task Force on Climate Preparedness and Resilience 2014).

Policy Objectives

Based upon the impacts identified in the NCA, each report identified several guiding principles and policy objectives to support climate resilience (Table 5). The integration of science into policies and practices and the application of science-based, risk-management tools and information to support decision-making were among the most common policy objectives across the plans. Each plan also identified the application of such tools to protect and restore natural resources to support ecosystem and

community resilience while achieving the co-benefit of climate change mitigation as essential policy goals. The ICCATF and the Task Force on Climate Preparedness and Resilience also recommended establishing multi-sector and multi-scale partnerships to facilitate collaboration and coordination to address the crosscutting effects of climate change as critical objectives to be achieved by federal-level climate resilience strategies.

Table 5. Summary of policy objectives.

Report	Policy Objectives
The President's Climate Action Plan	• Build stronger and safer communities and infrastructure • Protect the economy and natural resources • Use sound science to manage climate impacts • Lead international efforts to address climate change
Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy	• Integrate climate change preparation into core policies, planning, practices, and programs whenever possible • Prioritize people, places, and infrastructure that are most vulnerable to climate impacts • Use best-available scientific understanding of climate change risks, impacts, and vulnerabilities • Build strong multi-sector and multi-scale partnerships • Apply risk-management methods and tools • Apply ecosystem-based approaches to build resilience and reduce the vulnerability of people and their livelihoods to climate change impacts • Use strategies that complement or directly support other related climate or environmental initiatives • Include measurable goals and performance metrics to continuously assess whether adaptive actions are achieving desired outcomes
President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience: Recommendations to the President	• Require consideration of climate-related risks and vulnerabilities as part of all federal policies, practices, investments, and regulatory and other programs • Maximize opportunities to take actions that have dual-benefits of increasing community resilience and reducing GHG emissions • Strengthen coordination and partnerships across sectors and scales • Provide actionable data and information on climate change impacts and related tools and assistance to support decision-making • Consult and cooperate with tribes and indigenous communities
Priority Agenda Enhancing the Climate Resilience of America's Natural Resources	• Protect important landscapes and develop the science, planning, tools, and practices to sustain and enhance the resilience of the Nation's natural resources • Manage and enhance U.S. carbon sinks by conserving and restoring soils, forests, grasslands, wetlands, and coastal areas that store carbon • Enhance community preparedness and resilience by utilizing and sustaining natural resources • Modernize Federal programs, investments, and delivery of services to build resilience and enhance sequestration of biological carbon

Policy Approach, Tools, Implementation Philosophy, and Point of Intervention

Table 6 includes a selection of recommended actions and associated resilience goals and principles drawn from each of the reports, distributed across five policy tools, recommended action, and resilience goals and principles supported by each. The integration of science-based, sector-specific climate change impacts into existing policy and program practices was a nearly universal recommendation across each plan. Often referred to as climate mainstreaming, this approach supports adaptive management and seeks to ensure the consideration of the short- and long-term effects of climate change in departmental decision-making and administrative processes. Additionally, the development of extensive, cross-jurisdictional, and multi-sector partnerships was a common recommendation across the plans. Another common approach to enhance preparedness, adaptive capacity, and adaptive management included recommendations that increase climate literacy through education and outreach and the availability, accessibility, and utility of climate data and resilience-building tools to the public and private sectors. The use of regional information-based and decision-making tools, such as centralized clearinghouses and interdisciplinary indices, were among the most commonly identified strategies to support these efforts.

Table 6. Selection of federal-level adaptation policy recommendations.

Report	Policies	Resilience Goal (Principle)
Progress Report of the ICCATF	• Implement adaptation planning within federal agencies • Employ a flexible framework for agency adaptation planning	• Plan/Prepare (Homeostasis)
	• Use a phased and coordinated approach to implement agency adaptation	• Adapt (Flexibility)
The President's Climate Action Plan	• Department of Health and Human Services help train public health professionals and community leaders to prepare communities for health impacts of climate change, including effective communication of health risks and resilience measures	• Plan/Prepare (Preparedness & Planning); Absorb (Diversity)
	• Establish a public-private partnership to explore risk and catastrophe modeling, and develop information and tools needed to respond to long-term climate change impacts and near-term effects of extreme weather	• Plan and Prepare (Anticipation & Foresight); Absorb (Diversity)
	• Create a virtual climate-resilience toolkit that centralizes access to data-driven resilience tools, services, and best practices.	• Recover (High-Flux); Plan/Prepare (Anticipation & Foresight)
President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience: Recommendations to the President	• Incentivize investments in resilient, distributed and renewable energy microgrids through federal programs	• Absorb (Diversity; Redundancy)
	• Work with state and local governments, tribes, and territories to support development of comprehensive regional data-provision and modeling to provide decision-makers with information to plan and adapt to impacts on water quality and quantity	• Plan/Prepare (Anticipation & Foresight); Absorb (Diversity); Adapt

		(Flexibility)
	• EPA and other agencies should improve stormwater and water quality BMPs, including green infrastructure, to reflect enhanced understanding of climate impacts on water quality, and help institutionalize them into stormwater and water quality management programs at all levels of government	• Plan/Prepare (Homeostasis); Absorb (Robustness & Buffering)
	• Delivery of downscaled climate data and development of regional and sub-regional projections and mapping to ensure availability of data and information to local decision makers	• Plan/Prepare (Anticipation & Foresight)
	• Increase support and incentivize efforts that bring together states, territories, counties, localities, and Tribes to leverage federal resources more efficiently and collaborate across jurisdictional lines to develop regional indicators, projections, planning tools, and response options, and implement joint climate preparedness and resilience strategies	• Plan/Prepare (Homeostasis); Absorb (Diversity)
Priority Agenda Enhancing the Climate Resilience of America's Natural Resources	• Decision-support tool to provide baseline resilience data and measure the progress of restoration, conservation	• Plan/Prepare (Anticipation & Foresight); Adapt (Learning)
	• Build or maintain ecologically connected network of terrestrial and aquatic conservation areas likely to be resilient to climate change and support a range of wildlife under changing conditions	• Absorb (Diversity); Recover (High-Flux); Adapt (Flexibility)
	• Federal resources to help local communities integrate green infrastructure planning into broader community development efforts, including transportation systems and parks/open spaces	• Absorb (Robustness & Buffering, Diversity)

The point of intervention for most policy recommendations focused on public and private actors at the local level. Each plan recommended establishing partnerships with local healthcare providers, facilities, and community leaders to facilitate effective communication of the health consequences of climate change health risks and the development of resilience metrics for communities. In this context, decreased air quality due to extreme heat is among the most significant health threats. Whereas previous environmental epochs have relied primarily upon point-source pollution regulation to improve local air quality, air quality impacts from increasing temperatures cannot be directly regulated. Therefore, recommended actions to support public health include increased and integrated monitoring of air quality conditions in response to climatic changes, the proximity of such changes to vulnerable populations, and increased outreach and information to increase the adaptive capacity of public health providers and the general public.

Several recommendations throughout the plans also supported sustainability goals while improving resilience. For example, interagency and multijurisdictional collaboration through the federal Green Infrastructure Collaborative, in which the federal government provides technical assistance to local

governments to increase installations of green infrastructure to build robust stormwater management systems and increase urban green space. Additionally, the conservation and restoration of climate-resilient ecosystems through federal conservation and land acquisition programs and the use of incentive programs to support private investments in conservation enhance resilience by creating redundancy, diversity, and connectivity in natural systems while enhancing ecosystem services such as carbon sequestration. Lastly, providing incentives and technical assistance to communities to increase investments in distributed, renewable energy microgrids supports robustness by increasing redundancy and can also help reduce GHG emissions produced by the electric power sector.

In 2015, President Obama issued a final executive order to integrate climate resilience into federal-level operations further. Executive Order 13693 superseded Executive Order 13514 and directed federal agencies to incorporate climate resilience into their energy efficiency and environmental performance efforts (Exec. Order No. 13693, 2015). However, this effort and the various other climate change and climate resilience initiatives established under the Obama administration were short-lived. After entering office in 2017, newly elected President Donald Trump began to rescind the national climate resilience agenda established under the previous administration. Two months into his term, President Trump revoked Executive Order 13653, replacing it with an Executive Order 13783, and in 2018 Executive Order 13693 was revoked by Executive Order 13834. Executive Order 13783 directed agencies to reduce the regulatory burdens associated with domestic energy production, while Executive Order 13834 sought to improve the economic efficiency of administrative agency programs and operations (Exec. Order No. 13783, 2017; Exec. Order No. 13834, 2018). The opposing climate policy agendas of President Obama and President Trump are exemplary of the party politics that have persistently plagued climate change policy discussions.

While the climate adaptation and resilience policy agenda and planning processes established by the Obama administration are no longer in effect, federal facilities and agencies continue to be directly involved in climate change adaptation efforts. Since 2014, the USGCRP's National Climate Assessment has included scientific insights into actionable knowledge to help decision-makers anticipate and prepare for specific climate-change impacts. Additionally, various federal climate data and information clearinghouses and tool kits continue to operate under the administration of a wide range of agencies to provide public and private decision-makers with access and technical support for building climate resilience (FedCenter 2019).

Climate Resilience in the States

Political and Institutional Context

Twenty states have adopted a statewide adaptation plan, 85 percent (17 plans) of which were initiated from 2007 to 2009. In contrast to the federal government's experiences, the integration of climate change resilience into state-level policies has occurred through a combination of executive and legislative action. Although most adaptation initiatives were initiated through executive order (60 percent), 20 percent of state-level adaptation efforts were initiated through legislative action, and the remaining 20 percent of plans were developed by agency-level action (Table 7). A formal, interagency panel of representatives drawn from state-level agencies developed nearly all of the adaptation plans. One exception to this model was Colorado's plan, which was developed by a team of university researchers and technical consultants with the support of various state agencies (WWA 2011). Many of these cross-agency collaborations were led by environmental or natural resource administrative agencies with the support of a collection of sector-specific workgroups comprised of interagency staff in specialized areas distributed across three systems, social (e.g., emergency management, public health), infrastructure (e.g., energy, land use transportation, buildings), and natural systems (e.g., biodiversity, forests, ocean and coasts, agriculture, and water). In Rhode Island, the Chief Resilience Officer, a position created by Governor Gina Raimondo in 2017 to manage the state's climate resilience efforts and develop a climate resilience action strategy, led the completion of the state's 2018 plan, which reflected a more focused framing on resilience (Exec. Order No. 17-10, 2017).

Table 7. State climate adaptation plans.

State	Initiated	Completed	Plan	Initiated By
AK	2007	2010	Alaska's Climate Change Strategy: Addressing Impacts in Alaska	Governor
CA	2008; 2013; 2017	2009; 2014; 2018	California Climate Adaptation Strategy	Governor; Legislature
CO	2007	2011	Colorado Climate Action Plan	Governor
CT	2008	2011	Connecticut Climate Change Preparedness Plan	Legislature
DE	2013	2014	Climate Framework for Delaware	Governor
FL	2007	2008	Florida's Energy & Climate Change Action Plan	Governor
ME	2009	2010	People and Nature Adapting to a Changing Climate: Charting Maine's Course	Legislature
MD	2007; 2007	2008; 2011	Comprehensives Strategy for Reducing Maryland's Vulnerability to Climate Change: Phase 1: Sea-Level Rise and Coastal Storms; Phase 2: Building Societal, Economic, and Ecological Resilience	Governor
MA	2008	2011	Massachusetts Climate Change Adaptation Report	Legislature
MN	2009; 2012; 2016	2010; 2013; 2017	Adapting to Climate Change in Minnesota: Preliminary Report of the Interagency Climate Adaptation Team; Adapting to Climate Change in Minnesota: 2013 Report of the Interagency Climate Adaptation Team; Adapting to Climate Change in Minnesota: 2017 Report of the Interagency Climate Adaptation Team	Agency
NH	2007	2009	New Hampshire Climate Action Plan: A Plan for New Hampshire's Energy, Environmental and Economic Development Future	Governor
NY	2009	2010	New York State Climate Action Plan Interim Report	Governor
NC	2009	2012; 2020	Climate Ready North Carolina: Building a Resilient Future; Climate Risk Assessment and Resilience Plan Impacts, Vulnerability, Risks, and Preliminary Actions: A Comprehensive Strategy for Reducing North Carolina's Vulnerability to Climate Change	Agency
OR	2009	2010	The Oregon Climate Change Adaptation Framework	Governor
PA	2010	2011	Pennsylvania Climate Adaptation Report	Agency
RI	2010	2014; 2018	A Resilient Rhode Island: Being Practical About Climate Change; A Resilient Rhody: An Actionable Vision for Addressing the Impacts of Climate Change in Rhode Island	Legislature
VT	2008	2011	Vermont Climate Adaptation White Papers	Governor
VA	2007	2008	Governor's Commission on Climate Change Final Report: A Climate Change Action Plan	Governor

WA	2009	2012	Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy	Governor
WI	2007	2011	Wisconsin's Changing Climate: Impacts and Adaptation	Agency

Each planning process included climate scientists from various agencies and universities to provide technical support concerning the observed and projected effects of climate change and their implications for SES. Additionally, the federal government administers the management of many resources within the U.S. (e.g., ecosystems, public land, infrastructure, and water resources); therefore, the planning process frequently included representatives from federal-level agencies as formal and informal contributors. Engagement of local governments and public, private, and nonprofit entities was also facilitated through the planning process to varying degrees to reflect the multi-sector nature of the challenges associated with climate change and the policy strategies required to address them effectively.

Problem Identification

State-level policymakers primarily relied upon regional climate change impact assessments to define the climate change problem. Regional assessments generally draw upon global climate models produced by the IPCC and USGCRP and use statistical downscaling to produce a finer-scale understanding of localized impacts to support decision-making to enhance climate resilience. Thirteen states conducted supplemental regional assessments to support their climate adaptation initiatives, while the remaining states integrated climate assessments into their adaptation plans (Table 8). Each state-level effort benefitted from climate science and modeling produced by regional, national, or international scientific bodies. Maryland's assessment, for example, drew from reports and documents produced by the IPCC, the U.S. Climate Change Science Program, and the Northeast Climate Impacts Assessment (NECIA), a collaboration between the Union of Concerned Scientists and various independent climate science experts, to produce its regional projections (Boesch 2008). Whereas Oregon's 2010 climate change assessment, produced by the Oregon Climate Change Research Institute (OCCRI), adopted the IPCC's usage of confidence categories to assign the likelihood of occurrence for each climate risk discussed in the report (OCCRI 2010).

Table 8. State climate change impact assessments.

State	Climate Change Impact Assessment	Completed	Vulnerability/Risk Assessment	Co-Production
Alaska	Arctic Climate Impact Assessment	2004		
California	California Climate Change Assessment	2009; 2012; 2015; 2018	X	X
Colorado	*In Plan*			
Connecticut	The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health	2010	X	X
Delaware	Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment; Delaware Climate Change Impact Assessment	2012; 2014	X	X

Florida	*In Plan*			
Maine	Maine's Climate Future	2009; 2015; 2020		
Maryland	Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland	2008		
Massachusetts	*In Plan*			
Minnesota	*In Plan*			
New Hampshire	*In Plan*			
New York	Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State	2011	X	X
North Carolina	North Carolina Climate Science Report	2020	X	
Oregon	Oregon Climate Assessment Report	2010; 2017; 2019	X	
Pennsylvania	Pennsylvania Climate Impact Assessment	2009; 2015	X	X
Rhode Island	*In Plan*		X	
Vermont	Considering Vermont's Future in a Changing Climate	2014	X	
Virginia	*In Plan*			
Washington	The Washington Climate Change Impacts Assessment	2009		
Wisconsin	Wisconsin Initiative on Climate Change Impacts: Working Group Reports	2011	X	

Nine states supplemented their regional assessments with formal vulnerability and risk assessments to provide greater detail concerning the magnitude of context-specific impacts (Table 8). Climate scientists often define vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change and conceptualize a system's vulnerability as a function of its degree of exposure and level of sensitivity to climate impacts and its existing capacity to moderate or offset them (IPCC 2018). In contrast, a risk assessment identifies the probability that an impact on a particular system may occur and evaluates the severity of the associated consequences of those effects (IPCC 2018). The completion of vulnerability and risk assessments requires integrating regional impact assessments with context-specific data related to the resilience of social, natural, and built systems. Each

serves as a decision-support tool to help decision-makers distribute and prioritize adaptation actions and allocate financial resources.

Whereas the completion of climate assessments generally occurs through a top-down approach that relies upon the expertise of climate scientists, vulnerability and risk assessments are often characterized by a bottom-up approach that relies upon the co-production of knowledge between scientists, resource managers, and public and private stakeholders (Djenontin and Meadow 2018). Delaware's Department of Natural Resources (DNR) and the state's Sea Level Rise Advisory Committee (SLRAC), for example, completed a statewide vulnerability assessment to provide a comprehensive accounting of the effect that sea level rise will have on a variety of resources (DDNR 2012). The SLRAC included representatives from various state-level departments, local governments, the University of Delaware, utility companies, and environmental organizations. The assessment utilized a spatial analysis of sea level rise projections under various scenarios to identify the level of exposure of various state-level resources to rising tides. Resource mapping and the assessment of vulnerabilities and risks occurred with the support of input from experts distributed across three workgroups (social and economic, public safety and infrastructure, and natural resources) that included representatives from state departments, nonprofit organizations, the private sector, academia, and federal agencies. The DNR and SLRAC held a series of public workshops to collect public feedback and input concerning vulnerabilities and risks to inform the assessment (DDNR 2012).

The completion of regional assessments has primarily been supported through formal partnerships with universities and scientific organizations, the support of neighboring regions with existing technical capacity, and, in some cases, the establishment of formal state-level climate science advisory bodies. For example, the NECIA partnered with Connecticut, Maryland, New Hampshire, and Vermont to support the completion of their climate change impact assessments (Boesch 2008; Galford et al. 2014; GSC 2010; NHDES 2009). In California, the state's Natural Resources Agency, in partnership with researchers from various universities and state and federal agencies, produces a triennial California Climate Assessment to assess the impacts, vulnerabilities, and risks from climate change and identify potential solutions to inform policy actions (CNRA 2018). In some cases, the completion of a formal climate change assessment was explicitly mandated via executive order or legislative action. The Pennsylvania Climate Change Act of 2008, for example, directed the state's Department of Environmental Protection to conduct a study of the potential impacts of global climate change on Pennsylvania over the next century (Pennsylvania Climate Change Act of 2008). Similarly, the OCCRI was established by the Oregon State Legislature in 2007 and consists of researchers from the state's various universities who conduct the state's climate assessment and serve as a clearinghouse for climate information (House Bill 3543 2007).

Collectively, the process of completing informal and formal impact assessments resulted in the identification of a nearly universal set of concerns regarding the projected effects of climate change (i.e., long-term stressors and short-term socks) on SES was nearly universal among the states (Table 9). Each adaptation plan identified rising temperatures, increased occurrences of flooding, and more frequent and intense storms and droughts as problems to be addressed by climate resilience efforts. Heat waves, air pollution, wildfires, and ecological changes were also identified, although concerns regarding these climate shocks and secondary effects were not included in every plan. Seventeen (85 percent) of the states that have completed an adaptation plan have coastal areas, and sea level rise was a notable concern for each of these states, although only thirteen of these states identified coastal erosion as a problem.

Table 9. Problems identified in state-level adaptation plans.

	Climate Stressors				Climate Shocks					
	Rising Temp.	Sea Level Rise	Coastal Erosion	Ecological Impacts	Flood	Storms	Droughts	Heat Waves	Wild-fires	Air Quality
Alaska	X	X	X	X	X	X	X	X	X	X
California	X	X	X	X	X	X	X	X	X	X

Colorado	X			X	X	X	X	X	X	X
Connecticut	X	X	X	X	X	X	X	X	X	X
Delaware	X	X	X		X	X	X	X	X	X
Florida	X	X		X	X	X	X	X	X	
Maine	X	X		X	X	X	X			
Maryland	X	X	X	X	X	X	X	X	X	X
Massachusetts	X	X	X	X	X	X	X	X	X	X
Minnesota	X	X		X	X	X	X	X	X	X
New Hampshire	X	X	X	X	X	X	X	X		X
New York	X	X	X	X	X	X	X	X		X
North Carolina	X	X	X	X	X	X	X	X	X	X
Oregon	X	X	X	X	X	X	X	X	X	X
Pennsylvania	X	X		X	X	X	X	X	X	X
Rhode Island	X	X	X		X	X	X	X	X	
Vermont	X	X		X	X	X	X	X		X
Virginia	X	X	X	X	X	X	X	X	X	X
Washington	X	X	X	X	X	X	X	X	X	X
Wisconsin	X		X	X	X	X	X	X		X

Policy Objectives

Although each state identified a standard set of concerns regarding the long-term stressors, short-term shocks, and secondary effects of climate change on regional SES, each adaptation plan identified a unique set of policy goals (Appendix A). In some cases, these objectives included directives to enhance the resilience of specific systems. For example, New Hampshire prioritized natural systems by including recovery from climate disturbances and the capacity to adapt to new patterns of climate variability and environmental conditions as a primary goal for species and ecosystems (NHDES 2009). In contrast, Florida identified the enhancement of adaptive capacity for social systems by disseminating climate change information and education materials using outreach and public education programs (GATEC 2008). The identification of specific principles to guide climate resilience efforts is likely a function of context-specific information resulting from vulnerability and risk assessments performed within each state and stakeholder engagement in the assessment and planning processes.

Despite the variability of specific state-level climate resilience objectives, several common themes were identified across adaptation plans. For example, due to uncertainties regarding the magnitude, timing, and, in some instances, the spatial distribution of climate stressors and shocks, the formation of cross-scale and cross-sector partnerships was frequently identified as a guiding principle for the development of climate resilience initiatives. In order to address such uncertainties, several states also emphasized the importance of strategies that support increased understanding and awareness of climate change impacts amongst the public and decision-makers through the application of science-based initiatives, investments in the development of climate research and decision-making tools, the provision of accessible information, and increased public engagement through outreach and education. Many plans also included policy objectives that focus on natural systems and public health as critical sectors for focusing efforts to increase resilience to the effects of climate change.

One of the most common policy objectives across the plans was prioritizing vulnerable communities and considering social equity in the development of resilience initiatives. An emergent trend

concerning climate resilience objectives has been the inclusion of crosscutting initiatives to address disproportionate risks and vulnerabilities of climate stressors on specific societal groups. California's most recent *Climate Adaptation Strategies* report includes a *Climate Justice Working Group* to identify crosscutting strategies to increase the adaptive capacity of communities who are most vulnerable to climatic changes (CNRA 2018). Similarly, North Carolina's plan included crosscutting recommendations designed to reduce vulnerable populations' exposure to climate change impacts. The plan, *North Carolina Climate Risk Assessment and Resilience Plan*, considers the compounding vulnerabilities of minority populations who are likely to have disproportionate exposure to climate impacts in addition to existing environmental, social, economic, and health burdens (State of North Carolina 2020).

Policy Approach, Tools, Implementation Philosophy, and Point of Intervention

Each state-level adaptation plan included a range of policy tools designed to improve state agencies' preparedness and adaptive capacity to climate stressors and shocks and enhance environmental resilience. Given the diffuse institutional structure of administrative agencies, the policy approach to supporting climate resilience was primarily discussed within the context of specific sectors. However, due to the integrated, interagency structure of adaptation planning, the cross-sector effects of climatic changes were identified throughout each sector, and many of the proposed actions include interagency coordination and collaboration to support policy implementation.

Many of the proposed actions included in state-level adaptation plans are analogous to those proposed at the federal level, although the focus of implementation centered on state-level agencies and the management of state resources (Table 10). For example, climate mainstreaming to enhance adaptive management practices and the formation of multijurisdictional and multi-sector partnerships to support comprehensive management of terrestrial, aquatic, and coastal systems were both frequently recommended actions across plans and sectors. A unique aspect of state-level adaptation plans, relative to efforts applied at the federal level, is the nearly universal recommendation for continued investments in risk and vulnerability assessment and the development of various integrated indices to support monitoring and decision-making. The application of such tools was frequently recommended across a range of sectors as an approach for state agencies to identify the social and ecological effects of various climate stressors, such as low air quality and ecosystem resilience, prioritize points of intervention, and facilitate monitoring of adaptation efforts.

Table 10. Selection of state adaptation policy recommendations.

Policy Tool	Policy Recommendation	Resilience Goal (Principle)
Regulatory	• **California:** Mitigation for poor indoor air quality for new and existing buildings near major roadways. Consider San Francisco's Air Pollutant and Exposure Zone ordinance as a potential model for state-level standards (CNRA 2018, 103).	• Absorb (Robustness & Buffering)
	• **Oregon:** Climate preparation and adaptation needs to be 'mainstreamed' into agency programs and operations (State of Oregon 2010, 84).	• Plan/Prepare (Anticipation & Foresight)
	• **Vermont:** Establish policies that set new infrastructure further back from waterbodies and retains naturally vegetated buffers to protect infrastructure from predicted higher frequency and magnitude of flooding and lake level fluctuations (Pealer and Dunnington 2011,4)	• Absorb (Robustness & Buffering, Diversity)
	• **Wisconsin:** Incorporate climate change scenarios into modeling efforts, watershed management and restoration	• Plan/Prepare (Anticipation &

	plans, then engage in community planning (NIES et al. 2011, 66). **Wisconsin:** Incorporate water management strategies based on climate projections into farm-based nutrient management plans (NIES et al. 2011, 66).	Foresight)
Knowledge Generation	• **California:** Conduct social-ecological climate vulnerability assessments on the impacts of ocean acidification and increased temperatures on marine and estuarine fisheries, fishing communities, and food supply and integrate results into management strategies (CNRA 2018, 50). • **California:** Promote Healthy Places Index and Climate Change and Health Vulnerability Indicators for use by local, regional, and state agencies to prioritize funding, community engagement, jobs, and services for communities facing disproportionate climate and health risks. (CNRA 2018, 94). • **Maine:** The scientific community, under the leadership of the University of Maine, should identify thresholds where key natural systems are at risk of disruption (MDEP 2010, 22). • **Pennsylvania:** Integrate water management planning approaches to identify vulnerabilities and address risks with no-regret, low cost priorities including conservation and green infrastructure (PDEP 2011, 14).	• Plan/Prepare (Anticipation & Foresight, Preparedness & Planning, Homeostasis) • Plan/Prepare (Anticipation & Foresight, Preparedness & Planning) • Plan/Prepare (Anticipation & Foresight) • Plan/Prepare (Anticipation & Foresight, Homeostasis); Absorb (Robustness & Buffering, Diversity)
Knowledge Mobilization	• **Maine:** Develop and disseminate tools that will allow local and regional planning authorities to initiate and implement their own adaptation planning processes (MDEP 2010, 26). **Minnesota:** Enhance capacity to collect, analyze, share and communicate measured and projected climate data at all scales to ensure that people, communities, and organizations can plan for, respond to, and withstand impacts through implementing climate adaptation practices (ICAT 2017, 63).	• Plan/Prepare (Anticipation & Foresight, Preparedness & Planning); Absorb (Diversity); Recover (Flatness, High-flux)
Education and Training	• **Delaware:** Provide internal outreach, education, and training for staff on climate change impacts and risks to health (State of Delaware 2014, 22).	• Plan/Prepare (Preparedness & Planning)
Direct Program Spending	• **Minnesota:** Develop contiguous migration corridors for wildlife and native plants to increase resilience of terrestrial and aquatic communities to climate change impacts, with priority focus on at risk populations (ICAT 2017, 62). • **Wisconsin:** Assisted migration to facilitate long-term species survival (NIES et al. 89).	• Absorb (Robustness & Buffering, Diversity); Recover (High-flux) • Recover (High-flux); Adapt (Flexibility)
Coordinatio	• **Maryland:** Strengthen federal, state, local, and regional	• Plan/Prepare

n and Collaboration	observation systems to improve the detection of biological, physical, and chemical responses to climate change and sea level rise (Boicourt and Johnson 2010, 25).	(Homeostasis); Absorb (Diversity); Adapt (Learning)
	• **Washington:** Encourage partnerships with federal, tribal, and local government, private landowners, and conservation organizations to implement landscape planning and foster adaptation strategies and actions that protect and restore habitat corridors across jurisdictional and land ownership boundaries (WDE 2012, 72).	• Plan/Prepare (Homeostasis); Absorb (Redundancy, Diversity); Adapt (Learning)

The modification and application of state-level incentives and funding mechanisms were also frequently identified as priority strategies to establish local-level partnerships and disseminate best practices for water and energy efficiency improvements. The use of incentives was also frequently recommended to support green infrastructure development to enhance the robustness of natural systems and mitigate the water quality impacts associated with stormwater runoff during extreme precipitation and storm events. Local and regional partnerships to increase the adaptive capacity of health care providers, public health organizations, and at-risk communities were the preferred approach for supporting resilience to air quality impacts from extreme heat and wildfires. Most of these public health efforts included the development of public outreach and education and training programs.

Government management and incentives served as the primary recommendations to support the resilience of natural systems. For example, the acquisition of land and adaptive management of existing state-owned lands to support ecosystem redundancy and diversity and manage connectivity were frequent action items. Implementing adaptive management practices through assisted plant migration and direct support of seed banks to produce resilient native plant species and restore terrestrial ecosystems was also recommended to support natural systems resilience in several plans. The need for more comprehensive, "climate-smart" management through increased data collection and monitoring was a commonly recommended policy to support the identification, prioritization, and adaptive management of such systems.

The importance of knowledge mobilization to the public and private sectors to increase adaptive capacity was also identified across sectors and plans, although the centralization of outward-facing databases to inform resilience decision-making was less common. For example, Colorado's adaptation plan led to the creation of The Colorado Climate Preparedness Project, a database that provides a publicly available database of organizations, individuals, projects, and products related to the state's adaptation efforts (WWA 2011, 13). Additionally, California's 2009 Climate Adaptation Strategy included recommendations to develop a centralized clearinghouse and database to support climate resilience planning throughout the state (CNRA 2009, 106). The recommendation led to the development of Cal-Adapt and the California Adaptation Clearinghouse. The former serves as a database and data visualization site for local-level stakeholders, while the latter is a searchable database of resources for local, regional, and statewide climate adaptation and resiliency planning and decision-making (CEC 2020; GOPR 2020).

Climate Resilience in the Cities

Political and Institutional Context

Although cities have been engaged in climate adaptation planning for more than a decade, early and ongoing efforts to identify and implement policies to support resilience to the effects of climate change have primarily been integrated into climate action plans, which focus on climate mitigation initiatives. The emergence of climate adaptation planning as a stand-alone policy agenda has only recently emerged. As of 2020, 16 of the 50 largest U.S. cities have completed climate adaptation plans or climate action plans in which climate adaptation is a significant component. The city mayor initiated eight

plans (50 percent) while city councils initiated four plans (25 percent), and four plans (25 percent) were developed through departmental actions (Table 11). Although the City of Long Beach's adaptation plan was initiated by the mayor, the city is also required to complete an adaptation plan to comply with the state of California's 2015 law, S.B. 379, which mandates the consideration of climate adaptation in all municipal general plans (City of Long Beach 2019). Additionally, Columbus developed its adaptation plan through a collaboration between city departments and researchers at The Ohio State University (Cervenec et al. 2018).

Table 11. City adaptation plans.

City	Started	Completed	Plan	Initiated By
Austin, TX	2013	2014	Toward a Climate-Resilient Austin	City Council
Boston, MA	2015	2016	Climate Ready Boston	Mayor
Chula Vista, CA	2009	2011	City of Chula Vista: Climate Adaptation Strategies	City Council
Columbus, OH	2016	2018	Columbus Climate Adaptation Plan	Agency and Technical Advisors
Denver, CO	2012	2014	City and County of Denver: Climate Adaptation Plan	Agency
Indianapolis, IN	2017	2019	Thrive Indianapolis	Mayor
Long Beach, CA	2018	2019	City of Long Beach Climate Action and Adaption Plan	Mayor
Miami, FL	2019	2020	Miami Forever: Climate Ready	Mayor
New York, NY		2013; 2015	One New York: The Plan for a Strong and Just City	Mayor
Philadelphia, PA	2012	2015	Growing Stronger: Toward a Climate-Ready Philadelphia	Mayor's Office of Sustainability
Portland, OR	2013	2014	Climate Change Preparation Strategy	Agency
San Antonio, TX	2017	2019	San Antonio Climate Ready: A Pathway for Climate Action and Adaptation	City Council
St. Louis, MO	2016	2017	Climate Action and Adaptation Plan: For the City of St. Louis	Mayor
St. Paul, MN	2018	2019	St. Paul Climate Action & Resilience Plan	Mayor
Seattle, WA	2015	2017	Preparing for Climate Change	Agency
Virginia Beach, VA	2014	2020	Virginia Beach Sea Level Wise Adaptation Strategy	City Council

Multinational network organizations that provide resources and technical assistance to support climate adaptation have also supported the development of local-level adaptation plans. Six cities, Boston, Columbus, Long Beach, Seattle, St. Louis, and Saint Paul, each joined the Compact of Mayors (now called the Global Covenant for Climate and Clean Energy) before completing their adaptation plans

(Cervenec et al. 2018; Long Beach 2019; City of Boston 2014; SOSE 2017; City of St. Louis 2017; City of Saint Paul 2019). Launched at the U.N. Climate Summit in 2014 and overseen by the C40 Cities Climate Leadership Group, ICLEI Local Governments for Sustainability, and the United Cities and Local Governments, the initiative is an international coalition of city leaders who commit to preparing for the future impacts of climate change through the completion of a climate adaptation plan. Additionally, St. Louis and Indianapolis each completed their plans as participants in the Bloomberg American Cities Climate Challenge (City of St. Louis 2017; City of Indianapolis 2019). The initiative, launched by Michel Bloomberg with the support of various partners following the U.S. exit from the Paris Agreement in 2017, provides financial and technical support to assist cities with the completion of climate change mitigation and adaptation plans (Bloomberg Philanthropies 2019).

Similar to state-level adaptation efforts, the institutional approach to municipal climate adaptation planning relies upon existing municipal departments and interagency collaboration. However, the formation of sector-specific workgroups was not a frequent feature and was only applied to support the development of Boston's *Climate Ready Boston* plan (City of Boston 2014). Each planning process included the opportunity for stakeholder engagement, although the formal inclusion of participants from the public and private sectors and representatives from state and federal government was relatively limited when compared to their state-level counterparts.

Problem Identification

At the city level, the completion of climate change impact assessments is a common feature of the climate adaptation planning process (Table 12). However, most impact assessments were integrated into local-level adaptation plans, and only five cities (Boston, Columbus, New York, Philadelphia, and Seattle) commissioned a separate climate change impact assessment that focused explicitly on city-level impacts. Two cities, Indianapolis and St. Louis, utilized downscaled data and analysis tools produced from the Great Lakes Integrated Sciences + Assessments and U.S. GCRP's U.S. Climate Resilience Toolkit, respectively, to produce informal assessments that focused on the effects of observed and projected temperature and precipitation patterns (City of St. Louis 2017; City of Indianapolis 2019). However, most of the assessments were broader and more detailed in scope and were conducted through formal partnerships with universities and technical consultants. For example, Seattle's climate assessment was led by researchers at the University of Washington who collaborated with several Pacific Northwest universities and representatives from local, state, and federal agencies (Mauger et al. 2015). Portland and New York City's impact assessments were produced by the OCCRI and the New York City Panel on Climate Change (NYCPCC), respectively (Horton et al. 2015; OCCRI 2010). The NYPCC is a mayor-appointed advisory board consisting of an interdisciplinary team of climate change experts. Initially convened by Mayor Michael Bloomberg in 2009, the NYCPCC was codified into law in 2012 and charged with providing an authoritative and actionable source of scientific information on future climate change and its potential impacts (City of New York 2020).

Table 12. City climate change impact assessments.

City	Impact Assessment	Completed	Vulnerability/Risk Assessment	Co-Production
Austin, TX	*In Plan*	2014		
Boston, MA	Climate Ready Boston: Climate Change and Sea Level Rise Projections for Boston	2016	X	X
Chula Vista, CA	*In Plan*	2011	X	X

Columbus, OH	Climate Change in Columbus Ohio An Assessment of Columbus' Key Climate Changes, Impacts, and Vulnerabilities of Concern	2016	X	X
Denver, CO	*In Plan*	2014	X	
Indianapolis, IN	*In Plan*	2019	X	
Long Beach, CA	*In Plan*	2019	X	
Miami, FL	*In Plan*	2020		
New York, NY	New York City Panel on Climate Change Reports	2013; 2015	X	
Philadelphia, PA	Useful Climate Information for Philadelphia: Past and Future	2014	X	
Portland, OR	*In Plan*	2014	X	
San Antonio, TX	*In Plan*	2019		
St. Louis, MO	*In Plan*	2017		
St. Paul, MN	*In Plan*	2019	X	
Seattle, WA	State of Knowledge Report: Climate Change in Puget Sound	2015		
Virginia Beach, VA	*In Plan*	2020		

Ten of the 16 cities relied upon the completion of vulnerability assessments to establish policy objectives and prioritize policy actions, a more significant proportion relative to the states. However, only three cities applied co-production methods. For example, Columbus' vulnerability assessment drew from ICLEI's Local Governments for Sustainability's "Building Adaptive and Resilient Communities" program to integrate extensive stakeholder input to contextualize sector-specific vulnerabilities (GLISA and UMCC 2016). The city's Climate Working Group invited two groups of sector-specific stakeholders to assess their respective interests' adaptive capacity and sensitivity based upon projected climate impacts. An online survey supplemented the in-person assessment, and following refinement of vulnerabilities, city policymakers and stakeholders participated in a risk assessment, in which they identified the consequences of climate change impacts, given the likelihood of occurrence. The process resulted in 14 high-priority climate impacts based on their overall vulnerability and risk score. The assessment results were shared using a public awareness campaign and formed the basis for the city's climate adaptation strategies (GLISA and UMCC 2016).

The potential system disturbances resulting from the direct and compound effects of climate change identified by state-level climate change impact assessments were nearly universally shared. In contrast, local-level vulnerability and risk assessments resulted in more discrepancy concerning the types of climate shocks and stressors to be addressed through resilience efforts (Table 13). Increased temperatures and sea level rise were among the most common long-term stressors identified in adaptation plans, although the latter was limited to coastal cities. Among the climate shocks, heat waves and more

intense precipitation and storm events, associated declines in urban air quality, and more frequent urban flooding occurrences were among the most common concerns. Several cities also identified the social vulnerabilities to climate stressors and shocks as a critical concern amongst policymakers and community stakeholders.

Table 13. Problems identified in city-level adaptation plans.

	Climate Stressors			Climate Shocks							
City	Rising Temp.	Sea Level Rise	Coastal Erosion	Ecological Changes	Flooding	Storms	Droughts	Heat Waves	Wild-fires	Air Quality	Social Impacts
Austin	X				X		X	X			
Baltimore	X	X		X	X	X		X		X	
Boston	X	X	X		X	X		X			X
Chula Vista	X	X		X	X			X	X	X	
Columbus	X			X	X			X		X	X
Denver	X					X		X			X
Indianapolis	X				X			X			X
Long Beach	X	X			X		X	X		X	X
Miami	X	X	X		X	X		X		X	
New York	X	X			X	X		X			
Philadelphia	X	X			X	X		X		X	X
Portland	X			X	X		X	X	X		X
San Antonio					X				X	X	X
Seattle	X	X	X		X	X	X	X			X
St. Louis	X				X	X		X			X
St. Paul	X			X	X	X		X	X	X	X
Virginia Beach		X	X	X	X	X					X

Policy Objectives

Each city translated the risks and vulnerabilities of climate change into various policy objectives to support climate resilience (Appendix B). The protection, preservation, and enhancement of ecosystem resilience to mitigate climate change effects was an overarching policy objective in 75 percent (12) of plans, many of which identified the climate mitigation co-benefits of protecting urban green spaces. Building public health resilience to the impacts of climate change, such as low air quality and extreme heat, by enhancing the adaptive capacity of public health services and the general public, was identified as a policy objective in 50 percent (8) of plans. Mitigating the exposure of vulnerable populations was also a common theme across policy objectives. Improving the resilience of vulnerable populations through direct policy action and inclusion in adaptation plan development and decision-making was identified as a policy objective in half of the plans (8). To a lesser extent, city-level plans identified climate mainstreaming, adaptive management, and increased redundancy through efficiency improvements in water, energy, and infrastructure, as key policy objectives.

Policy Approach, Tools, Implementation Philosophy, and Point of Intervention

Each city adaptation plan devised a range of policy tools designed to address context-specific climate impacts across the built, social, ecological, and governance systems. The policy approach and policy tools developed to enhance local-level climate resilience have primarily mirrored those found at the federal and state levels (Table 14). For example, organizational changes to facilitate climate

mainstreaming, the modification of existing regulations such as land use and building codes, the establishment of regional partnerships and collaborative management practices, and incentives (e.g., to improve energy efficiency, increase green infrastructure) were each identified in several plans as priority actions. Among the most common policy tools to support climate resilience recommended across city-level plans were information and public outreach, government spending to enhance ecosystem and green space management, and increased monitoring and data collection.

Table 14. Selection of city adaptation policy recommendations.

Policy Tool	Policy Recommendation	Resilience Goal (Principle)
Regulatory/ Organization	• **Austin:** Expand alternative transportation modes to ameliorate air quality. (City of Austin 2014, 11)	• Absorb (Diversity, Redundancy); Recover (High-Flux)
	• **Long Beach:** Update the building code to mandate the installation of cool roofs on all new and retrofitted roofs (Long Beach 2019, 6)	• Absorb (Robustness & Buffering)
	• **Denver:** Continuing to assess water resilience to climate change using latest local climate projections, and adjust practices accordingly (DDEH 2014, 55)	• Plan/Prepare (Anticipation & Foresight); Recover (High-Flux); Adapt (Flexibility)
	• **Seattle:** Prioritize tree planting and other natural systems strategies to reduce heat islands, buffer pollution sources prioritizing neighborhoods with poor air quality and higher levels of health issues (SOSE 2017, 22)	• Absorb (Robustness & Buffering)
	• **Portland:** Review city codes and drainage rules to evaluate their ability to protect and improve stream flows, wetland function, and water quality (City of Portland 2014, 20)	• Prepare/Plan (Anticipation & Foresight); Absorb (Robustness & Buffering)
Knowledge Generation	• **Boston:** Establish a panel on climate to update climate projections every five years to inform plans, policies, and regulations and be translated into accessible reports and maps (City of Boston 2014, 84)	• Prepare/Plan (Anticipation & Foresight, Preparedness & Planning)
	• **Portland:** Develop and analyze demographic, hazard and risk factor data and maps (urban heat islands, air quality, and access to air conditioning) to understand localized climate impacts and prioritize preparation and mitigation strategies (City of Portland 2014, 18)	• Prepare/Plan (Anticipation & Foresight)
	• **St. Louis:** Study climate change impacts on plant and tree species and maintain inventory of appropriate plant and tree species that can tolerate altered climate (City of St. Louis 2017, 77)	• Prepare/Plan (Anticipation & Foresight); Adapt (Flexibility)
Knowledge Mobilization	• **Chula Vista:** Educate residents and businesses about the benefits and appropriate uses of local water supplies and integrate recycled water and onsite water reuse systems into new development and redevelopment plans. (City of Chula	• Prepare/Plan (Anticipation & Foresight); Absorb (Robustness &

	Vista 2011, 14) • **Indianapolis:** Increase reach of information and education to the public regarding health issues, including climate-related illnesses related to more anticipated heat, ozone and mosquitoes. (City of Indianapolis 2017, 65) **Philadelphia:** Provide information on projected changes in climate and increases in high heat days in health bulletins and outreach materials. (City of Philadelphia 2015, 29) **Portland:** Develop early warning system and response plans that alert community members when projected heat conditions or poor air quality days pose a health risk (City of Portland 2014, 18)	Buffering) • Prepare/Plan (Preparedness & Planning); Recover (High-Flux)
Direct Program Spending	• **Columbus:** Increase number of air quality monitoring stations to provide baseline data and public educational opportunities (Cervenec et al. 2018, 15) • **Columbus:** Continue upgrades to water and sewage treatment infrastructure to reduce harmful alagal bloom toxins in drinking water (Cervenec et al. 2018, 51) • **Columbus:** Establish a larger, coordinated, responsive network of cooling centers (Cervenec et al. 2018, 15) • **Denver:** Develop community-scale renewable and district energy pilot systems, remove existing regulatory barriers (DDEH 2014, 44) • **Miami:** Complete network of resilience hubs at strategically selected properties to prepare communities for climate change impacts and accelerate recovery after disruptions (City of Miami 2020, 16) • **New York City:** Green infrastructure installations across the five boroughs, including bioswales, rain gardens, permeable pavement, and green roofs to reduce the amount of stormwater entering the sewer system (City of New York 2015, 240) • **Portland:** Identify habitat diversity and connectivity needs and prioritize habitat corridors for protection and enhancement, including through acquisition, restoration, regulations and innovative techniques such as vegetated streets, to create an interconnected network of terrestrial and aquatic habitats. (City of Portland 2014, 20) **San Antonio:** Assess opportunities for creating connected networks to manage water and regulate temperature through ecosystem-based adaptation measures (San Antonio 2019, 46)	• Prepare/Plan (Anticipation & Foresight) • Absorb (Robustness & Buffering) • Absorb (Robustness & Buffering, Diversity); Recover (High-Flux) • Absorb (Redundancy); Recover (High-Flux) • Absorb (Robustness & Buffering, Diversity); Recover (High-Flux) • Absorb (Robustness & Buffering) • Prepare/Plan (Anticipation & Foresight); Absorb (Diversity); Recover (High-Flux)
Coordination and Collaboration	• **Miami:** Host Climate Resilience Committee meetings in neighborhoods for residents to learn about and advocate for resilience initiatives (City of Miami 2020, 15) • **New York City:** In partnership with The Nature Conservancy, develop strategies to evaluate the best available science on the urban heat island effect in order to invest in better data	• Prepare/Plan (Anticipation & Foresight, Homeostasis) • Prepare/Plan (Anticipation &

	collection and develop effective capital investment and operational strategies to adapt to the impacts of urban heat. (City of New York 2015, 228)	Foresight)
	• **Saint Paul:** Create an environmental justice advisory committee to advise the city on equitable resilience actions (City of Saint Paul 2017, 26)	• Prepare/Plan (Homeostasis); Absorb (Diversity)

Across city-level adaptation plans, community education and outreach served as a primary mechanism to support the general public's adaptive capacity to the health risks posed by climate change. While this approach was recommended to support water, land use, and energy management efforts, it was often a foundational mechanism to enhance public health resilience. Primarily designed as a strategy to reduce exposure to extreme heat and low air quality, such initiatives were designed in a variety of ways, including the integration of climate health risk information into community outreach materials, hosting formal community meetings to facilitate direct stakeholder engagement and the dissemination of health-risk information via municipal early warning systems (Table 14). While such initiatives were a standard recommendation at the state level, policy intervention primarily focused on public health providers. In contrast, at the local level, public health outreach efforts mostly centered on community members.

An innovative approach that many cities identified to address public health impacts are establishing neighborhood resilience hubs and public cooling centers. Typically funded by local government and community-managed, these types of facilities can serve as informational centers and shelters during extreme heat and low air quality events. Resilience hubs, however, may offer a more diverse suite of services to support community-level resilience, such as shelter during storm events or sources of information regarding distributed energy and energy efficiency programs for neighborhood residents. Each of these approaches supports community preparedness, adaptive capacity, and robustness to the health effects of short-term shocks, among other things.

Several cities integrated actions to address the disproportionate impact of climate stressors and shocks on minority and low-income communities. While many of these efforts sought to integrate equity concerns into climate resilience policies more generally, such as the city of Saint Paul's recommendation to establish an environmental justice advisory committee, some focused more explicitly on addressing the disproportionate health effects of climatic changes (Table 11). For example, Seattle included an initiative to prioritize tree planting and other natural systems strategies to reduce heat islands and buffer pollution sources in neighborhoods with low air quality and higher levels of health issues (Table 14). This approach provides co-benefits by supporting the robustness of vulnerable populations while also increasing the diversity and redundancy of urban natural systems and supporting climate change mitigation.

A unique policy recommendation to support knowledge generation through data collection and monitoring was integrating citizen science to assist local agencies with data collection and environmental monitoring. Two coastal cities, Long Beach and Virginia Beach, each identified the use of mobile applications to collect real-time, crowdsourced data to monitor, track, and map coastal and flood conditions (City of Long Beach 2019, 41; City of Virginia Beach 2020, 35). Miami's adaptation plan recommended developing a plan to supplement city-level data with crowdsourced data to support participatory planning and better understand flood, heat, and storm risks and monitor the impacts of installed green and grey solutions (City of Miami 2020,12). Additionally, Denver identified the use of social media applications as an approach to help city residents identify, tag, and assist in managing invasive species populations (DDEH 2014, 85).

Discussion

The long- and short-term impacts associated with rising average global temperatures, as well as compounding effects such as increased air pollution and water quality concerns, have compelled policymakers at each level of governance to pursue integrated and crosscutting and approaches to support

climate resilience. Such efforts have drawn from the various approaches developed during previous epochs of environmental policy while also contributing innovative methods to account for the climate change issue's scientific complexity and the uncertain, nonlinear environmental effects of a changing climate. Table 15 applies the Environmental Epoch framework to summarize what is likely to be critical components of an epoch characterized by resilience for each component of the framework. The discussion below reviews each element based upon the results provided above (see Appendix C for a table depicting each of the four Epochs of U.S. Environmental Policy).

Table 15. Fourth Epoch of Environmental Policy: Governing for Resilience.

Dimension	Characteristics
Problem Identification and Policy Objectives	• Global environmental change • Long term stress, short term shocks, and compound effects • Exposure, sensitivity, adaptive capacity • Projections and scenarios • Enhance adaptive capacity, connectivity, robustness, redundancy, and diversity
Implementation Philosophy	• Climate mainstreaming • Science-based and data-driven decision making • Knowledge mobilization
Points of Intervention	• Existing local, state, and federal institutions • Ecological, social, infrastructure, economic, and governance systems • Neighborhood-scale • Vulnerable social and ecological systems
Policy Approaches and "Tools"	• Integrated comprehensive planning and management under multiple scenarios • Co-production of knowledge • Resilience as a guiding principle in building codes, land use planning, and development policy • Public/nonprofit/private partnerships • Collective action and collaboration to restore/preserve natural systems • Smart governance and adaptive management • Citizen science initiatives and information crowdsourcing • Information and education campaigns • Neighborhood resilience "hubs" and micro grids • Data and toolkit clearinghouses
Information and Data Management Needs	• Vulnerability and risk assessment • Downscaled projections of environmental change • Real-time data gathering, monitoring and sharing systems • Data integration platforms
Predominant Political/ Institutional Context	• Local/regional/state/federal-level partnerships • Formal partnerships with scientific organizations • Interagency coordination and collaboration
Key Events and Public Actions	• U.N. Framework Convention on Climate Change • Intergovernmental Panel on Climate Change 2007 Assessment

- 2030 Agenda for Sustainable Development
- Regional extreme weather events and disasters (e.g., Hurricanes Katrina and Hurricane Sandy)
- Global Covenant of Mayors

Since the late 2000s, policymakers and administrative agencies have increasingly applied the concept of resilience to frame environmental policy and planning discussions. As the most pervasive environmental challenge of the 21st century, the focus of these efforts has primarily centered on the issue of global climate change. Whereas the sustainability epoch primarily focused on bringing into harmony human and natural systems to live within the limits of the Earth's ecological boundaries, environmental governance in the Anthropocene centers on the understanding that critical planetary boundaries have been surpassed. The new normal will become increasingly characterized by uncertainty and nonlinear environmental change primarily driven by short-term shocks and compound effects resulting from the long-term changes to the Earth's climate system. Consequently, policymakers have become increasingly dependent on supporting the development of complex scientific information to provide medium- to long-term projections under a range of potential scenarios to plan for future change. To address less certain short-term extreme weather events and compound effects, assessing the relative exposure, sensitivity, and adaptive capacity is a prerequisite for identifying and prioritizing policy strategies that integrate resilience principles to support the long-term viability of desired conditions.

The range of environmental problems addressed by past environmental epochs has produced an intricate system of environmental governance comprised of various administrative agencies with oversight over an increasingly complex network of policies and programs to manage human interactions with the environment. The formation of interagency collaboration across levels of governance and the establishment of multi-sector partnerships to support policy formulation and implementation proliferated during the sustainability epoch. In an epoch defined by climate resilience, this approach to environmental governance has continued to expand. While the range of environmental challenges caused by climate change will be experienced most acutely at the local level, the multijurisdictional management structure applied to many social and environmental systems warrants the formation of public-private partnerships, interagency cooperation, and intergovernmental coordination in order to address the crosscutting impacts of climate change effectively. Indeed this polycentric approach to environmental governance has been extensively applied to support climate adaptation planning efforts. Additionally, given the scientific complexity of the climate change issue, formal and informal partnerships with scientific bodies and co-production of knowledge have also been critical components of climate resilience planning and policy formulation.

The implementation philosophy across each governance level primarily relies upon integrating climate projections and scenarios into existing policies and programs to inform sector-specific management practices and support agency preparedness to address a range of potential stressors and shocks. A focus on climate mainstreaming requires policymakers and decision-makers to support efforts to provide the best available science and interdisciplinary data to predict local-level and regional impacts, assess vulnerabilities, and monitor system trends and resilience. In instances in which direct government intervention to mitigate environmental impacts is ineffective, the mobilization of knowledge to public and private stakeholders to support preparedness and adaptive capacity will be critical, particularly in the public health sector.

To address the crosscutting effects of the climate change issue and the interdependency of SES, rather than focusing on a particular industry, population, ecosystem, or level of governance, efforts to support climate resilience frequently identified entire natural, social, infrastructure, economic, and governance systems, as a critical point of intervention. Given the widespread focus on climate mainstreaming, administrative agencies served as the primary point of intervention for adaptation strategies developed at each governance level. Social and ecological systems with relatively high levels of exposure, sensitivity, and limited adaptive capacity to system disturbance were frequently prioritized for

such interventions. State- and local-level adaptation efforts often identified the interrelationships between these systems. For example, efforts to enhance the resilience of stormwater systems through the development of green infrastructure can also increase the robustness of social groups by mitigating exposure to extreme heat and low air quality.

To achieve their respective policy objectives, stakeholders at each level of governance relied upon integrative and comprehensive planning that considers various environmental change scenarios and draws upon the co-production of knowledge. Collective action and collaboration through the formation of formal and informal multi-sector partnerships to enhance the resilience of multijurisdictional natural systems is a fundamental policy approach at each level of governance. Additionally, investments in environmental monitoring technology and innovation in data collection and integration to support adaptive management and the development of outward-facing climate and resilience databases to support decision-making are important policy tools for climate resilience, particularly at the federal and state levels. The preferred approach to protecting public health and vulnerable populations from the threat of extreme heat and low air quality is the dissemination of information via outreach programs and education campaigns. Regulatory approaches to support climate resilience have primarily been applied at the local level through modifications to building code, land use, and development requirements. The provision of neighborhood resilience hubs to support community adaptive capacity and connectivity during extreme events was an innovative approach to support community resilience at the local level.

The policy approach, objectives, and tools across governance levels each applied and operationalized various resilience-based principles to enhance the recovery of SES from the direct and compound effects of climate change. The application of resilience-based principles to initiatives intended to protect SES systems primarily reflected the theoretical perspective offered by Gunderson and Holling's (2002) *Panarchy* framework. Climate change impact assessments and policy recommendations, for example, frequently applied a nested-scales approach that considered the interaction between smaller and larger systems, although each predominantly focused on disturbances and policy interventions at the regional and local scales. Concerning SES equilibrium, many policy actions reflected the SER and *Panarchy* perspectives wherein SES are characterized by incremental adaptation and, in some cases, transformational change in lower-level systems in response to disturbances from larger scales. For example, assisted migration, climate-resilient species selection, and the expansion of green infrastructure are all examples of policy efforts that incrementally alter the preexisting conditions of SES to enhance resilience. At the same time, the ER perspective, which emphasizes a return to a preexisting or a new stable state, was also reflected in policy recommendations. For example, employing outreach and educational approaches to enhance social resilience to low air quality exposure during extreme heat days represent efforts to sustain the existing social system equilibrium. In contrast, the integration of climate change projections and scenarios into decision-making processes and existing policies, via climate mainstreaming, would produce a new stable state within an existing institutional system.

The integration of climate change impacts into existing policies and programs at each level of governance creates unique information needs and data management challenges for agency and stakeholder decision-makers. Predicting climatic changes relies on complex quantitative models designed to simulate interactions of the various natural and anthropogenic factors that interact to affect the Earth's climate, and our ability to predict the long-term development of these factors with high levels of certainty is limited. At the local level, the uncertainty of climate change projections increases as climate models are downscaled. To provide actionable scientific information to support climate mitigation and adaptation decision-making, climate scientists often produce various scenarios that provide a range of potential long-term changes. Thus, the application of climate mainstreaming requires the integration of climate projections and scenarios into sector-specific management practice to enhance system resilience to a range of potential stressors and shocks.

In addition to climate mainstreaming, the application and recommendation of vulnerability and risk assessment were nearly ubiquitous. Identifying relative vulnerabilities and risks to climate change impacts facilitates the prioritization of policy interventions to enhance the adaptive capacity of infrastructure, social, ecological, and governance systems. Effective assessment requires an accurate

accounting of the relative exposure and sensitivity of each system, and its various components, to a particular disturbance. In the past, decision-makers have generally drawn upon historical data to assess the resilience of systems to linear and predictable changes. However, the uncertainty and nonlinearity of environmental change resulting from climate change on environmental conditions require expansion and innovation in real-time monitoring and data collection and management at all levels of governance to identify thresholds and support adaptive management. Additionally, the development of integrated tools, such as resilience indices, designed to account for the crosscutting effects of climate change will be required to understand the effects of climatic changes and compounding events.

The cross-scale nature and scientific complexity of climate change and the polycentric institutional structure of existing environmental laws within the U.S. will require intergovernmental coordination and collaboration to support climate resilience efforts. The establishment, administration, and enforcement of policies regarding water management, ecosystem protection, and air quality, for example, often involve the interplay between federal, state, and local-level laws. Therefore, as climate change unfolds, agencies at various governance levels will benefit from increased legal coordination related to monitoring and compliance with existing laws and developing new or modified policies to support environmental resilience. Additionally, in some cases, the technical capacity required to conduct climate change impact and vulnerability assessments may exceed local governments' capabilities. Therefore, formal partnerships with entities that possess technical resources and data, such as research institutions and state and federal agencies, will be critical to developing effective local-level resilience initiatives.

Conclusion

There is reasonable evidence of the emergence of a new epoch in U.S. environmental policy in which the focus of environmental policy has made a notable shift to emphasize the importance of resilience. However, as the environmental epoch framework's originators have asserted, the beginning of a new environmental epoch does not mean its predecessor's end (Mazmanian and Kraft 2009b, 12). The regulation and abatement of environmental pollution and efforts to support environmental sustainability to reduce society's ecological footprint will continue to be an imperative goal to alleviate environmental stressors and protect SES. Nonetheless, in an era characterized by unprecedented, uncertain, and nonlinear global change, adaptation has emerged as a crucial element of environmental policy and planning discussions amongst policymakers at each level of governance in the U.S.

The problem has primarily been framed as one of climate change risks and vulnerabilities. In the U.S., the issue rose onto the political agenda in the late 2000s, amidst a change in federal-level leadership, improvements in the scientific understanding of the effects of climate change, and increased public awareness of the costly effects of extreme weather events. Largely developed through interagency climate adaptation planning with technical support from climate scientists and, in some cases, extensive stakeholder engagement, the implementation philosophy focuses on the integration and dissemination of climate science to support public and private decision-making practices. A wide range of tools to support data gathering and monitoring and the development of cross-sector and intergovernmental partnerships have developed to support comprehensive systems resilience at various scales. Supporting these efforts requires downscaling of data collection and projections as well as increased monitoring efforts.

The approach to environmental governance has developed from the institutional and policy structures established during prior epochs of environmental policy. However, the crosscutting and cross-sector characteristics of the stressors, shocks, and compounding effects of global climate change require innovation in the formulation and application of environmental policy. To understand the risks and vulnerabilities of these impacts, the integration of scientific models that account for the long-term nature and uncertainties of the climate change problem into decision-making has become increasingly imperative. Whereas the sustainability epoch mostly centered on reducing the environmental impact produced by urban areas, enhancing social and ecological resilience will require efforts at both the local and regional scales.

Despite this trend, there has been relatively little inquiry focused on the political dimensions of resilience planning and policy within the U.S., particularly within the context of climate change. Although the concept of resilience is not plagued by the definitional ambiguities and normative debates that have frequently surrounded policy discussions concerning sustainability and sustainable development, resilience scholars have noted the normative aspects of its implementation. Policy and planning efforts designed to enhance SES resilience will require public and private actors to prioritize the distribution of limited financial resources to enhance resilience across a range of natural and social systems. Therefore, assessing the distributional outcomes associated with resilience policy development and implementation is a critical area of inquiry for answering questions concerning what is to be made resilient and for whom (Carpenter et al. 2001; Cutter 2016; Folke et al. 2010).

Additionally, research concerning the effectiveness of crosscutting and sector-specific resilience policy initiatives, and perhaps whether such efforts conflict with environmental sustainability goals, is a fundamental question that can provide actionable knowledge for policy practitioners in the Anthropocene. While such analyses require exposure to a shock to occur following the implementation of adaptation measures, as more adaptation efforts unfold, there will be many opportunities to carry out such investigations. Research concerning the effectiveness of various efforts to integrate scientific information into policies and programs and the successes and challenges associated with interagency and intergovernmental coordination and collaboration can further advance our understanding of how such institutional structures function and may be improved.

Lastly, the emergence of resilience, through the application of climate adaptation planning, as a fundamental strategy to address the crosscutting effects of global climate change in the U.S. is a significant indicator of the rise of resilience as a new and pragmatic approach for framing environmental problems and designing policy solutions in the Anthropocene. Most climate adaptation efforts in the U.S. have applied an integrated, cross-agency approach to address the various environmental quality issues caused by the wide-ranging effects of climate change by improving the resilience of SES. However, to firmly authenticate the emergence of a new epoch in U.S. environmental policy and politics, in which the focus of environmental governance centers on resilience, warrants additional inquiry concerning the integration of resilience-based principles into environmental initiatives that are independent of the climate change issue. Therefore, future research should examine how policymakers, policy practitioners, and planners interpret and apply the concept of resilience to address concerns in specific areas of environmental policy such as air and water quality, waste management, energy, and biodiversity protection.

Appendix A: State Climate Adaptation Objectives

Alaska	• Engage governments, private business, communities, and individual households • Accessible information on climate and adaptation is to enable public and private entities to act • Recognize the need for immediate action to address effects of climate change and data, policies, and knowledge about adaptation to enable successful long term adaptation
California	• Consider climate change in all functions of government • Partner with most vulnerable populations to increase equity and resilience • Support continued climate research and data tools • Identify significant and sustainable funding sources to reduce climate risks • Collaborative partnerships with federal, local, tribal, and regional government • Increase investment in vulnerability assessments of critical infrastructure systems
Colorado	N/A
Connecticut	• Develop crosscutting adaptation policies, that have available resources, a positive cost to benefit ratio, political support, and identifiable leadership • Seek to retain cultural values by empowering local communities • Provide a defined timeline for adaptation actions with achievable benchmarks, a detailed implementation plan, and co-benefits for other non-climate management programs • Gain experience through demonstration projects and communicate successes • Have a clearly-defined entity responsible for implementation • Ensure adequate coordination across political and societal boundaries • Provides ongoing state and local government support and collaboration
Delaware	• Develop agency-specific recommendations for improving preparedness and resilience • Cross-cutting themes • Interagency coordination • Support for local governments • Outreach and education to the public
Florida	• Support scientific data, analyses, and predictive modeling • Amend local, state, and regional comprehensive plans based on the best available data and include goals, objectives, and policies to prepare the state for adapting to future impacts • Manage ecosystems and biodiversity to support resiliency by enhancing their ability to naturally adapt to the stresses of climate change and other pervasive threats • Conserve all water uses and alternative water sources, and include stakeholder involvement in statewide and regional water supply planning processes • Reduce potential damage to the built environment from the impact of natural hazards • Support the ability of Florida's economy to adapt to climate change • Equitable and affordable insurance rates that reflect risks from climate change • Ensure sufficient capacity and efficacy in protecting public heath and welfare against the risks from climate change • Incorporate considerations of climate change into Florida's health plan • Address issues of social justice • Establish a single point of focus within state government to assess the risks posed by climate change, develop informed adaptation planning, and adjust adaptation planning • Fund the protection of human health and critical infrastructure • Establish collaborative relationships with federal agencies, other states and countries, and key professional societies • Become a national and international leader in the dissemination of climate change information and education

Maine	• Policy decisions must be collaborative, transparent, and open to change • Utilize data-gathering, monitoring, and assessment to inform decision makers, resource managers, stakeholders, and the public • Support research to provide the public with information about pace and extent of change • Maintain healthy ecosystems • Specify which current stressors are likely to be exacerbated by climate change impacts • Recognize and promote economic opportunities, and develop incentives to take advantage • Address slower-arriving immediate or acute impacts simultaneously • Climate planning efforts should seek to avoid passing to future generations what are likely to the potentially catastrophic costs of inaction in some areas • Use current policies that successfully address climate change • Include participation of vulnerable communities and take special account of their needs • Do not view adaptation as an alternative strategy to reducing GHG emissions
Maryland	• Reduce the impacts of climate change within the following sectors: Human Health; Agriculture; Forest and Terrestrial Ecosystems; Bay and Aquatic Environments; Water Resources; and Population Growth and Infrastructure • Guide and prioritize climate science and adaptation policy activities within short to medium-term timeframes • Promote programs and policies aimed at the avoidance and/or reduction of impacts to the built environment, as well as to future growth and development in coastal areas • Shift to sustainable economies and investments and avoid development and redevelopment in hazardous coastal areas • Enhance preparedness and planning efforts to protect human health, safety, and welfare • Protect and restore natural shoreline and its resources
Massachusetts	• Broad-based participation • Use best available science and technology • Strong leadership • Coordinate efforts • Assist vulnerable populations • Apply cost-effective and risk-based approaches
Minnesota	• Adapt, reduce risks and impacts, increase the resilience of communities
New Hampshire	• Increase natural resilience in species and ecosystems to facilitate recovery from climate disturbances or adjust to new patterns of climate variability and climate extremes • Facilitate responses to climate change that help human communities and ecosystems to continue to exist under new conditions • Help human communities and ecosystems resist impacts and maintain resources
New York	• Develop a process to maintain, disseminate and explain to decision-makers a set of best-available climate projections • Identify and track key climate change indicators important • Develop a framework to monitor, assess, and share progress on local, state, and federal government adaptation planning and implementation • Initiate research to develop new adaptation strategies and provide detail and confidence to support adaptation strategy decisions • Evaluate emergency preparedness, management and response capabilities in light of climate projections, to determine where these capabilities will be compromised by climate threats • Initiate widespread education and outreach, including both school curricula and community outreach, to build public support and awareness

	• Develop adaptation policies that protect communities most vulnerable to climate change
North Carolina	• Develop resilience strategies that support communities and sectors of the economy most vulnerable to the effects of climate change and enhance the state government's ability to protect public and private assets • Promote comprehensive adaptation planning among state agencies • Facilitate communication and education to support local, regional and state planning efforts • Collaborate with partners to provide relevant information for decision-making • Encourage broad collaboration and partnerships to leverage resources • Partner with communities to facilitate local climate adaptation efforts • Refine adaptation strategies as information becomes available and tools improve
Oregon	• Prevention should be the first priority • Prioritize the most vulnerable • All government agencies should adopt preparation plans • Redesign planning tools • Plan at larger scales to ensure that climate preparation in one sector or region does not affect preparation elsewhere • Link climate preparation to existing economy and to new economic development efforts • Limit non-climate stresses • Use and improve adaptive management processes and contingency planning • Assess capacity, develop appropriate governance systems for the rate and scale of change • Assess existing finance mechanisms and develop new funding options as needed • Coordinate research agendas across states and regions
Pennsylvania	• Green infrastructure practices for improved capture of storm water, water conservation, decreased sedimentation and pollution to waterways and less adverse impacts to the built environment and for wildlife • Alternative forms of transportation to provide health benefits and safe passage to numerous destinations and also reduce vehicle miles traveled resulting in lower carbon emissions • Conserve wildlife and fish habitat by building resilience to the impacts of climate change • Integrate adaptation and mitigation strategies as part of planning and operations of government agencies, non-profit organizations, businesses, farms and academic institutions • Include climate adaptation, including public health response, as a key component of future climate change action plans • Support the establishment of a climate adaptation team within state government to provide technical expertise, resources, and enlist stakeholders to implement plans for each sector • Work with the higher education community to develop a coordinated strategy to increase understanding and awareness of science-based approaches to climate change, and clear coordinated messages relevant to various stakeholders that provide practical information and opportunities for local engagement

Rhode Island	• Prioritize actions and investments the state can make today • Leverage planning work already done by state agencies and statewide organizations • Identify actions and investments ready for implementation in the near-term • Recognize competencies that are shared among multiple state agencies • Provide Resources and tools to municipalities • Equitably reduce the burden of climate change impacts with particular attention to environmental justice communities
Vermont	N/A
Virginia	• Provide direct adaptive responses, required research, and increased capacity and coordination within state and local government
Washington	• Use best-available science • Build on principles of sustainability • Increase resilience and protect the most vulnerable populations • Ensure integrated approaches, maximize mutual benefits and avoid unintended consequences • Emphasize collaboration and strengthen partnerships • Recognize the impacts of decisions made by other regions and countries
Wisconsin	• Determine which actions to implement first • Build flexibility into management practices • Choose strategies that increase resilience and provide benefits across all climate scenarios • Apply the precautionary principle • Support adaptive management • Consider the restrictions and special circumstances of place-based impacts • Support adaptation and mitigation

Appendix B: City Climate Adaptation Objectives

Austin	• Uncertain nonlinear effects of climate stressors and shocks • Identify vulnerabilities and risks • Consider climate change in management decisions • Identify climate-related threats and thresholds
Boston	• Increase Boston's ability to thrive in the face of intensifying climate hazards, leading to improved quality of life for all residents, especially the most vulnerable, and creating stronger neighborhoods and a healthier environment. o Generate multiple benefits o Incorporate local involvement in design and decision making o Create layers of protection by working at multiple scales o Design in flexibility and adaptability o Leverage building cycles
Chula Vista	• Build upon existing municipal efforts rather than create new, stand-alone policies or programs • Minimizing the risks associated with climate impacts now, future costs and public health concerns can be avoided and/or minimized
Columbus	• Address climate risks and vulnerabilities
Denver	• Buildings and Energy Sector o Reduce vulnerability to building energy supply disruptions o Reduce vulnerability of buildings to extreme weather • Health and Human Services Sector o Safeguard health of Denver residents in the context of climate impacts o Preserve ability of health care and other service providers to provide utilities during extreme heat events • Urban Natural Resources Sector o Enhance and preserve existing urban forest resources o Ensure all Denver streams are fishable and swimmable • Water Consumption Sector o Reduce per capita use of potable water • Land Use and Transportation Sector o Improve mobility within the City and its communities o Prepare and enable urban infrastructure to adapt to climate impacts • Food and Agriculture sector o Increase food security o Protect local agricultural resources against increased threat of pests, invasive species and noxious weeds
Indianapolis	• Increase community resilience by prioritizing equity in policy, planning and project implementation • Achieve net zero GHG emissions by 2050
Long Beach	• Distinguish Long Beach as a leader in climate mitigation and adaptation planning • Be inclusive of the entire community while prioritizing vulnerable and disproportionately impacted populations • Create a healthier community by addressing climate change • Consider social, environmental, and economic co-benefits holistically • Empower young people to be leaders in creating a most sustainable community • Invoke personal sense of responsibility among residents and businesses • Be an actionable plan (right balance of innovation and practicality)

Miami	• Build a resilient and sustainable future for Miami by preparing for, adapting to, and mitigating current and future climate risks. • Maximize multiple benefits • Use public resources efficiently and maximize partnerships • Incorporate local involvement in design and decision- making • Address equity • Utilize technology and innovation • Leverage and protect our natural systems • Create layers of protection by working at multiple scales • Design in flexibility and adaptability
New York City	• Eliminate disaster-related long-term displacement more than one year of New Yorkers from homes by 2050 • Reduce the Social Vulnerability Index for neighborhoods across the city • Reduce average annual economic losses resulting from climate-related events • Neighborhoods-Every city neighborhood will be safer by strengthening community, social, and economic resiliency • Buildings-The city's buildings will be upgraded against changing climate impacts • Infrastructure-Infrastructure systems across the region will adapt to maintain continued services • Coastal Defense-New York City's coastal defenses will be strengthened against flooding and sea level rise
Philadelphia	• Reduce vulnerabilities and build resilience to future impacts • Integrate climate considerations in relevant decision making • Protect vulnerable populations • Help residents and businesses with resilience-building efforts
Portland	• Prepare for a Range of Possible Futures • Building Resilience Requires Reducing Risks and Building Response Capacity o Meet the needs of vulnerable populations o Build resilience of natural systems and infrastructure o Prepare for impacts to public health • Reducing Risks to Populations Most Vulnerable to Climate Change Impacts Must Be Prioritized • Climate Change Preparation Yields Multiple Benefits • Climate Preparation Must Be A Collaborative Effort • Implementation and Coordination
Saint Louis	• Build a string, equitable & climate resilient city o Preserve & Enhance the Natural Environment o Protect Human Health & Safety o Maximize Preparedness Efforts
Saint Paul	• Support community resilience among residents to prepare for, withstand, and adapt to climate-related impacts. • Protect natural infrastructure and enhance it to maximize its ability to mitigate weather and climate impacts • Ensure the long-term integrity and reliability of built infrastructure systems by considering future climate impacts in long-term planning

San Antonio	• Increase Infrastructure Resilience • Strengthen Public Health Systems • Enhance emergency management and community preparedness • Promote, Restore, and Protect Green Infrastructure and ecosystems • Protect local food security • Increases resiliency awareness and outreach • Ensure equity in adaptation
Seattle	• Equity: Prioritize actions that reduce risk and enhance resilience in frontline communities (e.g., communities of color, lower income communities, immigrant and refugee communities, disabled residents and seniors), as they are at greater risk from the impacts of climate change and often have the fewest resources to respond to changing conditions. • Co-benefits: Design and implement resilience strategies that advance community goals by enhancing physical spaces and services in ways that support quality/livable urban environments, health, and social cohesion. • Natural systems: Use nature-based solutions that leverage ecosystem services and foster natural systems resilience.
Virginia Beach	• Natural mitigations • Prepared communities • Engineered defenses • Adapted structures

Appendix C: The Four Epochs of U.S. Environmental Policy (adapted from Mazmanian and Kraft 2009b)

Dimension	Regulating for Environmental Protection, 1970–1990	Efficiency-Based Regulatory Reform and Flexibility, 1980–2000s	Toward Sustainable Communities, 1990–present	Governing for Resilience, Late 2000s-Present
Key Events and Public Actions	• Santa Barbara oil spill • Earth Day • passage of the 1970 CAA and 1972 CWA • passage of National Environmental Policy Act • creation of the Environmental Protection Agency	• Carter administration focus on cost of environmental regulation • election of President Ronald Reagan • Love Canal, Bhopal • RCRA and SARA • growth in state and local environmental policy capacity	• Brundtland report, Our Common Future Earth Summit (UNCED) • Montreal Protocol on CFCs • Kyoto Protocol • Intergovernmental Panel on Climate Change, series of reports • Hurricane Katrina	• U.N. Framework Convention on Climate Change • Intergovernmental Panel on Climate Change 2007 Assessment • 2030 Agenda for Sustainable Development • Regional extreme weather events and disasters (e.g., Hurricanes Katrina and Hurricane Sandy) • Global Covenant of Mayors
Predominant Political/ Institutional Context	• rule of law • adversarial relations • zero-sum politics • focus on national regulatory agencies and enforcement mechanisms	• alternative dispute resolution techniques • greater stakeholder and public participation, especially, at the state and local level • reliance on the market place	• public/private partnerships • local/regional collaborations • community capacity building and consensus building • mechanisms created to enforce "collective" decisions	• Local/regional/state/federal-level partnerships • Formal partnerships with scientific organizations • Interagency coordination and collaboration
Problem Identification and Policy Objectives	• pollution caused primarily by callus and unthinking business and industry • establish as national priority the curtailment of air, water, and land pollution caused by industry and other human activity	• managing pollution through market-based and collaborative mechanisms • subject environmental regulations to cost-effectiveness test • internalize pollution costs • pursue economically optimal use of resources and energy • introduce pollution prevention • add policies on toxic waste and chemicals as national priorities	• bringing into harmony human and natural systems on a sustainable basis • balance long-term societal and natural system needs through system design and management • rediscovery of/emphasis on resource conservation • halt diminution of biodiversity • embrace an eco-centric ethic	• Global environmental change • Long term stress, short term shocks, and compound effects • Exposure, sensitivity, adaptive capacity • Projections and scenarios • Enhance adaptive capacity, connectivity, robustness, redundancy, and diversity
Policy Approaches and "Tools"	• policy managed by Washington, D.C. • command-and-control regulation • substantial federal technology R&D • generous federal funding of health and	• policy managed more by states and affected communities • federal role shifts to facilitation and oversight • introduction of	• comprehensive future visioning • regional planning based on sustainability guidelines, • Total Quality Environmental Management (TQEM)	• Integrated comprehensive planning and management under multiple scenarios • Co-production of knowledge • Resilience as a guiding principle in building codes, land use planning, and development policy

	pollution prevention projects	incentive- based approaches (taxes, fees, emissions trading) for business and industry • creation of emissions- trading markets	and life-cycle- design practice in industry • various experiments with new approaches	• Public/nonprofit/private partnerships • Collective action and collaboration to restore/preserve natural systems • Smart governance and adaptive management • Citizen science initiatives and information crowdsourcing • Information and education campaigns • Neighborhood resilience "hubs" and micro grids • Data and toolkit clearinghouses
Points of Intervention	• end of the production pipeline • end of the waste stream • at the point of local, state, and federal governmental activity	• the market-place, which serves as the arbiter of product viability • provide education and training at several points along the cradle-to-grave path of materials and resource use	• societal level needs assessment and goal prioritization • industry-level attention to product design, materials selection, and environmental strategic planning • individual behavior and life-style choices	• Existing local, state, and federal institutions • Ecological, social, infrastructure, economic, and governance systems • Neighborhood-scale • Vulnerable social and ecological systems
Implementation Philosophy	•develop the administrative and regulatory legal infrastructure to ensure compliance with federal and state regulations	• shift to state and local level for initiative in compliance and enforcement • create market mechanisms for protection of the environment	• develop new mechanisms and institutions that balance the needs of human and natural systems, both within the U.S. and around the globe • focus on outcomes and performance	• Climate mainstreaming • Science-based and data-driven decision making • Knowledge mobilization
Information and Data Management Needs	• firm-level emissions • waste stream contents and tracking • human health effects • environmental compliance accounting in industry	• costing out environmental harms and benefits of reduced pollution • provision of readily accessible emissions data (e.g., through Toxics Release Inventory and right-to-know programs) • professional protocols for environmental accounting in industry • ecosystem mapping	• sustainability criteria and indicators • eco-human support system thresholds • region/community/global interaction effects (e.g., regarding CO_2 emissions and depletion of ozone layer) • utilization of ecological footprint analysis • use of material and energy "flow- through" inventories and accounting • computer modeling of human- natural systems interactions	• Vulnerability and risk assessment • Downscaled projections of environmental change • Real-time data gathering, monitoring and sharing systems • Data integration platforms

References

Adger, W.N. (2000). Social and ecological resilience: are they related?, *Progress in Human Geography*, 24(3):347–364.

Adger, N. & Hodbod, J. (2014). "Ecological and social resilience." In *Handbook of Sustainable Development*, 2nd ed. eds. G. Atkinson, S. Dietz, E. Neumayer, M. Agarwala, 91-104. Cheltenham, UK: Edward Elgar.

Ahern, J. (2013). Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology,* 28(6):1203–1212.

American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. (2009).

Anderies, J.M., Folke, C., Walker, B., & Ostrom, E. (2013). Aligning Key Concepts for Global Change Policy: Robustness, Resilience, and Sustain- ability. *Ecology and Society*, 18(2):8.

Benson, M. H., & Craig, R. K. (2014). The end of sustainability. *Society & Natural Resources*, *27*(7):777-782.

Benson, M. H., & Garmestani, A. S. (2011). Can we manage for resilience? The integration of resilience thinking into natural resource management in the United States. *Environmental Management*, *48*(3):392-399.

Berkes, F. & Folke, C. (eds.) (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge, UK: Cambridge University Press.

Berkes, F., Colding, J., & Folke, C. (2003). *Navigating socialecological systems: Building resilience for complexity and change*. Cambridge, UK: Cambridge University Press.

Blackmore, J.M., & Plant, R.A.J. (2008). Risk and resilience to enhance sustainability with application to urban water systems. *Journal of Water Resources Planning and Management*, 134:224–233.

Bloomberg Philanthropies (2019). *Climate Action Playbook Brief*. New York, NY: Bloomberg Philanthropies.

Boesch, D.F. (ed.). (2008). *Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland: Report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change*. Cambridge, MD: University of Maryland Center for Environmental Science.

Boicourt K & ZP Johnson (eds.). (2010). *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, Phase II: Building societal, economic, and ecological resilience*: *Report of the Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Groups*. Annapolis, Maryland: Department of Natural Resources,.

Bradberry, L.A., & Jacobson, G.C. (2015). The Tea Party and the 2012 presidential election. *Electoral Studies*, 40:500-508.

Brondizio, E. S., Settele, J., Díaz, S., & Ngo, H. T. (eds.). (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

C40 Cities. (2020). *Climate Action Planning Framework*. New York, NY.

California Energy Commission (CEC). (2020). *Cal-Adapt*. Retrieved from: https://cal-adapt.org/

California Natural Resources Agency (CNRA). (2009). *California Climate Adaptation Strategy*. Sacramento, CA.

____. (2018). *Safeguarding California Plan: 2018 Update*. Sacramento, CA.

Campbell, S. (1996). Green Cities, Growing Cities, Just Cities? Urban Planning and the Contradictions of Sustainable Development. *American Planning Association Journal*, 62(3):296–312.

Carpenter, S., Walker, B., Anderies, J.M., & Abel, N. (2001). From metaphor to measurement: resilience of what to what? *Ecosystems*, 4(8):765-781.

Carpenter, S. R., Westley, F., & Turner, M. G. (2005). Surrogates for resilience of social–ecological systems. *Ecosystems*, 8(8):941-944.

Cervenec, J., Wilson, A. B., Dipre, G. R., Shockey, A., & Celebrezze, D. (2018). *Columbus Climate Adaptation Plan*. Columbus, OH

City of Austin. (2014).*Toward a Climate Resilient Austin*. Austin, TX.
City of Boston. (2014). *Climate Ready Boston*. Boston, MA.
City of Chula Vista. (2011). *Climate Adaptation Strategies*. Chula Vista, CA.
City of Indianapolis (2017). *Thrive Indianapolis*. Indianapolis, IN: City of Indianapolis
City of Long Beach. (2019). *Draft City of Long Beach Climate Action and Adaptation Plan*. Long Beach, CA.
City of Miami. (2020). *Miami: Forever Climate Ready*. Miami, FL.
City of New York. (2015). *One New York: The Plan for a Strong and Just City*. New York, NY
____. (2020). *Mayor de Blasio Appoints Leading Scientific Experts to the Fourth New York City Panel on Climate Change*. The Official Website of the City of New York. Retrieved from: https://www1.nyc.gov/office-of-the-mayor/news/430-20/mayor-de-blasio-appoints-leading-scientific-experts-the-fourth-new-york-city-panel-climate
City of Philadelphia. (2015). *Growing Stronger: Toward a Climate-Ready Philadelphia*. Philadelphia, PA.
City of Portland (2014). *Climate Change Preparation Strategy*. Portland, OR.
City of Saint Paul (2017). *Saint Paul Climate Action and Resilience Plan*. Saint Paul, MN.
City of San Antonio. (2019). *SA Climate Ready: A Pathway for Climate Action & Adaptation*. San Antonio, Texas.
City of St. Louis (2017). *Climate Action and Adaptation Plan*. St. Louis, MO: City of St. Louis
City of Virginia Beach. (2020). Virginia Beach Sea level Wise Adaptation Strategy. Virginia Beach, VA.
Colding, J., & Barthel, S. (2019). Exploring the social-ecological systems discourse 20 years later. *Ecology and Society*, 24(1):2.
Council on Climate Preparedness and Resilience (CCPR) (2014). *Priority Agenda Enhancing the Climate Resilience of America's Natural Resources*. Washington, D.C.
Council on Environmental Quality (CEQ) (2010). *Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy*. Washington, D.C.
Cutter, S. L. (2016). Resilience to what? Resilience for whom?. *The Geographical Journal*, 182(2):110-113.
Davoudi, S. (2012). Resilience: a bridging concept or a dead end? *Planning Theory and Practice*, 13:299–333.
Djenontin, I. N. S., & Meadow, A. M. (2018). The art of co-production of knowledge in environmental sciences and management: lessons from international practice. *Environmental Management*, *61*(6):885-903.
Delaware Department of Natural Resources (DDNR). (2012). *Preparing for Tomorrow's High Tide Sea Level Rise Vulnerability Assessment for the State of Delaware*. Dover, DE.
Denver Department of Environmental Health (DDEH). (2014). *City and County of Denver Climate Adaptation Plan*. Denver, CO.
Dryzek, J. & Pickering, J. (2019). *The Politics of the Anthropocene*; Oxford, UK: Oxford University Press.
Dunlap, R.E., & Jacques, P. J. (2013). Climate Change Denial Books and Conservative Think Tanks: Exploring the Connection. *American Behavioral Scientist*, 57:699–731.
Dunlap, R.E., & McCright, A.M. (2008). A widening gap - Republican and Democratic views on climate change. *Environment*, 50(5):26-35.
Dunlap, R.E. & McCright, A.M. (2011). "Organized Climate Change Denial". In *The Oxford Handbook of Climate Change and Society*, eds. J.S. Dryzek, R.B. Norgaard and D. Schlosberg, 144-1600. Oxford, United Kingdom: Oxford University Press.
Dunlap, R.E., McCright, A.M., & Yarosh, J.H. (2016). The political divide on climate change: Partisan polarization widens in the US. *Environment: Science and Policy for Sustainable Development*, 58(5):4-23.

Durant, R. F., Chun, Y. P., Kim, B., & Lee S. (2004). Toward a New Governance Paradigm for Environmental and Natural Resources Management in the 21st Century? *Administration and Society*, 35:643–682.

Elsasser, S.W., & Dunlap, R.E. (2013). Leading voices in the denier choir: Conservative columnists' dismissal of global warming and denigration of climate science. *American Behavioral Scientist*, *57*(6):754-776.

Executive Office of the President (EOP) (2013). *The President's Climate Action Plan*. Washington, D.C.

Exec. Order No. 13514, 74 Fed. Reg. 194 (October 8, 2009).

Exec. Order No. 13653, 78 Fed. Reg. 215 (November 6, 2013).

Exec. Order No. 13693, 80 Fed. Reg. 90 (March 25, 2015).

Exec. Order No. 13783, 82 Fed. Reg. 61 (March 31, 2017).

Exec. Order No. 13834, 83 Fed. Reg. 99 (March 31, 2018).

Exec. Order No. 17-10, (September 15, 2017).

FedCenter. (2019). *Climate Adaptation: Supporting Information and Tools*. Retrieved from: https://www.fedcenter.gov/programs/climate/

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, 16(3):253–267.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *AMBIO: A journal of the human environment*, 31(5):437-440.

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and society*, *15*(4).

Galford, G.L., Hoogenboom, A., Carlson, S., Ford, S., Nash, J., Palchak, E., Pears, S., Underwood, K., & Baker, D.V. (eds.) (2014). *Considering Vermont's Future in a Changing Climate: The First Vermont Climate Assessment*. Gund Institute for Ecological Economics.

Gelbspan, R. (1998). *The Heat is On: The Climate Crisis, The Cover-up, The Perception*. Updated Edition. New York, New York: Perseus Books

Global Change Research Act (GCRA) of 1990, 15 U.S.C. §§2921-2938 (1990).

Global Resilient Cities Network (GRCN). (2020, February 6). *Chief Resilience Officers from around the world announce the evolution and expansion of the Global Resilient Cities Network* [Press Release]. Retrieved from: https://www.rockpa.org/wp-content/uploads/2020/02/GRCN-WUF-Press-Release-Network.pdf

Governor's Action Team on Energy and Climate (GATEC). (2008). *Florida's Energy & Climate Change Action Plan*. Tallahassee, FL.

Governor's Office of Planning and Research (GOPR). (2020). *About the Adaptation Clearinghouse*. Resilient.CA.org. Retrieved from: https://resilientca.org/about/

Governor's Steering Committee on Climate Change (GSC). (2010). *The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health*. Hartford, CT.

Great Lakes Integrated Sciences and Assessment and the University of Michigan Climate Center (GLISA and UMCC). (2016). Climate Change in Columbus Ohio: An Assessment of Columbus' Key Climate Changes, Impacts, and Vulnerabilities of Concern. Columbus, OH.

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M.C., Shyamsundar, P., Steffen, W., Glasser, G., Kanie, N., & & Noble, I. (2013). Sustainable development goals for people and planet. *Nature*, *495*(7441):305-307.

Guggenheim, D. (2006). An inconvenient truth. Lawrence Bender and Participant Productions.

Gunderson, L.H. (2000). Ecological resilience—in theory and application. *Annual review of ecology and systematics*, 31(1):425-439.

Gunderson, L., Holling, C. (eds.) (2002). *Panarchy: Understanding Transformations in Systems of Humans and Nature*. Washington, D.C.: Island Press

Hempel, L. (1998). "Sustainable Communities: From Vision to Action". Claremont, CA: The Claremont Graduate University.

____ (2009). "Conceptual and Analytical Challenges in Building Sustainable Communities". In *Toward Sustainable Communities: Transition and Transformations in Environmental Policy*, 2nd ed., ed. D.A. Mazmanian and M.E. Kraft, Cambridge, MA: MIT Press.

____ (2012). "Evolving Concepts of Sustainability in Environmental Policy". In Towards Sustainable Communities: Transition and Transformation in Environmental Policy, ed. D.A. Mazmanian and M.E. Kraft, 3-32. Cambridge, Massachusetts: MIT Press

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual review of ecology and systematics*, 4(1):1-23.

____. (1996). Surprise for science, resilience for ecosystems, and incentives for people. *Ecological Applications*, 6(3):733-735.

Horton, R., Bader, D., Kushnir, Y., Little, C., Blake, R., & Rosenzweig, C. (2015). New york city panel on climate change 2015 Report Chapter 1: Climate observations and projections. *Annals of the New York Academy of Sciences*, *1336*(1):18-35.

House Bill (HB) 3543, 74th Oregon General Assembly. (2007).

Hunt, J. (2009). Integrated policies for environmental resilience and sustainability. *Engineering Sustainability*, 162:155–167.

ICLEI. (2019). *Resilient cities, thriving cities: The evolution of urban resilience*. Bonn, Germany

Interagency Climate Adaptation Team (ICAT). (2017). *Adapting to Climate Change in Minnesota*. Saint Paul, MN.

Intergovernmental Panel on Climate Change (IPCC). (2014a). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. eds. Core Writing Team, R.K. Pachauri and L.A. Meyer. Geneva, Switzerland: IPCC.

____. (2014b). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. eds. C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White. New York, NY: Cambridge University Press.

____. (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. eds. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield. New York, NY: Cambridge University Press.

Jacques, P.J., Dunlap, R.E., & Freeman, M. (2008). The organisation of denial: Conservative think tanks and environmental scepticism. *Environmental Politics*, 17(3):349-385.

Klyza, C. M., & Sousa, D. (2008). *American Environmental Policy, 1990–2006: Beyond Gridlock.* Cambridge, MA: MIT Press.

Knab, R.D., Rhome, J.R., & Brown, D.P. (2011). *Tropical Cyclone Report: Hurricane Katrina*. National Hurricane Center. Washington, D.C.: National Oceanic and Atmospheric Administration.

Kraft, M. E. (2018). *Environmental Policy and Politics*. 7th ed. New York, NY: Routledge.

Kraft, M.E. (2021). "Environmental Policy in Congress". In *Environmental Policy: New Directions for the Twenty-First Century*. eds. N.J. Vig, M.E. Kraft, and B.G. Rabe, 111-136, Thousand Oaks, California: CQ Press.

Kyoto Protocol to the United Nations Framework Convention on Climate Change, December 10, 1997 37 I.L.M. 22 (1998); 2303 U.N.T.S. 148; U.N. Doc FCCC/CP/1997/7/Add.1

Layzer, J. A. (2007). "Deep Freeze: How Business Has Shaped the Global Warming Debate in Congress." In *Business and Environmental Policy: Corporate Interests in the American Political System*, eds. M. Kraft and S. Kamieniecki. Cambridge, Massachusetts: MIT Press.

Layzer, J.A. (2014). *Open for Business: Conservatives' Opposition to Environmental Regulation. Cambridge*, Massachusetts: MIT Press.

Lew, A.A., Ng, P.T., Ni, C., Wu, T. (2016). Community sustainability and resilience: similarities, differences and indicators. *Tourism Geographies*, 18:18–27.

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenko, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., & Taylor, W.M. (2007). Complexity of coupled human and natural systems. *Science* 317:1513–1516.

Lizarralde, G., Chmutina, K., Bosher, L., Dainty, A. (2015). Sustainability and resilience in the built environment: the challenges of establishing a turquoise agenda in the UK. *Sustainable Cities and Society*, 15:96–104.

Maine Department of Environmental Protection (MDEP). (2010). *People and Nature: Adapting to Climate Change*. Augusta, ME.

Maser, C. (1997). *Sustainable Community Development: Principles and Concepts*. Del Ray, Florida: St. Lucie Press.

Mason, L. (2015). "I disrespectfully agree": The differential effects of partisan sorting on social and issue polarization. *American Journal of Political Science*, 59(1):128-145.

Mauger, G.G., Casola, J.H., Morgan, H.A., Strauch, R.L., Jones, B., Curry, B., Busch Isaksen, T.M., Whitely Binder, L., Krodby, M.B., & Snover, A.K. (2015). *State of Knowledge: Climate Change in Pudget Sound*. Report Prepared for the Pudget Sound Partnership and the National Oceanic and Atmospheric Administration. Seattle, WA: Climate Impacts Group, University of Washington.

Mazmanian, D.A., & Kraft, M.E. (eds.) (2009a). *Towards Sustainable Communities: Transition and Transformation in Environmental Policy*. Cambridge, Massachusetts: MIT Press.

Mazmanian, D.A., & Kraft, M.E. (2009b). "The Three Epochs of the Environmental Movement". In Towards Sustainable Communities: Transition and Transformation in Environmental Policy, ed. D.A. Mazmanian and M.E. Kraft, 3-32. Cambridge, Massachusetts: MIT Press.

Mazmanian, D. A., & Nijaki, L.K. (2012). "Sustainable Development and Governance". In *The Oxford Handbook of US Environmental Policy*, eds. M.E. Kraft and S. Kamieniecki, 184-206. New York, New York: Oxford University Press.

McCright, A.M., & Dunlap, R.E. (2000). Challenging global warming as a social problem: An analysis of the conservative movement's counter-claims. *Social Problems*, 47(4):499-522.

McCright, A.M., & Dunlap, R.E. (2003). Defeating Kyoto: The conservative movement's impact on U.S. climate change policy. *Social Problems*, 50(3):348-373.

McCright, A.M., Dunlap, R.E., & Xiao, C. (2014). Increasing influence of party identification on perceived scientific agreement and support for government action on climate change in the United States, 2006–12. *Weather, Climate, and Society*, 6(2):194-201.

McCright, A.M., Xiao, C., & Dunlap, R.E. (2014). Political polarization on support for government spending on environmental protection in the USA, 1974–2012. *Social science research*, 48:251-260.

Meerow, S., Newell, J.P. & Stults, M. (2016). Defining urban resilience: a review. *Landscape and Urban Planning*, 147:38–49 .

National Oceanic and Atmospheric Administration (NOAA). (2018). *Costliest U.S. tropical cyclones*. National Hurricane Center. Washington, D.C.

Nelson Institute for Environmental Studies, University of Wisconsin-Madison and the Wisconsin Department of Natural Resources. (2011). *Wisconsin's Changing Climate: Impacts and Adaptation. Madison*, WI: Wisconsin Initiative on Climate Change Impacts.

New Hampshire Department of Environmental Services (NHDES). (2009).The New Hampshire Climate Action Plan. Concord, NH.

Normandin, J.M., Therrien, M.C., Pelling, M., & Paterson, S. (2018). The Definition of Urban Resilience: A Transformation Path Towards Collaborative Urban Risk Governance. *Urban Resilience for Risk and Adaptation Governance*, 9–25.

Oregon Climate Change Research Institute (OCCRI) (2010). *Oregon climate assessment report*. eds. Field, K.D. Dello & P.W. Mote. Corvallis, OR: College of Oceanic and Atmospheric Sciences, Oregon State University.
Conference of the Parties, Paris Agreement, December 12, 2015 U.N. Doc. FCCC/CP/2015/L.9/Rev/1
Pealer, S. and Dunnington, G. (2011). Climate Change and Vermont's Waters. Montpelier, VT: Vermont Agency of Natural Resources.
Pennsylvania Climate Change Act of 2008, P.L. 935, No. 70. (2008).
Pennsylvania Department of Environmental Protection (PDEP). (2011). *Pennsylvania Climate Adaptation Report*. Philadelphia, PA.
Portney, K.E. (2013). *Taking sustainable cities seriously: economic development, the environment and quality of life in American cities*, 2nd ed. Cambridge, Massachusetts: MIT Press.
Portney, K.E. and Hannibal, B. (2021). "Sustainability and Resilience in Cities: What Cities Are Doing". In *Environmental Policy: New Directions for the Twenty-First Century*. eds. N.J. Vig, M.E. Kraft, and B.G. Rabe, 249-274, Thousand Oaks, California: CQ Press.
President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience (Task Force on Climate Preparedness and Resilience) (2014). *Recommendations to the President*. Washington, D.C.
Press, D. & Mazmanian. D.A. (2006). "The Greening of Industry: Combining Government Regulation and Voluntary Strategies." In *Environmental Policy,* 6th edition, ed. Vig and Kraft, 264–287.
Prior, T. & Hagmann, J. (2013). Measuring resilience: Methodological and political challenges of a trend security concept. *Journal of Risk Research*, 17(3):281–298.
Rabe, B.G. (2004). *Statehouse and Greenhouse: The Emerging Politics of American Climate Change Policy*. Washington, D.C.: Brookings Institution Press.
Redman, C.L. (2014). Should sustainability and resilience be combined or remain distinct pursuits?. *Ecology and Society*, *19*(2).
Rogers, J.D., Kemp, G.P., Bosworth Jr, H.J., & Seed, R.B. (2015). Interaction between the US Army Corps of Engineers and the Orleans Levee Board preceding the drainage canal wall failures and catastrophic flooding of New Orleans in 2005. *Water Policy*, *17*(4):707-723.
Roser, M., & Ortiz-Ospina, E. (2017). World Population Growth. *Our World in Data*.
Schaffartzik, A., Mayer, A., Gingrich, S., Eisenmenger, N., Loy, C., & Krausmann, F. (2014). The global metabolic transition: Regional patterns and trends of global material flows, 1950–2010. *Global Environmental Change*, *26*,:87-97.
Skocpol, T. (2013). Naming the Problem: What it Will Take to Counter Extremism and Engage Americans in the Fight Against Global Warming. *Symposium on The Politics of America's Fight Against Global Warming*. Harvard University.
Seattle Office of Sustainability and Environment (SOSE). (2017). *Carbon Neutral Climate Ready: Preparing for Climate Change*. Seattle, WA.
Senate Bill (HB) 379, 74th California General Assembly. (2016).
State of Delaware. (2014). *Climate Framework for Delaware*. Dover, DE.
State of North Carolina. (2020). *Climate Risk Assessment and Resilience Plan*. Raleigh, NC.
State of Oregon. (2010). *The Oregon Climate Change Adaptation Framework*. Salem, OR
Steffen, W., Crutzen, P. J., & McNeill, J. R. (2007). The Anthropocene: are humans now overwhelming the great forces of nature. *AMBIO: A Journal of the Human Environment*, *36*(8):614-621.
Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.E., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.G., Persson, L.M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science,* 347(6223):1259855–1259855.
U.S. Global Change Research Program (USGCRP). (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. eds. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart. Washington, D.C.: U.S. Global Change Research Program.

Walker, B.H., Carpenter, S.R., Anderies, J.M., Abel, N., Cumming, G.S., Janssen, M.A., Lebel, L., Norberg, J., Peterson, G.D., Pritchard, L. (2002). Resilience management in social–ecological systems: a working hypothesis for a participatory approach. *Conservation Ecology*, 6 (1):14.

Walker, B.H., Gunderson, L.H., Kinzig, A.P., Folke, C., Carpenter, S.R., & Schultz, L. (2006). A handful of heuristics and some propositions for understanding resilience in social- ecological systems. *Ecology and Society*, 11(1):13.

Walker, B., Holling, C.S., Carpenter, S.R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and society*, *9*(2).

Walker, B. & Salt, D. (2006). *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, D.C.: Island Press.

Walker, B. & Salt, D. (2012). *Resilience practice: building capacity to absorb disturbance and maintain function*. Washington, D.C.: Island Press.

Wardekker, A., Wilk, B., Brown, V., Uittenbroek, C., Mees, H., Driessen, P., Wassn, M., Molenaar, A., Walda, J., & Runhaar, H. (2020). A diagnostic tool for supporting policymaking on urban resilience. *Cities*, 101, 102691.

Washington Department of Ecology (WDE). (2012). *Preparing for a Changing Climate Washington State's Integrated Climate Response Strategy*. Olympia, WA.

Weber, E.P. (2003). *Bringing Society Back In: Grassroots Ecosystem Management, Accountability, and Sustainable Communities*. Cambridge, MA: MIT Press.

Western Water Assessment (WWA) (2011). *Colorado Climate Preparedness Project: Final Report*. Boulder, CO: Regents of the University of Colorado.

Williamson, V., Skocpol, T., & Coggin, J. (2011). The Tea Party and the remaking of Republican conservatism. *Perspectives on Politics*, 25-43.

Wondolleck, J.M., & Yaffee, S.L. (2000). *Making Collaboration Work: Lessons from Innovation in Natural Resource Management*. Washington, D.C.: Island Press.

Woodruff, S.C., Meerow, S., Stults, M. & Wilkins, C. (2018). Adaptation to resilience planning: Alternative pathways to prepare for climate change. *Journal of Planning Education and Research, 1-12*.